

Talking science in South African high schools: Case studies of Grade 10-12 classes in Soweto

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Abstract

Research has established a close link between talk and cognition; that talk is central to the meaning-making process and thus to learning science. However, the challenge is shifting teacher pedagogical practices to those that promote meaningful learner talk and mediate substantive engagement with science concepts. Research suggests that long-term school based teacher support programmes do bring about changes in teacher beliefs and classroom practices. My study was part of a five year project to investigate teaching strategies for the implementation of South Africa's new science curriculum in Soweto high schools. Taking a socio-cultural perspective I sought to understand the use of science talk as a tool for teachers to mediate meaningful engagement with and understanding of high school science. I investigated teacher-learner interactions in three experienced teachers' classrooms following their participation in the intervention programme. I wanted to understand how they used talk to create dialogic discourse and how meaning making was negotiated within this discourse. Taking a collaborative research approach I used case study methodology to collect and analyse observational data from each teachers' lessons. Data analysis was informed by Mortimer and Scott's model for analysing classroom interactions and Toulmin's Argument Pattern (TAP). My findings indicated that classrooms had become interactive. Although teachers took up a largely authoritative stance there was tendency to a dialogic communicative approach. That is, while traditional IRE discourse persisted, there was significant evidence that teachers created dialogic discourse (eliciting and taking up learners' ideas). Teachers both opened up and shut down talk, through evaluative and elaborative feedback, respectively. I observed the emergence of spontaneous argumentation in two teachers' lessons. Argumentation differed from forms reported in literature in two significant ways. First, arguments were co-constructed by the teacher and learners and secondly, an unusual form of argumentation to make sense of conventional science concepts as opposed to the usual argumentation on socio-scientific issues as observed in local South African studies so far. Whereas most argumentation research has focused on the structure of arguments constructed by individual participants, I observed arguments co-constructed collaboratively by several participants. These findings have been published in a peer reviewed journal. A further, unrecorded finding for South Africa was engagement in talk within hybrid spaces, which are combinations of formal scientific ways of talking with context-based and culturally informed forms of talk. Lastly, science talk was enriched in these classrooms by linking it to other forms of engagement, such as reading, writing, practical activities and computer technology. This too has not been reported in South Africa. Some methodological findings emanating from my study included the positive effects of the model adopted by the Project on Implementation of Curriculum Change (ICC Project). The project employed a model of sustained on-site teacher support, systematic teacher-researcher collaboration, co-teaching and modelling of teaching strategies. I also discuss the implications of my findings for teacher professional development as well as for science teacher education in South Africa and further afield.

Keywords

Argumentation; classroom interactions; dialogic; hybrid spaces; interactive; pedagogic shifts; science talk; teaching strategies

Declaration

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

_____ day of _____ 2013

Dedication

I dedicate this work to the people of my village, Emgomeni, eTsholotsho, the community that raised me and taught me the value of hard work and responsibility to others.
Ngiyabonga – nginjenje ngenxa yenu.

Together with my parents
My mother Danisile Sibanda, *eMpofu mama, Musi, Nqagwana lakusasa Ntombendala*
My late father Mxotshwa Daniel Sibanda, *nga ubesekhona bengizakuthi eJamela, Dawuduna, Vodloza, Esaswelamabala sayabika enkosini, inkosi yasithi sihla!*

And the late Dr Keith Bishop
I dedicate Chapter 6 of this thesis to a departed colleague in the ICC Project, a friend that I never had the privilege to meet face to face, Dr Keith Bishop (University of Bath). Keith spent many hours on the phone sharing with me his passion for indigenous knowledge, which inspired the IK ideas and classroom activities reported in Chapter 6.

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Abbreviations

ICC Project:	Project on Implementation of Curriculum Change
EdQUAL:	Educational Quality Research Consortium
EPU:	Education Policy Unit
GDE:	Gauteng Province Department of Education
NCS:	National Curriculum Statement
CAPS:	Curriculum and Assessment Policy Statement
FET:	Further Education and Training (Grade 10-12)
GET:	General Education and Training (Grade R-9)
PS:	Physical Sciences
LS:	Life Sciences
NS:	Natural Sciences
IKS:	Indigenous knowledge Systems
IK:	Indigenous knowledge

Chapter 1

Perspectives on science talk in South African high schools

“The development of scientific knowledge involves “knowing” (a body of knowledge), “doing” (inquiry and process), and “talking” (discourse and communication). “Knowing” science involves making meaning by integrating new information with prior knowledge and personal experiences. As a way of knowing, students engage in “doing” science or scientific inquiry by manipulating materials, describing objects and events, making explanations, verifying evidence, and constructing and organizing ideas. Through “talking”, students clarify thoughts, organize ideas, share views, and inform one another using a specialized language of science or its way of talking ...” (Lee & Fradd, 1996, p. 273)

1.0 Preamble

I listen with fascination to talk about the language of teaching and learning, about how second language speakers struggle to learn because they are taught in a language that is not their own. I get a smile on my face, not because I do not sympathise with the learners’ plight but because I can empathise. It brings to my recollection incidents in my own life where learning failed to happen or when a relationship was almost ruined because of the way I talked or used language. One such incident remains prominent in my memory from way back in my second year of study at university.

The incident was triggered by my understanding (or lack thereof) of the word “cheap”. Some of the dictionary meanings of the word “cheap” are a) Inexpensive (adj.), also low priced, economical, discounted, cut-price, reduced, going for a song, b) Shoddy (adj.), also poor quality, inferior, second rate, sub-standard, c) Contemptible (adj.), also despicable, shameful or d) Stingy (adj.), also tight-fisted, miserly, mean. Until I was 19 I only knew and used the first meaning of the word “cheap”. This is no indictment on my schooling or my teachers. I had a good education and my high school English language and literature teacher was a first language speaker of English. I learnt to use the word cheap in my everyday context from an early age. From the age of eight or nine I picked up a trade to help raise my own school fees and money to buy uniforms. I became a part time trader buying fabric to resell or to make garments for sale. So I knew about buying discounted or low priced (cheap) fabric to re-sell at reduced prices (cheap) so as to beat the regular shop prices in my township (cheap-er). So, when I entered my first year of university I knew the meaning of the word cheap (or so I thought). I was to learn the other meanings of the word in unpleasant circumstances.

This was the first time I was in a multiracial multicultural class, a big adjustment for me. There were eight of us in the Biology class, four whites and four blacks. As part of our social interaction we organised a tea club. We would contribute a small amount per month towards the tea and biscuits. My newly found friend Vanessa volunteered to go and buy. She came back the following day with much more than we had expected our money to buy. She had found some bargains and had bought quite a good supply and variety for the little that we had contributed. So everyone thanked her for a job well done. In excitement I also expressed my thanks thus, “Thank you Vanessa for buying us cheap tea”. Vanessa caught her breath and her face went crimson red and then she turned and walked away without a word. I knew something was wrong, but what? I looked around the room for help but none was forthcoming. For days after that incident Vanessa wanted nothing to do with me and I did not have the courage to ask her. What if I said something that would offend her again? I had no idea why she was so angry with me. After all, she had bought the tea for a lot less than we expected? She had bought us cheap tea! I have since learned that Vanessa bought us tea at a *discounted* or *reduced* price, that the tea *cost less* but was not cheap as in the second and subsequent dictionary meanings of the word. Intellectually, I *understand* this but I still do not *see* why it was not cheap tea!

Language is a tool to be used to the benefit of the users. However, like any other tool language is open to misuse, abuse, distortion, misinterpretation, deliberately or through ignorance and when this happens language becomes a barrier to social interaction and communication may be halted or discontinued completely, relationships maybe threatened as in my case with Vanessa. In the classroom the results could be life changing for the learner (or the teacher). Even where the language itself is not a barrier, classroom interaction by its very nature requires that talk for sense-making be mediated and it is a taken-for-granted fact that this is the teacher’s role. Often it is assumed that any teacher should be able to perform this role. However, evidence indicates that teachers need to be supported in developing the skills needed to perform this role and that they need to practice and adapt it for their various contexts. In South Africa the diversity of the contexts and the participants (teachers and learners) is both a challenge and a resource to work with to achieve the level of talk required to afford learners access to science content and open for them the doors of higher education and opportunities for participation in the job market. This was my motivation to understand

the dynamics of development and management of science talk to create learning opportunities in Soweto science classrooms.

1.1 International and local issues on talk and the teaching and learning of science

Research suggests that there is a close relationship between talk or language use and cognition (Mercer, Wegerif, & Dawes, 1999) and that classroom discussion plays a central role in collective science knowledge construction (Mortimer & Scott, 2003; Sprod, 1995). In science and mathematics education, there is a considerable body of literature that argues for the promotion of discussion and argumentation as a means to develop critical thinking and group work skills (De Bono, 1990; Kieran, 2004; Osborne, Erduran, & Simon, 2004). Webb and Treagust (2006) assert that individual reasoning has part of its origins in dialogue with others, while Mortimer & Scott (2003, p. 3) “see talk as being central to the *meaning making* process and thus central to learning”. However, in many science classrooms throughout the world there is little evidence that learners are afforded the opportunity to discuss their ideas, either with the educator or with each other (Lemke, 1990; Mortimer & Scott, 2003). Similarly in South Africa, researchers also lament the lack of meaningful discussion in classrooms, especially in previously disadvantaged schools (Brodie, 2005a; Taylor & Vinjevold, 1999; Webb & Treagust, 2006). Where its use is attempted, discussion is usually unfocussed and unproductive. Teaching and learning is still largely teacher-centred, characterised by learner passivity and rote learning, teachers’ questioning aims at data recall and checking with cursory reference to applications of science knowledge in societal and developmental issues.

Research has established that learner participation and engagement can be achieved with well organised group work and structured discussions (see for example, Herrenkhol & Guerra, 1998). South Africa’s new science curriculum aims to transform classroom discourse with methods that promote learner participation and enhance learner engagement (Department of Education, 2003c, 2008, 2011c). The new curriculum demands a high level of knowledge from curriculum implementers and transforming these curriculum reform initiatives into effective practice is difficult for teachers. In South Africa, implementation of the new science curriculum is complicated by the fact that it takes place against a backdrop of low performance in science at secondary school attributable to historical, political and socio-economic factors. Thus, an understanding of the dynamics of teacher-learner interactions in these complex and diverse contexts may shed some light on how to achieve the requisite

shifts in pedagogy to teaching strategies that promote learner participation as anticipated in the new curriculum.

My study aimed to provide insights into the nature and dynamics of teacher-learner interactions resulting when teachers introduced science talk or structured discussions in high school science classrooms. I wanted to understand the potential of science talk as a tool to create opportunities for learners to engage in meaningful discussions to articulate, interrogate, evaluate and challenge each others' ideas and hence to facilitate construction of understandings and shared meaning-making.

1.2 Identification of the problem and purpose of my study

1.2.1 Problem identification

Almost two decades later, post-independence South Africa is still faced with the problems of inequity in access to schooling and poor uptake of science at post compulsory stages of schooling, especially among the previously disadvantaged communities. Access to meaningful learning still tends to be closely associated with social status and research continues to produce evidence of critical lack of epistemological access (Morrow 1994). By epistemological access I mean provision and utilisation of opportunities to engage meaningfully with and understand scientific knowledge. In science teaching and learning epistemological access therefore, would include not only learner understanding of science concepts but also the ability to determine what it is they do not know, how to know what they do not know as well as knowing how scientists come to know science. Where opportunities are not made available or are unequally afforded the inevitable outcome is inequitable access to science knowledge and thus the notoriously persistent trends in poor learner performance with a bias against learners from the poorer socio-economic backgrounds. To address some of these disparities the South African government has instituted a process of curriculum change since the late 1990s.

Among the objectives of the new South African science curriculum are inquiry, problem solving and critical thinking skills development. It is envisaged that citizens who are scientifically literate would be in a better position to participate in economic activity and in democratic structures, so as to engage with the social challenges that plague their communities, such as poverty, HIV/AIDS and other inequities in society. However,

transforming curriculum reform initiatives into effective practice is a challenge for educators and policy makers. Many South African teachers are unsure about what changes are required of them (Sanders & Kasalu, 2004) yet research indicates that if teachers are made aware of appropriate strategies and materials to use they can stimulate meaningful group work and classroom discussions (e.g. Brodie, Lelliott, & Davis, 2002a; Brodie & Pournara, 2005; Scholtz, Watson, & Amosum, 2004; Webb & Treagust, 2006). My study aimed to make a contribution to current science education research in South Africa that is addressing the challenges of improving learner uptake, throughput, performance and achievement in high school science at levels that allow them access to further education or entry into the job market. My study therefore, sought to understand whether and how with targeted support, teachers can adapt new innovations that aim to facilitate the shifts in pedagogical practices necessary for successful implementation of the new science curriculum. In the bigger picture my study makes a contribution to current understanding of the dynamics of creating opportunities for learner epistemic access and achievement within the South African context of learner (and teacher) multilingualism and diverse socio-cultural and socio-economic backgrounds.

1.2.2 The purpose of my study

The purpose of my study was to investigate the use of *science talk*¹ as a teaching strategy to stimulate learner participation, engagement and reasoning envisaged in the new curriculum for science learners in South African classrooms. The findings of such a study may shed some light on the potential of *science talk* to enable the shifts in pedagogical practices envisaged for successful implementation of the new science curriculum at high school in South Africa.

Research on teacher-learner and learner-learner verbal interactions has intensified in the last decade. However, most research has taken place in developed contexts and mostly with different historical and political backgrounds to the South African situation. My interest was in how science talk plays out in a developing, multi-lingual context in the process of

¹ *Science talk* is a term that I have coined to include all science-related speech in a lesson, that is, all talk that explicitly or implicitly, intentionally or unintentionally addresses the science content under consideration during the lesson. *Science talk* is defined in Chapter 2.

curriculum change such as is happening in South Africa currently. I sought to address this gap in knowledge of the nature and dynamics of teacher-learner interactions in the complex and diverse contexts found in South Africa and in Soweto in particular. I wanted to understand how science talk could be utilised as a tool to create opportunities for learner engagement and meaning-making.

1.3 Context

In the next section I provide for the reader an insight into the context in which I studied the development, adaptation, practice of science talk; the conditions under which teachers and learners actually utilised science talk and developed the various forms of competences discussed in the rest of my thesis. In discussing the context of my study I begin with a brief description of the curricular, socio-cultural and socio-economic context. I consider the curriculum reform context and provide some perspective in terms of the bigger project in which the study was located and finally, I position myself in terms of what I believe may have been the biggest influences on my interest and views of science talk.

1.3.1 Curriculum reform context

The process of curriculum change is a rough and contentious one the world over (see for example Adey, 1997; Alexander, 2004; Chisholm, 2003, 2005b; Jansen & Christie, 1999; Rogan, 2004; Verspoor, 1989, 2006). The introduction of a new curriculum always generates debate both at policy and implementation levels and in South Africa, this debate includes demands on educators to make big shifts in their pedagogical practices (Chisholm, et al., 2000) from transmission instructional strategies and rote learning to methods that promote high learner participation and development of higher order thinking skills (Brodie, Lelliott, & Davis, 2002b; Department of Education, 1996, 2003c; Hattingh, Aldous, & Rogan, 2007). Research findings so far in South Africa show that both teachers and researchers are struggling to find solutions to the challenge of curriculum change. The difficulties experienced by teachers range from poor preparation and understanding of the requirements of the new curriculum (Aldous, 2004; Sanders & Kasalu, 2004) to lack of adequate pedagogical preparation and poor subject matter knowledge (Loughran, Milroy, Berry, Gunstone, & Mulhall, 2001; Rollnick, Bennett, Rhemtula, Dharsey, & Ndlovu, 2008), lack of skills to develop and manage teaching and learning materials and activities that involve learners in constraining physical and social environments at school level (Chisholm, 2004;

MacDonald & Rogan, 1988; Scholtz, et al., 2004). Teachers often have to contend with the challenges of implementing learner-centred strategies with large class sizes in overcrowded classrooms and poorly prepared learners who themselves have been schooled in traditional ways for the bulk of their school years. This is confounded by the administrative demands that the new curriculum places on teachers (Brodie, 2000; Brodie, et al., 2002a; Hattingh, et al., 2007; Jansen & Christie, 1999; Stoffels, 2005a).

The policy statement of the post apartheid national Department of Education was first introduced as Curriculum2005 (C2005) in 1997. The document went through a public process of revision through 2002 to become the Revised National Curriculum Statement (RNCS) for implementation at the lower grades (Grade R-9). In 2006 the National Curriculum Statement (NCS) was finalised for implementation at Grade 10-12 levels, the Further Education and Training (FET) phase (Department of Education, 1996, 2002, 2003c). My study focused on implementation of the Physical and Life Sciences curriculum at the FET phase.

In the NCS a subject was defined by Learning Outcomes (LOs) as well as a body of content. “A Learning Outcome (LO) is a statement of an intended result of learning and teaching. It describes knowledge, skills and values that learners should acquire by the end of the Further Education and Training band” (Department of Education, 2003c, p. 7). The prescribed content was to be covered so as to assist learners to achieve the Learning Outcomes. This requirement was one of the main differences between the NCS and previous curricula which emphasised acquisition of content (Chisholm, 2005a).

The Life Sciences and Physical Sciences both had three Learning Outcomes, LO1, LO2 and LO3 as summarised in sections 1.3.3.1 and 1.3.3.2 respectively. By its nature science talk is relevant to all three LOs as a tool for learners to develop the requisite skills and competencies as well as engage with the content. My interest was in how science talk was used in any of the LOs, for example, how it aided science knowledge construction (LO1 & LO2) as well as how it played out when teachers and learners discussed mainstream science and indigenous knowledge concepts (LO3).

1.3.1.1 Learning Outcomes of the Life Sciences

- LO1: Scientific inquiry and problem-solving skills. The learner is able to confidently

explore and investigate phenomena relevant to Life Sciences by using inquiry, problem solving, critical thinking and other skills.

- LO2: Construction and application of science knowledge. The learner is able to access, interpret, construct and use science concepts to explain phenomena.
- LO3: Understanding the interrelationship of science, technology, the environment and society and of different attitudes and values. The learner is able to demonstrate an understanding of the nature of science, the influence of ethics and biases in the science, and the interrelationship of science, technology, indigenous knowledge (IK), the environment and society (Department of Education, 2003a).

1.3.1.2 Learning Outcomes of the Physical Sciences

- LO1: Practical scientific inquiry and problem-solving skills. The learner is able to use process skills, critical thinking, scientific reasoning and strategies to investigate and solve problems in a variety of scientific, technological, environmental and everyday contexts.
- LO2: Constructing and applying science knowledge. The learner is able to state, explain, interpret and evaluate scientific and technological knowledge and can apply it in everyday contexts.
- LO3: The nature of science and its relationship to technology, society and the environment. The learner is able to identify and critically evaluate scientific knowledge claims and the impact of this knowledge on the quality of socio-economic, environmental and human development (Department of Education, 2003b).

The national curriculum document has undergone several revisions since the beginning of my study and in both the Physical and Life Sciences there has been a gradual return to emphasis on content, particularly so in the Physical Sciences. In 2011, towards the end of my study the curriculum was further revised and a new document, the Curriculum and Assessment Statement, CAPS, was produced. While the basic philosophy and content of the curriculum remained unchanged the fundamental principles of outcomes based teaching and assessment were dropped. CAPS therefore became more content-based and inclined towards traditional school science as opposed to an inquiry based curriculum (Department of Education, 2011a, 2011c). There is however, a continued emphasis on inquiry and learner practical work both of which lend themselves well to argumentation.

1.3.2 The Project on Implementing Curriculum Change (ICC Project)

As in any other curriculum change situation many stakeholders are involved in the design, review, implementation and research of the South African curriculum change process. My study was conducted as part of such an initiative, a large scale project on the Implementation of Curriculum Change (ICC) Project by the University of the Witwatersrand jointly with the Educational Quality (EdQual) consortium of DFID funded projects. The project was conducted in partnership by education institutions in four countries; the United Kingdom (Bristol and Bath Universities), Pakistan, Uganda and South Africa (the University of the Witwatersrand). The ICC Project sought to identify ways of working with education stakeholders such that opportunities for teaching and learning mathematics and science are utilised more efficiently. The main objective was to understand the process of curriculum change in mathematics and science within disadvantaged contexts, hence the focus on Soweto. Underlying the ICC Project approach was a collaborative research methodology that aimed to drive change in practice. The researchers in the ICC Project worked together with teachers to explore and reflect on their practice, with a view to improving the ways in which learning opportunities were created within the local contexts of the targeted schools. The ICC Project team comprised a lead researcher (a mathematician) and two PhD students, one for mathematics and one for science (myself), which meant that I was the only science researcher on the team. Together with the participating teachers the team identified argumentation, critical thinking and problem solving as the skills to focus on. Since evidence from literature showed that it was possible to develop the skills of critical thinking and problem solving through argumentation, the science team decided to target argumentation both as a teaching strategy and a learning tool. However, indications from a baseline study were that students were not talking in class or if they did they were doing so in ways that did not help them with construction of science understandings and meaning-making. Also the teachers were not sure how to stimulate meaningful talk and/or how to manage it. For my PhD study I therefore, decided rather to begin the investigation by looking at talk in general and how it might build up to argumentation which is a more technical and highly structured form of talk.

1.3.3 The local school context

Soweto was targeted as the site of innovation for the ICC Project as part of its drive to work with previously disadvantaged schools to address issues of redress and equity (ICC Project proposal, 2006).

1.3.3.1 The schools

I have renamed the three schools that I worked with Sekolosarona, Nodumo and Imfundo secondary schools. The three schools were similar in many ways yet they were each sufficiently unique to present a different case from the others. For example, the fact that they were all in Soweto suggests that they catered for black learners from a low socio-economic background. However, most learners from the surrounding communities came from homes with a mortar and iron sheet roofed house with running water in the house or at least a few houses down the street. Most had toilets with running water. In some cases, particularly for Sekolosarona learners the homes were well developed with multiple rooms and more than one family living together in the same property. Some learners did commute to school, though. For example, Imfundo was located close to the local train station and learners would be seen disembarking in the morning or rushing to board at the end of the day.

All the schools were fenced with a two to three metre high net wire fence with access controlled gates which in the case of Sekolosarona and Nodumo were always locked and learners only exited the gates at the end of the school day. At Imfundo there were security personnel at the gate but it was not locked and learners could go in and out throughout the day. The grounds were generally neat and well maintained and both Sekolosarona and Imfundo had a small garden maintained by learners in turns by their classes. The situation at Nodumo was different when I first visited the school as will be explained in Chapter 3. The school was in a bad state of maintenance then with much litter and overgrown with uncut grass. This later changed and the grounds were well maintained for the rest of my study time. All three schools were big by local standards with an average student population of 1500-2000 for Grades 8-12. Each school had between three and five classes for each grade and on average 50 learners per class.

Because of the initial political structuring of Soweto in the apartheid era, the communities were clustered according to their tribal and language groupings. This structure was however, changing as there was now free movement of families to live closer to better facilities or near the main provider's work place. The trend was therefore, that the community shared a common language but also spoke or at least understood one or more other languages. Most of the teachers had moved from the same neighbourhoods in Soweto to nearby upmarket suburbs and commuted back to their old workplaces in Soweto schools. Most thus, shared the same historical and language backgrounds as their learners and the surrounding communities.

1.3.3.2 The teachers and learners

Mrs Thoba taught Physical Sciences and Mathematics at Sekolosarona High School. She lived in the same neighbourhood and spoke the same language with her learners. She also understood five other local languages. Her school was a more traditionally black township school, not very well resourced. While there were enough rooms for all the classes the school had only one laboratory for all science classes and this was reserved for Grade 12 classes. In the three years that I worked with Mrs Thoba she never took any of her Grade 10 – 11 classes to the laboratory. Any practical activities were conducted in a normal classroom where learners took their classes every day.

Mr Far taught Physical Sciences, Computer Application Technology (CAT) and Mathematics at Nodumo, in a previously all “coloured” community. In South Africa the word coloured is used to refer to people of mixed race. The school was in a state of transition from Afrikaans medium to English medium. This was a fairly well resourced school with traditional science laboratories used by all Grade 10-12 classes. All Grade 11 and 12 science lessons were conducted in the laboratory and Grade 10 lessons were in ordinary classrooms. However, the school was in a generally low income, high unemployment community and structures were run down and in a state of disrepair. The community was predominantly Afrikaans speaking but most learners spoke other local languages. However, while the learners were multi-lingual most teachers were not. Mr Far himself was bilingual with English and Afrikaans and therefore did not understand some of his learners languages. Mr Far lived some 15km away from his school, driving to and from the school every morning and evening.

Mrs Nkosi was a Life Sciences and Life Orientation teacher at Imfundo high school. She had moved house from the area to a more affluent suburb about five years before the start of my study and she drove to the school every morning. She spoke the same language as her learners and the local community and was therefore, still regarded as part of the local community although this could also be due to her involvement with learners in her other capacities as HIV/AIDS co-ordinator, head of the disciplinary committee and the weekend tutorial programme. Mrs Nkosi’s school was the newest of the three having been built to provide a second high school in the area so as to receive learners from the three surrounding primary schools. However, because of its reputation for good learner performance at matric Mrs Nkosi’s school enrolled many learners from as far as 10km from the school. As I have

already said many of their learners came from other parts of Soweto commuting on the local train every morning and evening.

1.3.4 Researcher positionality

Like Vygotsky (1978) and Bernstein (1996) I believe that my sense making of science knowledge is related to, perhaps even determined by my past experiences with formal science and with everyday knowledge. I will therefore, first provide some background to the possible sources of my assumptions and/or personal beliefs about talk, about science and about the teaching and learning of science as these are likely to have influenced the way I view science talk and how I made sense of it as it unfolded in the classrooms I worked in.

1.3.4.1 Where I have come from

I was born in the city of Bulawayo in Zimbabwe but was raised mostly in the village of Emgomeni, eTsholotsho where I lived with my mother and my extended family until I was ready to start school. My parents converted to Christianity soon after I was born but the rest of their families believed strongly and practiced traditional African religion. My maternal grandfather had been a herbalist – not quite a *sangoma* because he did not predict or see into people's futures but "saw" in his dreams plants that could be used to heal specific conditions or diseases. My grandmother was still a renowned brewer of the traditional beer locally dubbed "seven days" brew. For most of my childhood therefore, I traversed the two worlds of my parents' Christian values and belief system and my extended family's more indigenous one.

My parents spoke the same language, isiNdebele, so I had only one language to learn as a child. People often speak of their mother tongue, but for me both my mother tongue and father tongue were the same. The whole village spoke that one language and so I never struggled with language, I just spoke it. Then to start school I moved to Bulawayo city where my father worked and I lived there with him and my siblings in Luveve township. I was in the same class with friends from three or four adjacent streets so we knew each other long before we came to school. Class was therefore just a continuation of friendships from our streets. Although I knew that some of my friends spoke a different language at home it never occurred to me that that might be a problem. After all we all spoke the same language in the streets when we played. They were so fluent in my language they could have been my

brothers and sisters. So there were no language issues, at least not in my mind and I never thought about how it was to learn in a language that is not yours. I was in this blissful state for all of my foundation phase education, Sub-A and sub-B. Then in the third year in Standard one things changed. We had been reading words and sentences in English in Sub-A and Sub-B but our teacher always spoke to us in our language and she gave all instructions in isiNdebele, my language. Now in Standard one, we started reading whole stories in English and we did sums in English and we did Nature study in English. We now had to write letters not only in isiNdebele but also in English.

This was a milestone achievement for us children because back in the village reading and writing in any language was an important measure of a child's education. It was important for a child to be able to read and write a letter, as well as read the Bible to the elders. Letters were the only reliable means of communication between wives in the village and husbands in the city or between parents in the village and their grown children working in the city. All the mail came on the bus which came through our village from the city thrice a week on Wednesday, Friday and Saturday nights. It stopped at the grinding mill and we loved going down to the bus stop to wait for the bus and bring home the mail. Then when we got home the best reader among us would be asked to sit with each recipient and read their letters to them. Often the child would then be asked to help write a reply to the letter. So she would sit on the floor pen and paper in hand feeling important and the elder would dictate the reply. When the letter was done she would be asked to read it back to the writer to check that all their thoughts had been captured accurately. For the most part we wrote what the elders dictated. There were however, the occasional times when we were naughty and tampered just a little bit with the contents of the reply. This was our childish way of taking revenge on mean adults. There was the one time for instance when a letter came through for umamuJinethi from ubabuDlodlo her husband. UbabuDlodlo was a good man but umamuJinethi was not, at least we did not think so. She often mistreated us children and sent us on endless errands and we decided to take revenge. My cousin and I decided to tweak her reply to ubabuDlodlo just a little. Needless to say there were unpleasant consequences all round.

There was thus, much motivation to learn not only how to read and write English and isiNdebele but also to speak the languages well. By my final year of primary school

education I excelled not only in the languages but also in mathematics, nature study and social studies. I proceeded to high school and was quite well set for a successful four years to my O levels. However, unbeknown to me I apparently had a worrisome handicap – it worried my teachers and my parents, obviously, but not me. In spite of the little pranks I and my cousins pulled with letter writing I was a very quiet child. In fact I was so quiet all my teachers felt it necessary to comment about it in every report card they sent to my parents. So, I heard a lot about it at home where my quietness was initially described in very colourful negative words - until my first report card arrived. After that I still heard a lot about my quietness but the negative words had been replaced by more positive expressions of “At least she is passing, but she really needs to learn to talk, her teachers are concerned”. Of course I did not understand the fuss, why was it so important for me to talk? I got on with my school work quietly. Or so it seemed.

Like every other child I engaged in numerous lengthy discussions - with myself. I questioned my teacher's ideas, came up with my own alternatives and tried them out - all inside my head. My teachers had no clue to these private conversations of mine. I did well in my studies; in fact I was always somewhere in the top ten in my class. I was doing fine even in my quietness. I moved on from primary to secondary school and still did fine. Although I was an all rounder, I particularly enjoyed Biology and Mathematics. I would sit for hours on end working through the Math problems or reading Biology books. I found the relationships between form and function in Biology quite fascinating. I had two close friends who were not as fortunate with the Math and Biology, so they would ask me to go through the homework material with them every morning just before submitting it. I was happy to oblige. Initially it was just about helping my friends. They asked the questions, I provided the answers. I explained, we discussed, sometimes going over and over the solution until they got it. At times I got stuck too and could not recall how I had solved the problem alone at home and as I talked myself through it I would “see” it again or “see it another way”. It was then that I realised that as I talked through the problems with my friends something happened with my own understanding too. So my reasons for engaging in the discussions changed; not only was I explaining to my friends but I was clarifying things for myself too. To top it all I realised that as my friends' grades started improving so did mine. We extended the strategy to other subjects and we were rewarded. At age 15 I understood that I learned better by discussing my ideas with others and although I did not immediately come out of my “quiet child” shell,

learning became a much more pleasurable experience for me. I had made a valuable discovery – that while it was possible to score high grades working silently alone, it was even more rewarding to talk to others. It was a long journey though for me to break out of that shell completely and get to where I am today where talk has become for me such an invaluable tool for communicating my ideas and thoughts or expressing my doubts or lack of understanding of other people’s ideas or challenge their opinions and positions. That road has taken me in and out of the classroom as both a student and a teacher and into the field as an ornithologist and researcher in biodiversity conservation for a quarter of a decade. That journey however, has not only influenced my positionality as a non-native speaker of English and as a non-talker but also my thinking about the role of talk in teaching, learning and communication in the scientific world. To illustrate the latter, I now provide a brief synopsis of what I believe has influenced my positionality as a biologist.

1.3.4.2 Influences on my biologist positionality

My initial training was in Botany and Zoology followed by an Honours degree in Biological sciences four years later, a Master of Science in Zoology ten years later. Between the first degree and the honours degree I found myself in the classroom as a “temporary” (which meant untrained) Biology and Physical Science teacher. I later joined the Natural History Museum as a trainee researcher in the Ornithology department where I worked for a total of eleven years broken by a five year stint at the University of Botswana’s Department of Biological Sciences. When sixteen years after my first full time job as a teacher I found myself at Solusi University where I was assigned to teach all Biology to environmental science, agricultural science and education students I gave in to the thought that teaching might be my calling. I registered for a post graduate certificate in education and never looked back. To all intents and purposes those eighteen months of studying for the PGCE jolted my consciousness to the role of language in teaching and learning. For the first time I thought about how my students learned (or did not). Before then I had never questioned what happened as I learned. Nor did I ever stop to think about the times when I found it difficult to learn or about the plight of those fellow learners who found it difficult to learn some of what I was able to learn myself. In other words I took learning for granted; it was something that had to happen whenever one was taught and I got frustrated when it did not happen. Two of the assumptions that I have made about science talk in my study emanated from a combination of this personal background and some observations from literature.

First, I believe that students need to hear their own thoughts, think them through again, rework and reconsider them in the more public social plane in discussions with their peers or teacher. Like Kuhn (1992), Lemke (1990), Mercer (1995) and others I believe that talking can help students not only externalise their thinking but also to modify the everyday way of talking about their ideas so that they begin to talk about them in ways that enhance science learning. Secondly, I believe that while it may not be possible to get all learners talking, it is possible to get the rest to listen to those that are talking; that participation or even engagement is not only measured in terms of what we see students doing at the time but also in terms of what is going on inside their heads as they listen to someone else talk about their understanding (or lack thereof) of science concepts. I understand student participation and engagement as described by a colleague (Otulaja pers. comm., Johannesburg, May, 2010), “They are engaged when they turn around to face the student who is talking or when they scratch their heads or tap that pen or ruler on the desk in thought; when they whisper something, a comment, disagreement or agreement, or when they scribble down something as the other student is talking”. I believe that science talk – theirs or someone else’s can elicit these reactions and thus enrich the students’ classroom experience as it did for me. And if in the process they can be able to learn science better then, “eureka” for science teaching and learning in South African classrooms!

I believe as Berland and Hammer (2012, p. 90) do that science talk is a tool, not only to be developed, modified and adapted for the local context but more importantly, that participants should be afforded the opportunity to practice using the tool, gain competence in its use and actually utilise it to achieve what it is designed to do or use it to “find out something”. Thus I see a distinction between a study of how to develop in teachers and learners the skills of science talk and a study that aims to understand the dynamics of how science talk is used by teachers and learners to aid the process of meaning-making. My focus was on the latter.

1.4 *Aim and research questions*

In this section I articulate the aims of my research and the research questions that guided it. I also talk about what I proposed to do to answer my questions and how I went about doing it.

The aim of my study was to investigate the use of science talk as a teaching strategy to stimulate learner participation and a learning tool to facilitate scientific meaning making

during implementation of the science curriculum at FET level in South Africa. The Further Education and Training (FET), comprises the upper level of high school, that is, Grades 10-12. Learners exit high school at Grade 12 with a national or matriculation examination.

The question that guided my research was “How do teachers use science talk to stimulate learner participation and engagement in high school science classrooms and what is the nature and quality of ensuing teacher-learner interactions during science talk?” and I analysed my data in terms of the following sub-questions:

1.4.1 How do teachers shape science talk in high school classrooms?

Here I sought to understand what communicative approaches teachers adopted in order to guide and/or shape the talk so as to achieve their teaching purposes. I did this by using teacher interventions as codes to determine the teacher’s communicative approach at different stages of the lesson.

1.4.2 What patterns of interaction emerge as teachers and their learners engage in science talk?

To answer this question I identified the patterns of discourse that emerged during science talk. By mapping the sequence of teacher-student turns on the transcripts I determined whether traditional IRE triads prevailed or whether there was evidence of emergence of Mortimer and Scott’s (2003) more dialogic IRF, IRFRF or IRPRPR...E chains. According to Mortimer and Scott the IRF sequence is a relatively more dialogic version of the traditional IRE triad. In the IRF the third move is F, teacher feedback rather than E, evaluation. The way a teacher manipulates the F move in the IRF chain opens up or closes down classroom talk. They argue that dialogic interaction in the classroom can take two forms. The IRFRF or Initiation-Response-Feedback-Response-Feedback is a closed chain because it ends with a feedback move. In the IRPRPR...E or Initiation-Response-Probing-Response-Probing-Response...Evaluation sequence however, the teacher tends to open up the interaction with probing moves. I used these sequences to characterise student participation.

1.4.3 What is the quality of the interactions that emerge with science talk?

In this case I sought to understand how meaning making was negotiated between the teacher and learners and among the learners by determining whether and how students justified their claims with evidence and/or evaluated their own and others' arguments.

1.5 How I answered my research questions

Here I provide a brief explanation of my research paradigm, my data collection and data analysis methods.

1.5.1 Research design

A collaborative research methodology was adopted using qualitative research methods (Freebody 2003) and the researcher as a participant-observer. Darlington and Scott (2002) suggest that there is a range of forms of observation and participation. They argue that "Observation roles can be viewed along a continuum from complete observer through observer-as-participant to participant-as-observer to complete participant" and that "The observer is always in some respects a participant ..." (p78).

The ICC Project within which my study was located was structured along the lines of the CASE methodology (Adey & Shayer, 1994; Shayer, 1999). The UK project, Cognitive Acceleration through Science Education (CASE, 1984-1987) involved collaborative work between teachers and researchers. CASE's success was largely attributed to sustained collaboration and support provided for the teachers. Research has identified some features of effective intervention programmes that incorporate teacher professional development. These include duration (programmes must be ongoing), opportunities for individual reflection and group inquiry into practice, coaching and follow up programmes, collaborative engagement with peers, recognition of teachers as professionals and adult learners (Garet, Porter, Desimore, Birman, & Yoon, 2001; Ismat, 1996).

To create the necessary conditions of extended support and coaching the ICC project was designed to run in phases. The main activities in Year 1 were identification and recruitment of teachers, teacher workshops and conceptualization of the co-teaching model. A total of twelve Life Sciences (Biology) and Physical Science teachers were recruited and a series of workshops was held throughout the year for teachers to identify their needs/challenges; for

the researcher-teacher team to consider learner-centred teaching strategies and design appropriate tasks/activities. Teachers also identified challenging science content, mostly new topics in the curriculum and special workshop sessions were dedicated to this content.

A specialised co-teaching model was conceptualized for the second phase of the project which involved joint planning of lessons, post-teaching conferencing sessions for group reflection on video recorded lessons as well as turn taking in delivering the lessons. The model involved both teachers and researchers presenting lessons and then the team would critique the lesson presentation during the reflection meeting. Initially, the teachers seemed uncomfortable with this model and so the researchers volunteered to have the teacher-researcher team critique their lessons first. This helped to break the ice and teachers also became more open to critique of their practice during the reflection sessions.

The co-teaching model continued in the first half of the second year, to model selected teaching strategies. The focus was on creating what Mortimer and Scott (2003) called Interactive-Dialogic discourse in the classroom. This is a learner-centred strategy for facilitating meaning and student participation in whole class and small group discussions as well as more substantive engagement with the science content.

Teacher support and mentoring was intensive at first but was gradually reduced in the second year and finally stopped in the third. Teachers were given the choice to use or not to use the strategies in their lessons and I then followed three case studies (teachers), and observed sample lessons per teacher over a year to determine the use (or not) of the teaching strategies. Video and audio recordings of the lessons were transcribed and analysed to determine how interactive the lessons were and the quality of learner engagement with science talk.

1.5.2 The workshops

In the workshops I took the science teachers through some of the literature findings on the importance of talk in science classrooms; how to design tasks that can stimulate student talk; how to ask open ended questions that stimulate higher order thinking; how to manage the ensuing discussions such that they do not break down into unproductive bickering and/or meaningless sharing of personal opinions; the norms of argumentation and how to stimulate and manage student argument formation. After the workshops the teachers would return to

their classrooms and use their own discretion on when and how they wished to employ science talk in the next month. I would then visit them as often as I could within that month to observe them use (or not use) the strategy. I will revisit this point at several points during the course of this thesis to illustrate how it was both a limitation and a resource in understanding contextual influences on science talk.

1.5.3 Data collection methods and forms of data

My data collection methods were mainly video and audio recordings of classroom observations, semi-structured interviews and informal discussions. I also made field notes to record the details of the context and my own insights into the classroom interactions.

Data for this project were collected in several different forms. First, the teachers' workshops conducted in the first year of the study were video and/or audio recorded. Video recordings were also made of teachers and researchers co-teaching including where possible, the lesson planning meetings, the lesson presentation as well as the post-teaching reflection meetings. Selected lessons from each of the three cases in my study were later video and audio recorded. The recordings were then transcribed and analysed for teacher-learner and learner-learner interaction.

1.5.4 Data analysis and interpretation of results

From the volunteering teachers on the ICC Project the three keenest to try science talk in their classrooms were selected for classroom observation. The data from observations of their classrooms and conversations with the individual teachers was analysed for teacher-learner interactions with Mortimer and Scott's (2003) model to determine whether classrooms had become interactive, the extent to which the discourse was dialogic as well as whether and how substantive learner engagement with science content was being achieved. To determine if the lessons were interactive and dialogic I focused on the levels of student talk and what teacher interventions created the dialogic discourse. For quality of interaction I drew from argumentation theories to determine the nature of arguments emerging in each classroom.

1.6 Significance and delimitation of the study

My study aimed to make a contribution towards characterising the changes in pedagogical practice envisaged in the NCS to create learner-centred teaching and learning environments

in two ways. First, the use of science talk addresses the requirements of the new science curriculum for teachers to make use of teaching strategies that encourage greater learner participation and engagement in science classrooms, thus shifting responsibility for learning to the learners themselves. Secondly, talk has been suggested as a legitimate learning tool through which learners can construct scientific knowledge as they debate on concepts and issues in the classroom (see Chapter 2 Section 2.2.2). The objective was to determine whether and how talk was used as a tool for meaning making in the science classrooms observed. Also, the findings of such a study could indicate whether and how science talk research could be extended to other classrooms in South Africa and elsewhere.

My study might provide insights into the nature of interactions resulting when teachers introduce well structured and managed discussions (science talk) in science classrooms as well as the potential of science talk both in the implementation of the new South African curriculum and other curricula in similar contexts elsewhere in the world.

1.7 Thesis overview

1.7.1 Chapter 1 Introduction, *Perspectives on science talk in South African high schools*

In the introduction chapter I articulate the problem-purpose statement for my study. I identify the knowledge gap locally and internationally and use it to locate my study in the bigger debate on local and international issues on curriculum change, pedagogical reforms and the learning of science. I also locate my study within the bigger project that it was conducted as part of and highlight how they both influenced and shaped each other. Finally, I give a brief synopsis of my research paradigm that guided what I set out to do, the questions that I asked, what data I collected so as to be able to answer them as well as the tools I used to analyse the data.

1.7.2 Chapter 2 Literature review and theoretical frameworks

In the literature review chapter I provide a survey of research that has been done so far locally and internationally on each of my main concepts: classroom talk and science teaching, forms of talk and theories that deal with talk. I engage with various perspectives on learning that have influenced my thinking about science talk as a tool for meaning-making, thus Vygotsky's socio-cultural theories of socially mediated knowledge construction, the work of scholars like Lemke, Kuhn, Mercer and others on classroom interactions, in particular verbal

interactions. I also consider argumentation theories by international scholars starting with Toulmin and the adaptations of his model for science classrooms by Erduran and colleagues, Sampson & Clark and colleagues, Berland and colleagues as well as local South African work on argumentation by scholars like Braund, Lubben, Ogunniyi, Scholtz and their colleagues. I then show how the aims of my research, the research questions, the data collection methods and analysis tools fit into the bigger picture from my literature review.

1.7.3 Chapter 3 Research design and methodology

In this chapter I describe and explain my research methodology starting with the research paradigm that underpins my thinking about the concepts and the data that I collected. I elaborate on the methodological implications of the way my research is nested in the ICC Project and its co-teaching model and teacher workshops. I also address the question of how the decision to focus on science talk was taken, with the implications for methodology as opposed to purely argumentation studies. I describe the cases in the study and how they were decided on and how I worked with them in their individual contexts. Finally I explain in greater detail my actual data collection and analysis.

1.7.4 Chapter 4 My data analysis tools and data summaries

In Chapter 4 I present my analytic tools and show how they derive from the literature and how they help me answer my research questions. I also give a brief overview of my data locating the data forms and timing of collection in the timeline of the study in terms of teacher workshops, co-teaching and lesson observations. I present summaries of science talk observations in each teacher's classroom, characterisation of teacher communicative approaches and discourse types identified in the lessons observed. I then provide my interpretation of the results in terms of emerging teacher dialogic pedagogical practices and learner participation and engagement. In subsequent chapters I provide evidence for these emerging patterns.

1.7.5 Chapter 5 Opening up and shutting down talk: Teacher communicative approaches

Chapter 5 is the first chapter of three in which I engage with my findings. I discuss the data analysis relating to my first two research questions: "How do teachers shape science talk during the lesson?" and "What patterns of interaction emerge as teachers and their learners engage in science talk?" I examine the interactive discourse to determine learner participation

and I identify teacher communicative approaches, interaction patterns and teacher interventions that shape them. I do this for each of three selected lessons from each of my three teachers' classrooms. The focus of the discussion in this chapter is learner participation and it is extended in the next chapter to include learner engagement.

1.7.6 Chapter 6 Argumentation: Sense-making, articulating and persuading arguments

This chapter targets my third research question, "What is the quality of the verbal interactions that emerge as teachers and learners engage in science talk?" I use data from the teacher-led whole class discussions to illustrate teacher-learner co-construction of arguments that serve three different purposes: arguing to articulate understandings; arguing to make sense of the science content and arguing to persuade others. I illustrate how the teacher interventions considered in the previous chapter are critical in shaping argumentation starting with task design, teacher questioning, teacher response to learner talk and making the criteria and norms of engagement explicit.

1.7.7 Chapter 7 Emerging dialogic pedagogic practices: Facilitating learner engagement

Chapter 7 is the final results chapter targeting all three of my research questions. I bring together the key findings so far and extract themes relating to contextual factors for the development and management of science talk in the Soweto classrooms that I observed. I illustrate learner engagement with science content during Interactive-Dialogic (ID) and Interactive-Authoritative (IA) episodes, provide examples of elaborative teacher interventions during ID, as well as explore possible influences on each teacher's pedagogical practices.

1.7.8 Chapter 8 Talking science in Soweto classrooms: My conclusions

In the concluding chapter I first narrate what I view as the key insights emerging from my research, then I talk about the possible implications for research and theoretical considerations, methodological implications, implications for teacher development and finally I consider some policy issues emanating from my study.

1.8 Chapter summary

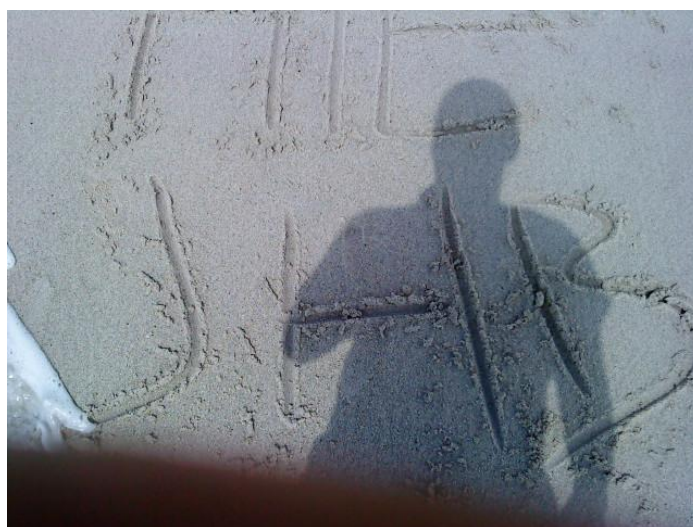
In this chapter I have provided a brief contextualisation of my study in terms of what I see as the problem and knowledge gaps as well as how I see my study addressing the problem. I have also briefly provided the theoretical and epistemological contexts as well as prevailing

curriculum change issues locally in South Africa and internationally. In confronting some of my own personal assumptions that influenced my thinking I have provided upfront some of my own background and how it might have coloured what I saw in the data. Finally I gave an overview of how I have presented the findings from my study in terms of chapter breakdown. In the next chapter, Chapter 2 I present a more detailed discussion of how my study is located in the bigger picture of local and international research on science education in general and classroom interactions and argumentation specifically.

Chapter 2

Literature review and Theoretical background

When we do research it is like watching the shadow and trying to figure out what casts it. The details we see on the shadow are largely dependent on the nature, position or intensity of the light shining on the object that casts the shadow. Theory is, as it were that light which we can move around to affect or alter the shadow. Sometimes we move the light so we can see “more” details of the figure and at other times we position it so that we can see only a few aspects in “greater” detail.



However, we can never position the light so we see from the shadow all that there is to know about the object that casts the shadow. For all we know, the real figure may be four-limbed and yet the shadow may only show two! (Prof Fatih Tasar, pers. comm. ESERA Summer school held at the University of York, UK, 2008)

2.0 Introduction

In this chapter I discuss how my study is located in literature. I do this by first establishing the link between science talk, (which is the focus of my study) and cognition as well as relate science talk to monologic and dialogic classroom discourses. Next I explain the theoretical view of science learning (and hence science teaching) that guided my study and then I show how I see science talk fit into this paradigm. In doing this I am guided by Silverman’s (2000) view of the purpose and role of theory. Silverman argues that theory provides the principles for understanding the relationship between the factors of a complex phenomenon and how they produce their effects. Theory is helpful in identifying the object of study, revealing the nature of the object and providing the language to describe the characteristics of the various facets of the object. Guided by this understanding of theory I establish the aim of my study

which was to investigate the use of science talk as a strategy to stimulate learner participation and engagement in high school science classrooms.

2.1 Science talk

2.1.1 Definitions

The terms “science talk” and “talking science” have been used by other researchers before me to refer to various teaching and learning strategies and activities both in the classroom and outside. Jay Lemke (1990), for example, code named the focus of his work “talking science”. He studied the ways in which teachers and learners talked about science in high school. Lemke’s focus was on the socio-linguistics of the science classroom, looking at structures and functions of language interaction, how science words and concepts were used in communication with each other. He argued that talking was crucial for the learning of science as learners externalise their thinking through talk. For Lemke what was critical was not merely talking about science but doing science through the medium of language, the importance of the social situations in which the talking happened, the unwritten rules of classroom interaction. Elizabeth Moje (1995) on the other hand focused on “talking about science”, how and why participants talked about science and how talk influenced or shaped meaning making and the culture of learning in the classroom. Gallas (1995) investigated teaching strategies to encourage young children to participate in primary science lessons. He called his model “Science talks”. In turn David Patrick Thurs (2007) in his book entitled “Science talk: Changing notions of science in American popular culture”, emphasised the fact that science is a separate form of knowledge and thus a different language is used to talk about this form of knowledge. He further argued that this language is not static but it is dynamic, changing all the time hence the need to equip its users with the ability not only to employ the language but to understand its dynamics.

Doris Ash’s work focused on students talking science together, using every day, scientific, and hybrid discourses (Ash, 2004, 2007). In studies of talk both in formal and informal settings she investigated learner use of everyday ways of thinking and concluded that rather than seeing science learning as just a “cognitive” task, researchers needed to see learning science also as a product of particular social practices and cultures, and of changing identities, values, and culturally valued ways of thinking about the world (e.g. Ash, et al., 2007). Wolf-Michael Roth (1994) investigated classroom science talk in Canadian

classrooms and argued that it comprised all forms of communication including body language like gestures, eye movement and signs.

Similarly, in the UK there have been various studies of science talk or talking science. For example, Mercer and colleagues working with primary school children investigated various approaches and activities to stimulate science talk in the classroom (Mercer & Hodgkinson, 2008; Mercer, et al., 1999; Wegerif, Mercer, & Dawes, 1999). Other studies investigated the use of puppets to stimulate talk in science in primary classrooms in the UK (Naylor, Keogh, Downing, Maloney, & Simon, 2007). In a review of literature on learner science talk in small groups, Bennett and colleagues reported that some studies had shown that untutored learner engagement could be improved significantly when skills for specific forms of talk were taught to both teachers and learners (Bennett, Hogarth, Lubben, Campbell, & Robinson, 2010). In studies of what they simply termed talk in the classroom, Scott and colleagues also investigated various pedagogical approaches to get learners talking in science classrooms in the UK and Brazil (e.g. Aguiar, Mortimer, & Scott, 2010; Scott, 2004, 2008). They were interested in teacher and student talk strategies as well as describing the patterns of teacher-student or student-student talk that resulted.

In Australia, a study by Ian Mitchell of teacher behaviours aimed at promoting, reacting to and using student talk established twelve principles for quality teaching (Mitchell, 2010). Mitchell concluded that talk was central to quality learning and that there were four kinds of student talk that developed quality thinking involving students' existing ideas and explanations; increasing student ownership of practical activities; constructive challenges to the teacher (or text's) idea; and lateral, reflective 'thinking' questions. Thus, science talk has been defined and studied from different perspectives in these various contexts. Some have defined it in terms of its socio-linguistics and structure, while others defined it in terms of its function in classroom interactions and others defined in terms of its function as a teaching strategy or as a product of cultural practices. In the next section I articulate my working definition of science talk as a tool in the mediation of science learning.

2.1.2 *My working definition of science talk*

For my purposes science talk includes all teacher and learner verbal interaction during discussions in the science lesson. I defined science talk in terms of all verbal interaction

during the lesson, that is, all speech intended to address the teaching or learning of science concepts, including talk about extraneous issues. By this I mean all scientific or technical speech as well as the non-technical, social speech about science. I included argumentation in my definition only in so far as it is a useful tool to foster and then characterise classroom talk. I used argumentation to help me determine the link and/or influence of talk on science teaching and learner conceptual understanding in the specific contexts that I worked in.

My literature review therefore includes a wide range of research on classroom talk, particularly in science classrooms. Since I worked in classrooms where learner talk was not part of the traditional form of engagement, I needed to understand how talk develops and what patterns of talk might emerge. To do this I borrowed from Mortimer and Scott's (2003) work in science classrooms in Brazil and the UK, which established the centrality of communication to classroom discourse. They examined teacher-student classroom interactions and established a relationship between teacher focus and teacher action in shaping patterns of communication in the classroom. Teacher focus comprises the teaching purpose and content of the lesson while teacher action consists of teacher interventions and the discourse patterns they produce. Thus, an understanding of how talk develops in the classroom is likely to come about as one examines the teacher's interventions as she guides learner talk on various science topics (content) to achieve the different teaching purposes. However, although my intention was to understand how teachers stimulated meaningful talk in science classrooms and how learners then talked when so stimulated, I also wanted to be able to determine the quality of the talk. My definition of science talk, therefore, included argumentation. For this reason I also drew from argumentation theories for my theoretical framework. Argumentation has been studied widely in science education research in a number of different capacities. Argumentation is viewed as: a practice of scientists and thus, as a desired discourse practice for (teachers and) learners in science classrooms; a methodological tool to foster classroom discussion of science concepts for meaning-making; as well as an analytical tool for science classroom discourse (e.g. Erduran, Ardac, & Yakmaci-Guzel, 2006; Jimenez-Aleixandre, Rodrigues, & Duschl, 2000; Zohar & Nemet, 2002).

The challenge in practice is that science talk as I have just defined it is not evident in classrooms. Research reports on classroom discourse in the South African contexts that I

worked in point to a largely monologic discourse or a discourse dominated by teacher talk, recitation, choral responses and low levels of participation and engagement (see for example Taylor, Muller, & Vinjevold, 2003; Taylor & Vinjevold, 1999; Verspoor, 2006). Classrooms are plagued by learner silences and teachers find it difficult to get to learner thinking so as to be able to scaffold learner conceptual development. Yet Lemke argues that talk is the tool that learners can employ to externalise their thinking. My study is therefore, seeks to make a contribution to a two decade long debate on development of a dialogic discourse aimed at promoting meaningful learner participation and engagement in South African science classrooms. For me participation includes taking part in activities or making a contribution and engagement means being absorbed or connecting with each other so as to negotiate meanings. I define participation and engagement more broadly in Section 2.2.2 below when I consider monologic and dialogic classroom discourse.

My definition of science talk, therefore, straddles two key theoretical positions, argumentation and Mortimer and Scott's notion of the centrality of communication or talk in the classroom. These two, together with the link between talk and cognition formed my theoretical framework but were also an integral part of my analytic framework. It seems that there is no consensus in literature about the difference between a theoretical and conceptual framework (Miles & Huberman, 1994). In deciding on the theoretical and conceptual frameworks for my study I was guided by the view that a theoretical framework consists of established, interrelated ideas, models or theories while a conceptual framework is the operationalisation of the theoretical framework (Stewart, 2011). The rest of this chapter comprises a discussion of the concepts of monologic and dialogic discourse, interaction, participation and engagement; a discussion of my research paradigm as well as my theoretical framework. I end with a brief discussion of my analytical framework. Later, in Chapter 4 I revisit my definition of science talk and show how it guided the construction of my analytic framework.

2.2 From monologues to dialogic pedagogies

One of the objectives of South Africa's new curriculum is to encourage learner active participation, which includes talking during classroom discussions (see for example Department of Education, 1996, 2002, 2008, 2011b). However, since all learners in township schools are second language speakers of English, their language of instruction, there is a

general concern that they are not able to engage with science concepts meaningfully in a language they are not proficient in. This results in a lack of conceptual understanding, poor performance in examinations and general under preparedness for tertiary science education. Thus, one of the expectations of the curriculum change process is a shift in teacher pedagogical practices to adopt strategies that can create opportunities for substantive learner engagement through classroom talk in spite of the challenges already identified. Talking might enhance learning in several ways:

- Talking about science concepts is essential for conceptual development (Kamen, et al., 1997; Keogh & Naylor, 2007; Lemke, 1990).
- Talking is a practice of scientists that school science aims to develop in learners (Lave & Wenger, 1991; Lederman, 1992; Mercer, Dawes, Wegerif, & Sams, 2004; Wenger, 1999).
- Talking helps learners gain fluency in the language of science which is itself different from both the learners' everyday language and from English, the language of instruction and is therefore quite difficult for learners to master (Lee & Fradd, 1998; Oyoo, 2009; Wellington & Osborne, 2001)
- Talking provides an opportunity for learners to practice and gain fluency in the language of instruction (Ash, 2004; Department of Education, 1997; Setati, Molefe, & Langa, 2008).

However, as reported in Chapter 1 (Section 1.1) literature records a paucity of learner talk not only in South African classrooms but all over the world (e.g. Chisholm, 2004; Laughran & Shaw, 1996; Taylor & Vinjevald, 1999; Wegerif et al., 2004). Teacher talk tends to dominate classroom discourse; learners are not afforded opportunities to discuss ideas with teachers and peers and where provided learners are reluctant to speak. Where they do attempt to speak, learner talk is predominated by a few short responses, usually responses to teacher questions. They often need prodding to speak. Thus, there is a need for pedagogic strategies to address both the low levels of learner participation and learner silences as well as the disproportionately high levels of teacher talk and teacher dominance of classroom talk.

2.2.1 *Monologues described*

In many classrooms discourse is largely monologic (Lyle, 2008). Monologic discourse targets the teacher goals of maintaining control of the classroom and learners and it is characterised

by recitation, rote learning and usually learner passivity. Lyle defines recitation as the accumulation of knowledge and understanding through teacher questions designed to test and stimulate recall. In such cases, teachers often cue learners to the answer; transmit pre-packaged knowledge and chorus responses predominate. Thus, learners' individual difficulties in engaging with the science concepts are compounded in monologic discourse. Studies have established that learners generally struggle to externalise their thinking (Keogh & Naylor, 2007; Kuhn, 1992) and therefore, dialogic discourse is preferable for effective teaching and learning of science. Dialogic discourse is characterised by authentic exchanges and forms of communication that create space for multiple voices, for shared meaning-making and for collaboration (Lyle, 2008, p. 225). The following cases illustrate this point from a few studies from around the world.

In the USA, for example, a study of discussions by pairs of 13-yr-old mathematics students, Kieran (2004) observed learners struggle to articulate their ideas and to explain their thinking. In a separate study of undergraduate students, Blanton, Stylianou and David (2003) also observed that public explanation of their thinking was not a familiar form of interaction for the students. They were not used to the requirement to explain their thinking publicly and besides feeling uncomfortable they also lacked the language to do so. They did not know how to explain why their solutions worked and were hesitant to challenge their classmates about their own thinking.

In a study in Tanzania, Wedin (2010), showed that less successful learners hid themselves at the back of classrooms to avoid participation and that in extreme cases they would abscond from lessons or absent themselves from school. In South African reports of non-participation in classroom activities coupled with poor performance are not uncommon (Chisholm, 2004; Fleisch, 2008; Msimanga & Lelliott, 2008; Verspoor, 2006). Often such learner inactivity escalates into a loss of interest in school, evident first as absenteeism and leading in many cases to dropout (Lotz-Sisitka, 2009; Wedin, 2010).

In Italy, a cost-benefit analysis of argumentation by Paglieri and Castelfranchi (2010) made some interesting observations about the strategic considerations that participants in argumentation have to make. The authors explained how these considerations might account for the silences observed in many situations where although conditions are conducive to

argumentation, it does not happen. They argued that the “dangers” (p80) of arguing relate to the level of personal responsibility implied in engaging in the argument. Among the possible dangers is the fact that an argument may backfire or fail to prove its conclusions, that it may result in disagreement (being labelled stubborn, or losing to the other, or raising other areas of disagreement, or being labelled unfriendly for doubting the other), or argumentation may draw unwanted attention to the participant (especially the shy) and finally, argumentation may place one’s reputation at stake (e.g. may fail to live up to expectations).

The last case on cost-benefit considerations for engaging in argumentation illustrates an important point that Lyle and other researchers make about the challenges of bringing about change to dialogic discourse in the classroom. It is an unfamiliar and potentially hazardous endeavour not only for the learner as Aikenhead and Jegede argued (Aikenhead & Jegede, 1999) but also for the teacher who is required to venture out of the familiar traditional pedagogical practices of monologic discourse. Lyle argues that the best interactional space to foster this transition is in whole class teaching (Lyle, 2008).

2.2.2 *Interaction, participation, engagement and dialogic discourse*

Dialogic teaching for meaning-making contrasts with monologic practices in that it introduces interactive approaches to whole class teaching (Aleixandre, 2004; Lyle, 2008). If managed appropriately, dialogic discourse can lead to learner engagement at a deeper level as well as raising the quality of classroom interaction. As Aleixandre (2004) argues, understanding is a dialogic process crafted through teacher-learner interaction in which the teacher values the learner’s voice and promotes reflective learning. To conceptualise interaction in my study I borrowed a definition of interaction by Armstrong and colleagues from their research on the use of interactive whiteboard technology (Armstrong, et al., 2005). They defined interaction as “the give and take between pupils and teachers, which goes beyond a superficial learning scenario to a stimulating interplay, which leads to new formulations and new understandings” (p 457). They argued that where a tool is used to stimulate interaction in the classroom, learning depends on how the tool is used which in turn relates to perceptions of how it can be used. In other words the effective use of the tool is related to both the teacher and the learner’s previous (whether immediate past or distant past) experience with the tool. In my study, science talk is therefore, a tool that can be used interactively in the “give and take” between teachers and learners and among learners.

According to Armstrong's argument, the use of science talk depends on the teacher and learners' perceptions of talk in general and those specific to the culture of the science classroom. These perceptions are related to the group cultural capital (what experiences they each bring to the classroom) as well as the ability (and will) of participants to "give and take". The give and take could be seen as the sum of the relations, commitment, motivation and trust inherent (or ultimately developed) among the participants. In a study of group size effect on discussions in a physics classroom, Alexopoulou and Driver (1996, p. 1100) found that in the "social process of knowledge construction in a group, peer negotiation of meaning ... is linked to the negotiation of their interaction in social space". They argued that progress in student reasoning was dependent more on openness about their own thinking as well as questioning their peers' thinking than on equal participation in a discussion.

A classroom that is interactive in the sense described by Armstrong and by Alexopoulou and Driver is by nature dialogic in terms of Alexandre (2004) and Lyle's (2008) definition of dialogic teaching that I gave at the beginning of this section. The discourse in dialogic teaching is characterised by negotiation of meaning (engagement) within an environment of give and take (interaction) in which knowledge construction takes place. Learners take part in the activities, sharing ideas and engaging in group meaning making and for me this describes participation. Participation has been variously defined and described. For instance, a study of learners with learning difficulties described participation in terms of behaviours that were consistently performed in this class (Agran, Wehmeyer, Cavin, & Palmer, 2008). The behaviours were placed into five categories: learner preparation for the lesson beforehand, including bringing their books and other instruments; taking required materials out when requested; beginning assignments or writing; engaging in-group activities. In other studies participation was defined to include negative behaviours like students' offhand comments or remarks that were not related to the topic under discussion as well as interruption of the teacher's talk (Crombie, Pyke, Silverthorn, Jones, & Piccinin, 2003) whether to ask a legitimate question or make a comment (Fritschner, 2000). All these descriptions of participation include both interaction and dialogic discourse which were my main interest: interaction as seen in "behaviours", engagement in group activities, making comments and remarks as part of the "give and take"; dialogic discourse in the same "behaviours", in questioning and making comments.

However, meaningful participation is not just about any interchange but also about intersubjectivity. According to Wertsch (1984) participants (or interlocutors as he refers to them) must hold the same meaning of the concept around which they are interacting. They need to be aware of the similarity in the meanings they hold. Wertsch argues that intersubjectivity ranges from simple agreement on the location of objects in communicating settings to situations where two interlocutors represent objects and events in identical ways. For me Wertsch's notion of intersubjectivity seems to bridge participation and engagement. I see engagement when the teacher and learners (or learners among themselves) move beyond the interchange of ideas or *attempts* at problem solving to a negotiation of meanings or co-ordination of individual contributions to the joint activity.

The kinds of participation and engagement described so far are desirable but not easy to achieve. This is evident from trends in education research in South Africa over the past fifteen years, for instance. South Africa's new curriculum aims to transform classroom discourse to promote learner participation and engagement (Department of Education, 2003a) and various initiatives have been put into place to help educators achieve this transformation. Yet, research findings continually indicate that there are challenges in transforming curriculum reform initiatives into effective practice. South African teachers are still uncertain about the pedagogical shifts they need to make (Lelliott, Doidge, Mwakapenda, Mhlolo, Nakedi & Msimanga 2009; Sanders & Kasalu, 2004). Where attempts are made there is variation in uptake of the reforms and the resultant classroom discourse types. I use examples from different contexts to illustrate this point. For example, findings from some large scale studies at national and provincial level revealed teacher difficulties with implementation of the new curriculum particularly in primary schools (Chisholm, 2004; Fleisch, 2008; Hattingh, et al., 2007; Rogan, 2007). At local levels, in teacher professional development contexts other studies showed diversity in teacher uptake and a wide variety of factors influencing the take up and use of the new strategies addressed in study programmes at universities (Brodie, et al., 2002b; Scholtz, Braund, Hodges, Koopman, & Lubben, 2008). Finally, studies conducted at classroom level also showed that teachers (and learners) were struggling with the changes required of them in enabling increased learner participation and engagement as espoused in the curriculum policy documents (Braund, Lubben, Scholtz, Sadeck, & Hodges, 2007; Msimanga & Lelliott, 2010; Stoffels, 2005b). However, research indicates that if teachers are

made aware of appropriate strategies and materials to use they can stimulate meaningful classroom discussions (Brodie, 2005b; Webb & Treagust, 2006).

Studies have shown that to be able to make the change in classroom discourse required of them, teachers have to be equipped with a diverse repertoire of strategies to select from as the need arises (Love & Mason, 1995; Nystrand, Wu, Gamoran, Zeiser, & Long, 2001). These authors argue that teachers need to be familiar with teaching strategies ranging from exposition, use of examples, to exploration and writing up. Teachers have to be aware of the types of questions to ask to achieve different aims and learners themselves need to be made aware of the teachers' intentions in questioning, both of which are sophisticated forms of interaction. Bishop and Denley (2007, p. 40) also argue that "student engagement does not come without effort ...(but) comes through unpredictability, surprise, fun, humour, stories and being prepared to do odd things". In investigating science talk I sought to understand the nature and variety of this range of the teaching strategies in selected teaching and learning contexts. In view of Alexander's (2004) argument that a dialogic discourse can lead to deep learner engagement I now discuss how I perceived talk (in dialogic discourse) to contribute to cognition in the science classroom.

2.3 The link between talk and cognition

Deanna Kuhn's (1992) study of the link between talk and the development of thinking skills in the science classroom is important for my purposes. According to Kuhn there are two concerns over whether schools are succeeding in educating young people. The first is that learners leave school without having acquired sound knowledge of the basic subject matter. The second and of greater concern to her is the fact that students do not "seem to have acquired the ability to think well" (p 155). For Kuhn scientific thinking involves ability to consider alternatives, weigh evidence, reach independent judgements and justify those judgements in a reasoned way. Kuhn further argues that knowing is the product of a process of reasoned argument. Thus, while some may argue that knowledge and understanding is relative, depends on the personal, subjective perspective of individuals, these "multiple perspectives or judgements are nevertheless subjectable to a process of inquiry and evaluation that can show some to be more correct than others". Teaching must therefore not only foster thinking skills but also help learners "progress towards this evaluative conception of thinking and knowing" (p 159). For Kuhn, thinking is a social activity, "learners replicate the

procedural logic of the social communications in which they participate” (p 160) and since thinking skills are often taught and learnt within social contexts, Kuhn sees contexts as important for learner understanding.

Other research has established a close relationship between language use and cognition (Mercer, et al., 1999) and that there is a link between talk and scientific thinking and reasoning (see for example Kuhn, 1992; Lemke, 1990). Thus classroom discussion is seen as playing a central role in the collective construction of science knowledge (Mortimer & Scott, 2003; Sprod, 1995; Verspoor, 1989, 2006). There is a considerable body of literature that argues for the promotion of discussion and argumentation as a means to develop higher order skills and critical thinking (e.g. De Bono, 1990; Kieran, 2004; Osborne, et al., 2004). Webb and Treagust (2006) assert that individual reasoning has part of its origins in dialogue with others, while Mortimer & Scott (2003, p. 3) “see talk as being central to the *meaning making* process and thus central to learning”. To explore the centrality of science talk for meaning making I engaged both the cognitive and socio-cultural theories of learning.

2.4 Cognitive and socio-cultural perspectives of talk in science learning

Since I view science talk as a tool both for teachers to promote participation and engagement in science lessons and for learners to construct scientific knowledge during ensuing discussions, I found both the cognitive and socio-cultural theories of learning appealing and appropriate in locating my study. For me, science talk is a both psychological (cognitive) and cultural tool. I therefore, approached my study from a constructivist perspective, locating it partly in the Piagetian individual cognition view of learning but largely in the Vygotskian socio-constructivist perspective as discussed in the next section.

2.4.1 *Talk and cognitive perspectives of learning*

Constructivism is a multiple perspective incorporating a continuum of paradigms from personal/radical to social constructivism. Piaget (1964) argued that learning is an individual process prompted by action leading to re-organisation of stimulus-response schema or internal structures in the individual mind. Hence knowledge is not a simple copy of reality but it is a modification, transformation or reconstruction of the object of knowledge, thus placing emphasis on the activity of the learner herself. This view came to be known as the personal constructivist paradigm. For the personal constructivist therefore, social

transmission is not critical and learning is an individual pursuit since knowledge is individually constructed through the restructuring of schema. In this perspective, the unit of analysis is the individual mind and learning happens inside the individual's head. Previous knowledge is important in this view and learning is a process of building more complex structures on the simpler pre-existing ones (Piaget, 1964, 2003). Misconceptions and preconceptions form part of previous knowledge, (albeit scientifically faulty extensions of that knowledge in the case of the former) and are an integral part of constructivist teaching and learning. They are resources for cognitive growth which facilitate learning. They have the potential to be re-arranged or discarded if they do not bring about equilibration and self-regulation. Cognitive equilibration is the act of finding balance through either assimilation or accommodation of new knowledge with respect to the learner's existing cognitive understandings. Assimilation is active organisation of new knowledge that matches the learner's current cognitive understandings so as to incorporate it into existing schemata or cognitive structures, whereas accommodation involves changes/re-adjustment of existing structures to accommodate new knowledge that does not match existing cognitive understandings. Either way the learner achieves cognitive equilibrium or balance in terms of the new knowledge or idea through this active process of self-regulation. Thus, the learner constructs knowledge by resolving the conflict between expectation and observation (Nesher, 1987).

In articulating the role of the teacher in this perspective von Glasersfeld (1991) argued that while teaching is a social activity involving others that the teacher hopes to influence, learning is a private activity. Learning happens in the student's mind and the focus of teaching is on the learner's understanding or conceptual operations. The teacher therefore, needs to have an idea of the learner's existing understanding of concepts. Since learning is not passive but active construction of meaning, language is important. However, language is not viewed as a means of simply transferring concepts to the learner but as an association of meanings of words with the learner's experiences enabling re-presentations of the experiences. The teacher is therefore, detached as it were and not interfering; just stoking the fire every now and then allowing learners to discover the science and construct meaning on their own (Aleixandre, 2004). Particularly because of the latter observation on the role of the teacher, cognitive theories were therefore, more useful for me in so far as learner engagement and conceptual development was concerned. However, they were limiting in terms of

achieving the aim of making classrooms more interactive, learners more participatory and the discourse more dialogic.

The socio-cultural perspective seemed to complement this limitation. According to Lemke taking a socio-cultural view of the teaching and learning of science means “viewing science, science education and research on science education as human social activities conducted within institutional and cultural frameworks” (Lemke, 2001, p. 296). I now discuss this statement in the next section in relation to the place of socio-cultural theories in my study.

2.4.2 *Talk and socio-cultural perspectives of learning*

The socio-cultural constructivist perspective is based on the theory of assisted learning (Davydov, 1995; Vygotsky, 1978). Learning involves an internalisation of social interaction and the child’s cultural development occurs first on the social level (between people) and then on the psychological (inside the child). In socio-cultural constructivism, learning is therefore, viewed as the *socially mediated active construction of knowledge*, through a process of psychological development at the external and internal planes. In other words, learning occurs first on the social level or the inter-psychological plane (between the learner and the people she interacts with) and then on the intra-psychological plane (inside the learner’s head). This is a process by which the learner moves from other-regulation to self-regulation: in other-regulation the learner is exposed to ideas in the social plane as they are discussed/considered/ between people (teacher explaining, parent clarifying a point or friends talking together) whereas in self-regulation the learner now reflects on the idea and makes sense of it. Vygotsky referred to the process of movement from other-regulation to self-regulation as internalisation of cultural development. Assimilation results from social interaction, collective activities between adult and child, and among children themselves. Since each participant brings a personal contribution to this interaction, the result is a collective activity of a group of adults and children and this is my unit of analysis.

In my view, Vygotsky’s perspective is learner-centred in that the learner is the authentic subject, with the collaborating adult guiding and directing the learner’s activities in order for development to take place. To explain this relationship between learning and development (and so how assisted learning takes place), Vygotsky (1978) advanced the notion of the zone of proximal development (ZPD), which he defines as

...the distance between the actual developmental level as determined by independent problem solving, and the level of potential development as determined through problem solving under adult guidance, or in collaboration with more capable peers. (Vygotsky, 1978:86)

Vygotsky recognises a progressive process of development of the learner between the actual developmental level (ADL) which accounts for what the learner is able to do unassisted and the level at which she can only perform with assistance from a more capable peer (the level of potential development). The difference between these two levels is what Vygotsky refers to as the ZPD (Davydov 1995). The ZPD is therefore, the region of mediation in teaching and learning and the adult guidance in the case of the classroom interaction would be from the teacher. Within the Vygotskian perspective therefore, the teacher plays an important role as a mediator within the learner's ZPD assisting her to negotiate the gap between what she is able to do on her own and what she can attain with assistance. Other learners in the classroom are an important part of the social or inter-psychological plane of interaction at which ideas can be rehearsed. The teacher must engage the learners, afford them opportunity to have individual experiences, allow for social interaction and allow for equilibration. The dictionary meaning of the word mediate includes "intervention ... negotiation ...". Both the terms intervention and negotiation seem appropriate to describe what should then happen in the ZPD, suggesting a situation where the teacher and learner work together using appropriate interventions and tools in negotiating meaning making. Tools such as language (words, gestures, silence, etc), symbols and signs (e.g. mathematical signs, chemical symbols, models, representations, etc) are the means of mediation to assist the learner in constructing scientific meaning (Davydov, 1995; Hedegaard, 1990). Thus talk is an important tool for the social process of mediation of the learner's ZPD. Hence, three key tenets of the socio-cultural perspective were crucial for my study:

- The notion of learning as *socially mediated active construction of knowledge*;
- The concept of *the ZPD as the region of (social) mediation in teaching and learning* and
- The use of *language as a tool in this process of mediation*, hence the importance of science talk as a tool for both teaching and learning in the classroom.

Mercer (1995) shows how talk relates to all three of the tenets of Vygotskian learning above. I have borrowed some of his ideas to explain how I too think of science talk in relation to the

theory of socio-cultural learning. Mercer (2010, p. 66) asserts that “knowledge exists as a social entity and not just as an individual possession” and that people make use of language to construct knowledge together. According to Mercer there are three important points about the notion of construction of knowledge, especially at school. First, knowledge construction must include verbalisation or putting things/ideas into words (in addition to other kinds of mental imagery that can lead to learning of concepts) in order for them to be shared. Secondly, verbalisation of ideas and understanding enables assessment of learner understanding as the lesson/episode progresses. Lastly, talking makes it possible to achieve the aims of school science, that is, learners must not only acquire the frames of reference for solving scientific problems but must also be accountable for the solutions they reach. They need to justify their solutions in terms of the scientific terms of reference. This they do using both the specialised language of the discipline and ordinary language as they explain their justifications. Mercer refers to the specialised language as an educated discourse or in this case, science discourse. Learners therefore, acquire specific ways of expressing/talking about their ideas. Indeed, most learning is about “learning to use language to represent ideas, to interpret experiences, to formulate problems and to solve them” (p 75). It is about ways of learning language that can shape thought and this is where my thinking about the role of science talk converges with both Mercer and Lemke’s. While Mercer (1995) argues that talking shapes thought, Lemke (1990) says that talking then externalises these thoughts and ideas. I view it as a cyclic process: as they learn how to talk science students also learn how to think science and as they become competent in thinking in scientific ways they become more adept at talking in scientific ways and so become more scientifically literate.

Closely linked to the role of language in knowledge construction is the notion of social mediation. Mercer claims that Vygotsky’s ZPD encompasses talk. While acknowledging that individual learners do differ in innate capacity, he argues that learner achievement is influenced by or is a measure of the communication between teacher and learner. Thus he says, “talk in and around learning activities can constrain or extend intellectual potential of the individual learner” (1995, p72). Secondly, Mercer posits that for instruction to be effective it should precede development. Therefore it is those learning activities that learners cannot do without help that can stretch their intellectual capacity, hence the importance of learning with assistance. This brings in the concept of scaffolding, which Mercer maintains is different from instruction. Scaffolding on the one hand, is about providing support and

guidance which is withdrawn or intensified depending on how development of learner competence is perceived to be progressing. Instruction on the other hand, conjures images of telling or instructing. The teacher's role therefore, is to prepare a learning environment that provides appropriate cognitive support to expand students' learning abilities.

2.4.3 Taking a cognitive and socio-cultural perspective of talk in my study

Paul Cobb (cited in Clark, 2010) argues that there is an interplay between the cognitive and the socio-cultural perspectives. Clark (2010) articulates the dialogic interplay in the following quotation:

The idea of this dialogue leads back to Vygotsky's idea of the interaction between a learner's internal "spontaneous concepts" and more culturally oriented "scientific concepts". Within the context of this interaction, we can see a link between the cognitive and socio-cultural perspectives. Through an interactive process of mediation, the culture and the collective individuals within it create a language of shared experience. At times, the individual is "disequilibrated", or cognitively challenged, by this culturally based shared experience, a state which generally leads to a period of reflective abstraction, accommodation and a realignment of the individual's cognitive structure. At the same time, however, the culture itself is disequilibrated by individuals as they construct new meaning and then share their perspectives with those around them. The balance between the two theories of cognitive and socio-cultural constructivism, Cobb believes, lies in the idea that while individual thought may progress toward culturally accepted ideas, this happens only within the context of a dynamic interplay which requires creative innovation and cognitive construction on the part of the individual.

Clark argues that both the cognitive and the socio-cultural perspectives recognise the role of activity in learning. In cognitive constructivism learning happens through the individual's conceptual activity through a process of self re-organisation while in the socio-cultural perspective learning is enabled through social engagements that allow the student to participate in culturally held knowledge. Thus, the importance of prior knowledge and personal knowledge in learning new knowledge is established and according to Lee and Fradd (1996, p. 268) "learning and understanding in science occurs when students successfully integrate new information with prior knowledge."

This dialogic view of the interplay between cognitive and socio-cultural theories of learning is shared by other science education researchers. For example, Wegerif and colleagues

investigated the impact of exploratory talk on learning among primary school learners and concluded that talk could improve both group and individual reasoning. Thus, that reasoning is embedded in a social process or that individual reasoning ability has part of its origin in dialogue with others (Mercer, et al., 2004; Wegerif, et al., 1999).

In studying the social factors that influence small group discussions and the learning that takes place, Alexopoulou and Driver (1996) adopted a dialogic approach. They drew on both the Piagetian notion of personal construction of knowledge premised on the psychological process of equilibration and the Vygotskian emphasis on construction of knowledge as a social process, the fundamental role of language and discourse in shaping meaning. “Central to this perspective is that through joint actions and communication with others, children internalise practices and discourse features and transform them to tools of conscious control.” (p1099). Thus, learning in science could be viewed as enculturation into the meanings of specialist discourse and talk facilitates this learning.

Also Leach and Scott (2003, pp. 103-104) developed a view of science learning that brought together,

“the social-interactive and personal-sense-making parts of the learning process and identifies language as the central form of mediational means on both intermental and intramental planes. It draws upon sociocultural approaches in conceptualising learning in terms of developing a new social language, and in identifying epistemological differences between social languages. It draws upon individual views in clarifying the nature of the learning demand as learners make personal interpretations of the social language of science in learning science we must buy into, and learn to work with, the conceptual tools, epistemological framing, ontological perspectives and forms of reasoning of the scientific community. Individual views on learning provide tools for characterising why students might find particular aspects of the social language of science difficult to internalise... Sociocultural views of learning draw attention to how scientific knowledge is ‘talked into existence’ ... on the social plane of the classroom, for showing how teachers control discourse on the social plane, and for considering student learning in response to teaching ... (explains) why internalisation is not a simple matter of transfer” (p104).

I too adopted a similar dialogic view of cognitive and socio-cultural perspectives of learning of science. My decision was guided by the fact that my study aimed to investigate science talk both as a psychological tool to enhance the individual’s conceptual activity (Leach and Scott’s personal-sense-making part of the learning process) as well as a cultural tool in the

social activity of interaction with others (Driver, et al., 2000; Howe & Mercer, 2007) or Leach and Scott's social-interactive part of the learning process. I viewed talk as an important tool for mediation of learning. I therefore wanted to understand how the teachers in my study fulfilled the expectations for teachers in a constructivist classroom. Clark (2010) argues that in preparing learning environments teachers must have three goals in mind: to recognise current cognitive understandings and provide for learners to engage them in the process of learning new knowledge; to provide opportunities for learners to create their own meanings by challenging learners through a process of accommodation; and to provide opportunities for learners to construct their own meanings through social interaction in the common cultural knowledge. Since learners cannot discover science concepts and/or make sense of them by themselves (see Aleixandre, 2004; Mortimer & Scott, 2003) I wanted to understand how teachers performed this role of facilitating learner construction of meanings through science talk. I examine some literature that relates to the role of science talk in the facilitation of learning in the science classroom.

2.5 Science talk and the teaching and learning of science

Mortimer & Scott (2003, p. 1) recognise a "traditional view" and "today's view" of teaching and learning science. In the traditional view the teacher stands up front and presents facts to the class while learners sit and listen or copy notes and answer the teacher's questions. In "today's view" both the teacher and the learners are "out of their seats" (p 1) and work alongside each other. Although there are indications of shifts to "today's view", especially at curricular level, the traditional view of teaching persists in many classrooms around the world. Often the classrooms with large student numbers have relatively educator-centred patterns of interaction. Where group activity is used to enhance learner participation, it is usually applied indiscriminately and does not result in improved practices or higher attainment (Aldous, 2004; Mercer, et al., 1999b). Researchers in South Africa also lament the lack of meaningful discussion in classrooms, especially in previously disadvantaged schools (Brodie, 2005b; Taylor & Vinjevoold, 1999; Webb & Treagust, 2006). Current education research in South Africa therefore includes looking into ways in which classroom communication promotes active learner involvement in making meaning of science concepts.

Research into the forms of knowledge communication specific to the classroom (classroom discourse patterns) is not new. There is a long history of research dating back to Sinclair and

Coultard's (1975) observation that classroom interactions between learners and teachers tended to be dominated by teacher questions/prompts (initiation moves) and learner answers. Communication could be characterised into teacher initiation moves or prompts in the form of a question or claim followed by learner response which the teacher evaluates and/or confirms. This was termed the Initiation-Response-Evaluation (IRE) questioning cycle. The IRE was criticised for promoting shallow thinking as learners struggled to come up with the *correct* answers expected by the teacher. Later, Lemke (1990) showed how the content of a subject is actually communicated through the language patterns that teachers and students use, arguing that authentic dialogue (children engaging in meaningful discussions about concepts) and cross-discussion (in which each individual's views are considered) could be generated in science classrooms by teachers asking authentic questions.

Authentic questions are those questions that require learners to expose their own ideas and points of view and through such questioning teachers could engage children in meaningful discussions. The teacher in such cases does not expect one particular answer but allows learners to explore various possible explanations. Lemke argues that true dialogue and cross-discussion support constructivist learning. The content of a subject is actually communicated through the language patterns that teachers and students use. Yet Lemke and others (see for example Bishop & Denley, 2007; Brodie, et al., 2002a; Driver, et al., 2000; Nystrand & Gamoran, 1991) observe that these are the least prevalent discourse patterns in science classrooms as many teachers either do not know how to stimulate these types of discussion or are not adequately equipped to manage classrooms where such talk takes place. Also those teachers who might be able to use and manage talk in science classrooms may have to make pragmatic decisions to revert to teacher-centred telling lessons because of the high content curricula they have to implement in the limited time available to them.

Research into the role of language in science learning goes beyond teacher-learner discourse to interactions between learners (Kamen, et al., 1997). Mercer (1995) describes three types of classroom talk by learners and argues that modes of talk are equivalent to modes of thinking. He names disputational talk (characterised by disagreement and individualised decision making), cumulative talk (speakers build on each other's ideas uncritically), and exploratory talk (partners engage critically but constructively with each other's ideas and joint decisions are made). The joint agreement reached in exploratory talk accounts for more progressive

learning as knowledge is made more publicly accountable and reasoning is more visible. Learners work collaboratively on open-ended activities and are encouraged to talk their way to solving problems (Scott, Mortimer, & Aguiar, 2006). Since they involve the public exercise of reasoning (Kuhn, 1992), lessons involving talk, dialogic discourse and argumentation require learners to externalise their thinking (Erduran, Simon, & Osborne, 2004). In my view this not only facilitates a cyclic process of Vygotskian learning but also a movement back and forth between the external and internal planes. On the one hand learners interact with concepts and ideas on the external plane (talk/discussion) and move to the internal plane (in the individual's mind) while on the other hand they move from the internal plane (of their individual perceptions of the concepts) and externalise their thinking (during the dialogical argument) (Erduran, et al., 2006). In the process children support each other in high quality arguments, engage in social interaction that promotes social construction of knowledge and development of beliefs and values (Erduran, et al., 2004). In essence, learners engage in a dialogic discourse or classroom interaction involving authentic dialogue (real talk about real ideas not *correct* answers in the teacher's mind), foregrounding learners' ideas for discussion. This way science learning becomes a process through which learners use tools for the generation of scientific knowledge (Kelly & Chen, 1999; Lemke, 1990) as well as develop the requisite skills for participation and engagement in authentic scientific activities.

Initiatives to promote this dialogic discourse have been explored in classrooms around the world: in Europe (e.g. Keogh & Naylor, 2007; Wegerif, 2002), South America (e.g. Rojas-Drummond, Perez, Velez, Gomez, & Mendoza, 2001; Scott, et al., 2006) and in South Africa (e.g. Webb & Treagust, 2006). More recently, science education research has turned to the age old notion of argumentation to explore ways in which it could be used to develop scientific reasoning and communication skills. I will now give a brief discussion of a selection of literature relating to argumentation as both a pedagogical strategy in science classrooms and an analytical tool for classroom discourse.

2.6 Argumentation and the teaching and learning of science

Argumentation is defined as the process of linking evidence to claims or the process of formulating an argument (Berland and Reiser, 2008; Toulmin, 1958). Since argumentation involves the use of data or evidence to support or dispute claims it serves as the public exercise of reasoning where learners externalise their thinking (Kuhn 1992). According to

Berland and Reiser (2008) there are three instructional goals of explanation and argumentation: to make sense of the phenomenon under study, to articulate personal understandings, and to persuade others of these understandings. They refer to the forms of engagement for each goal as “sense-making”, “articulating” and “persuading”, respectively. In sense-making, students seek to make sense of the task and/or the science content, while articulating is about using scientific language to communicate one’s ideas and/or explanations to others as well as clarify them for oneself. In this case students are open to each others’ ideas and can modify their ideas or understandings. Persuading on the other hand, involves collaborative, consensus building through evaluation and critique of alternative ideas and the evidence used to support them. It is both a practice of scientists that students need to learn and a teaching strategy to help students engage in meaningful knowledge construct practices in the classroom. Thus it is important for the teacher (and students) to be clear of the goals of the discussions in order to achieve specific desired outcomes.

The role and importance of argumentation in the teaching and learning of science has been debated. Ernst (1998) says that arguments are critical for development of epistemological knowledge of the discipline that they facilitate knowledge construction and participation in a dialectical process of criticism and warranting of others’ claims. Argumentation is cited in development of learner scientific reasoning, in conceptual understanding, (e.g. Erduran, 2007; McNeill & Pimentel, 2010; Zohar & Nemet, 2002) as well as for enculturation of learners into the practices of scientists as a community of practice (Driver, et al., 2000; Jimenez-Aleixandre & Erduran, 2008). Erduran (2007) sees argumentation at the core of science teaching and learning:

“Argument – justification of claims with evidence - is not a peripheral aspect of science; it operates at the heart of science ... Without a chance for pupils to talk to each other, without the space to debate and communicate their ideas, it is difficult to see how they can learn any concepts, let alone the discourse of science” (Erduran 2007, p 29)

Thus, argumentation has been investigated as a teaching strategy to stimulate learner participation in structured discussion in science classrooms. Its role as a tool for science knowledge construction has been investigated in science classrooms around the world (Erduran, et al., 2004; Jimenez-Aleixandre, et al., 2000; Zohar & Nemet, 2002).

2.6.1 Toulmin's argument pattern (TAP)

In his book *The uses of argument*, Toulmin articulated a view of an argument as having both a macro- and micro- structure comprising a series of claims supported by evidence and warrants or refuted with rebuttals and counter claims (Jimenez-Aleixandre, 2002). This structure has come to be known as Toulmin's Argument Pattern (TAP) (Fig. 2.01, p 50). TAP illustrates the structure of an argument in terms of an interconnected set of claims; data that support the claim; warrants that provide a link between the data and the claim; backings that strengthen the warrants and rebuttals which point to the circumstances under which the claims would not hold true (Erduran, et al., 2006; Erduran, et al., 2004). A claim is any form of position taking or conclusion – making an assertion, decision or prediction, a statement meant to answer a question or solve the problem, an expression of opinion or idea(s). Data includes any evidence that supports the claim – observations, facts, events, or various authorities while warrants provide the link between the claims and data. Backings are any scientific information, theory or law that explains how the warrant links the data to the claim. Warrants and backings provide justification for how the data supports the claim. Rebuttals are any assertions about situations where a claim is not valid or when it may not hold true (see Erduran, et al., 2004; von Aufschnaiter, Erduran, Osborne, & Simon, 2008). According to Toulmin (1958) making a claim involves making one's assertions public and open to inspection, debate and acceptance (or rejection). He defined argumentation as the process of making arguments which entails putting forward a claim and supporting it with evidence or using evidence systematically to reject or accept another person's claims.

Toulmin developed his model while working mainly in sociology. The concept was later adopted by various other disciplines to explain relevant reasoning processes. Researchers in science education have in the last decade worked with Toulmin's model adapting it for science classrooms in various contexts. The principal argument for adopting this model is that since science learning is a process through which learners construct scientific knowledge about their world (Kelly & Chen, 1999; Lemke, 1990) it involves the construction of scientific arguments. The cognitive value of classroom talk and argumentation has been debated (Erduran, et al., 2006; Jimenez-Aleixandre, et al., 2000; Scott, et al., 2006). Argumentation theories have been employed in analyses of quality of learner talk during the teaching and learning of science.

Evidently, there is vast literature on argumentation, most of which reports on work undertaken in Europe and the United States of America in different contexts from the South African situation. My selection of argumentation studies to review was guided by both my theoretical framework and the research questions I was addressing. I focused on research on argumentation as part of the knowledge to be taught (the skills, norms and values in the use of evidence to support claims) as well as argumentation as part of the teaching processes (Tiberghien, 2008). In so doing I addressed both the use of argumentation as a tool to foster learner engagement and its role in the meaning-making process.

2.6.2 Adaptations of TAP

Most research on argumentation has explored its potential as a tool to develop learner critical thinking while helping teachers and learners engage with issues of the nature of science (see for example Driver, et al., 2000; Erduran, et al., 2004; Kelly, Druker, & Chen, 1998). Argumentation has been used to sensitise learners to science as inquiry; how scientists engage in systematic practices of observing and explaining the world; how they make predictions, and formulate hypotheses and then consider evidence (observations) and reconsider theories, models and explanations. Often examples are cited from socio-scientific issues (SSIs) or situations where scientific arguments were constructed to solve real world problems and puzzles (Braund, et al., 2007). Examples include, Darwin's investigations (Erduran, 2007), human genetics (Zohar & Nemet, 2002) and activities in oceanography (Engle & Conant, 2002; Kelly & Takao, 2002). Thus, many of the activities used in the science classroom to develop or use argumentation as a tool centre around SSIs. However, research has also looked at more specific implications of argumentation for meaning-making and conceptual development specifically within the context of the school science.

The work of various groups in different contexts was of interest to me in looking at argumentation within the discourse of the science classroom. For example, studies have been conducted in the UK and Europe by Sibel Erduran and her colleagues, and in the USA by various research groups including Leema Berland and her colleagues, Clark and Sampson as well as.

Berland and others studied the curricula and pedagogical implications of argumentation as well as appropriate strategies for implementation (Berland & Hammer, 2012; Berland &

McNeill, 2010; Berland & Reiser, 2008). Of particular interest to me was the Berland and Reiser study which articulated the importance of learner understanding of the goals of argumentation. They showed how students engaged differently for purposes of sense-making, when articulating their understandings and when persuading others of these understandings. Thus, awareness of these goals of argumentation had implications for teacher decisions in the design and administration of instructional interventions to support student argumentation and conceptual understanding.

Two of Sampson and Clark's publications were important for my study. Their research on the impact of collaboration on the outcomes of scientific argumentation (Sampson & Clark, 2008b) examined questions of whether high school chemistry students found it easier to construct arguments in groups rather than individually, and whether students learned more in groups than as individuals. Their study highlighted the value of collaborative argumentation in small groups. They concluded that the collaboration during argumentation in small groups enhanced individual student learning. In their review of argumentation research, Sampson and Clark (2008a) examined how various research groups had adapted the model of argumentation to facilitate analysis of not only the structure of arguments but also the nature of justifications used, as well as the science content drawn upon for justification. They concluded that the nature of the argumentation framework selected by the researchers was dependent on the focus of the study and that therefore, the model should be viewed as a tool that can be adapted for different contexts and/or goals. One of the suggestions they advanced was that future research on argument in science education now needed to move on from micro-analysis of structure of student arguments to more holistic research that examines the interaction of "structural, conceptual, epistemic, and social aspects of argument generation". They also suggested that research had to now move on from identifying "patterns and themes in students' arguments" to identifying the "underlying reasons for these patterns" (p 469-470). I revisit this work in my review of argumentation research in Section 2.6.3 below.

It was therefore, against this background that I considered argumentation a suitable tool for researching science talk in Sowetan classrooms. My aim was twofold. I wanted to pursue both the traditional argumentation research, micro-analysis of the structure of arguments and Sampson and Clark's "reasons for the patterns". Micro-analysis would reveal the structure of the arguments constructed by the participants during science talk. I anticipated that

argumentation might play out differently in South African context than it did say, in the UK and USA. The South African classroom is by nature culturally and socio-economically diverse and might yield different patterns of argument construction. I therefore, hoped to be able to identify at least some of the possible reasons for the patterns emerging in the South African context. I now turn to a brief review of some research that has been done on argumentation using Toulmin's model.

2.6.3 Some research using TAP as a model for argumentation in science learning

Toulmin's Argument Pattern (TAP) was adapted for use in science classrooms by Sibel Erduran and her colleagues (Erduran, et al., 2004). As discussed in Section 2.6.1, Toulmin recognised argument structure comprising a claim (C), data (D), warrants (W), backings (B) and rebuttals (R). Both Toulmin (1958) and Erduran et al. (2004) alluded to the difficulty of distinguishing between Toulmin's components of argument, particularly data, warrants and backings and suggested that one way of distinguishing them could be to use words such as "because", "so" or "since" as cues to indicate data/evidence, a claim and warrant, respectively. I reconstructed the TAP diagram by Erduran and colleagues to include these cues as indicated in Figure 2.01.

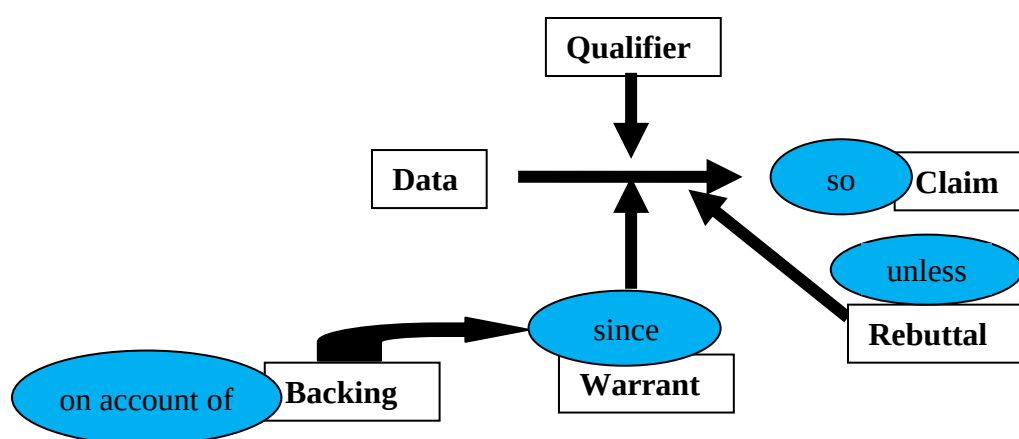


Figure 2.01 Toulmin's Pattern of Argument, TAP (After Erduran, et al., 2004; and Toulmin, 1958, 1964)

Erduran and her colleagues used the TAPping model first as a teaching strategy for teachers to instil scientific reasoning skills in their learners, and then as a research tool to analyse classroom discourse. As an analytic framework the TAPping model was used to determine the nature of arguments that learners in UK high school classrooms were able to construct.

Erduran and colleagues identified five levels of argument in student discussions (Table 2.01). They described the simplest arguments as comprising a series of claims or an unjustified counter-claim and they termed this Level 1 argument. This type of argument indicates that the students' argumentation skills are still basic or in the formative stages. Students are not yet able to support their claims with evidence. The most complex argument comprised all of Toulmin's components in an extended argument with one or more rebuttals. This they called Level 5 argument. In determining the complexity of arguments Erduran et al. (2004) focused on the number of components of an argument that were represented in an argument and clustered arguments according to the number of components counted.

Table 2.01 Levels of argument (adapted from Erduran et al., 2004) (text in italics is mine)

Level	Description of argument type
Level 1	Claim versus Claim or Claim versus Counter-claim (<i>no justification of claims</i>)
Level 2	Claim + data, warrant or backing but no rebuttal (<i>some justification of claims but no evaluation of the reasoning behind it</i>)
Level 3	Claim or Counter-claim + data, warrant or backing + weak rebuttal(s) (<i>some evidence of evaluation of the other's claims</i>)
Level 4	Claim(s) + clear Rebuttal(s) (<i>clear evidence of evaluation of the reasoning</i>)
Level 5	Extended argument with one or more rebuttals (<i>students engaging in complex arguments</i>)

After analysing arguments from discussions in several classrooms, Erduran and her colleagues observed that arguments were both teacher dependent and content dependent (Erduran et al, 2004). By this they meant that argument construction varied between teachers and with the content under discussion. This has been confirmed by other researchers and has been identified as one of several difficulties of doing comparative studies using TAP as a model. Other criticisms of the TAP model as a tool for analysis of science discourse include the difficulty in distinguishing the various components of an argument. Also, arguments are hardly a simple sequence of claim-evidence-warrant/rebuttal. They are often elaborate and complex. For example, a warrant for one claim in an argument may become a new claim in the continuing argument (Kelly & Takao, 2002).

I will just briefly outline some of the limitations of TAP that I have taken into consideration. Kelly, Druker and Chen (1998) identified some of the methodological issues in the application of TAP to the analysis of classroom-based verbal data:

1. Ambiguity of argument components – statements can double as claims in their own right or as warrants for other claims and counter-claims. As a result, it is up to the researcher to decide what should count as a claim, data, warrant or backing.
2. TAP is suitable for relatively short argument structures. When long arguments are made as in written work, for example, statements may become new claims or warrants (see 1 above).
3. Inability to judge the quality of justifications – according to Toulmin’s framework the structural components of an argument are field-independent (that is, claims, warrants, data, backings and rebuttals are features of an argument in any context). Thus, arguments would be scientifically valid if they adhered to agreed criteria for judging the quality of the justification. However, by using TAP, most argumentation studies have only been able to elaborate on the field-independent features of arguments (the structural components of an argument) and not the field-dependent ones like for example, the validity and/or reliability of the evidence that students use as data in their arguments (Sampson and Clark, 2008).
4. Inability to determine content accuracy – structurally strong arguments may be based on inaccurate science content.

Recognition of these limitations has led to modifications of Toulmin’s model in the different contexts that it has been used. For my study I drew largely from modifications of TAP by Sibel Erduran and colleagues in the UK and Europe. To resolve the first ambiguity listed above, Erduran and her colleagues suggested the use of words such as “so” to identify a claim or “because” to identify data as implied in Toulmin’s definition of an argument (Erduran, et al., 2004). I have included these “indicators” in my adaptation of TAP (Figure 2.01).

Although it seemed that the suggestion to use “so” and/or “because” to clarify claims and warrants worked for the classrooms in which Erduran and her teams conducted their research, I anticipated that it might not work for the kinds of classrooms I was working in. As observed previously in this thesis, most South African teachers and learners in township contexts are not first language speakers of English, the language of teaching and learning. They therefore

would not always be expected to be able to use Erduran's "indicators" appropriately enough for me to use them to identify claims and warrants. The "so" and/or "because" might be implicit in the discussions in my classroom and I would have to infer them according to my understanding of the context in which the utterances under consideration were made. I also anticipated that since the participants were not proficient in the language of instruction (and if discussions were not held in mother tongue), construction of arguments might be a challenge as they would not have sufficient command of the language to do so. For me, therefore these were two additional "ambiguities" to deal with.

I now turn to Sampson and Clark's (2008) comparative summary of how different researchers have modified Toulmin's or developed alternative models for analysis of classroom arguments for different purposes in different contexts. The focus in TAP analysis is normally on the logical use of evidence to support or refute claims or counter claims. TAP does not allow for the analysis of the accuracy of science content used in the process of argument construction. To make provision for analysis of content, Schwarz, Neumann, Gil, and Ilya (2003) worked with a modified definition of an argument.

Working with students' written arguments Schwarz and colleagues classified as an argument any conclusion supported with at least one reason and for them complex arguments were conclusions supported with multiple reasons or counterarguments. For it to be a sound argument the reasons provided should be acceptable and relevant. Schwarz's arguments ranged from conclusions with no justification, to one-sided arguments where one or more reasons were provided for the conclusion, to two-sided arguments comprising a conclusion with reasons to support or challenge it but without any evaluation of the justification. Complex or compound arguments were those comprising multiple conclusions and multiple reasons linked by a qualifier. Thus, in Schwarz's as in Erduran's model it would be up to the researcher to determine the acceptability of the justifications as genuine scientific evidence.

Sampson and Clark also reviewed the work of Zohar and Nemet (2002) and how they adapted the model for analysis of the content used in justification of an argument. Zohar and Nemet evaluated Israeli students written arguments about the decisions that people in different situations would have to make concerning inheritance of autosomal recessive genes. This is an example of a socio-scientific issue or an SSI where students could draw from

biological knowledge as well as social values and norms. Zohar and Nemet also redefined an argument for their study. For them an argument consisted “of either assertions or conclusions and their justifications; or of reasons or supports” (p. 38). Further, Zohar and Nemet did not identify data, warrants and backings separately but grouped them together into scientific ideas. They judged an argument in terms of the reliability and multiplicity of justifications so that for them arguments ranged from simple assertions with no consideration of scientific knowledge through those supported by inaccurate scientific knowledge and to those supported by more procedural or non-specific scientific knowledge and finally, good arguments in which the conclusions were supported with accurate specific scientific knowledge. In this model good arguments could be strengthened by the use of multiple justifications comprising relevant and accurate scientific concepts.

From this study Zohar and Nemet observed that student argument construction improved after explicit teaching about use of relevant scientific evidence to support arguments. Both this and the Schwarz studies highlighted the importance for development of argumentation skills of both students’ science content knowledge and the provision of opportunities for students to practice argument construction. However, from both, the question remains on how much is acceptable as sufficient scientific knowledge to support an argument.

Kelly and Takao’s (2002) study attempted to answer the question of sufficiency of content to support an argument. They analysed long written arguments by students in an oceanography course by determining the epistemic level or scientific nature and abstractness of students’ claims. This way they could determine whether students adhered to the conventions of the discipline. According to Sampson and Clark, the limitation of Kelly and Takao’s model was that it did not examine the links themselves to determine if they were sensible or scientifically accurate. The various adaptations of TAP discussed so far confirm Zohar and Nemet’s (2002) observation that the model is simply a tool that can be adapted for different purposes and different contexts and not a one-size fits all solution for analysing classroom discourse.

I now turn to another factor that research has shown to influence argumentation patterns in classrooms but which does not come about necessarily as a result of the limitations of the analytical model applied. This relates to the variation in the nature of arguments about

scientific concepts as opposed to socio-scientific issues (SSI). Both the Erduran et al., (2004) and the Zohar and Nemet (2002) studies observed that students' argument patterns were different for scientific and SSI issues. Students tended to use more formal/logical reasoning on scientific concepts and more informal reasoning on SSI. But what are socio-scientific issues? These are day to day issues based on some scientific concept/content. For example, ethical issues around stem cell research; organ transplants and the prevalence of organ trafficking or issues around climate change and global warming all qualify as SSIs. Socio-scientific issues have both a scientific and social aspect and learners' arguments are largely informal, based on both the scientific knowledge and their own opinions and emotions. Argumentation research in South Africa has focused on both science concepts and SSI (see for example, Braund, et al., 2007; Scholtz, Braund, Hodges, Koopman, & Lubben, 2008). However, as I argue in Section 2.5, talk and argumentation are important tools for learners to construct scientific knowledge and my study intended to extend knowledge of their potential for learning of mainstream science concepts.

2.6.4 Argumentation research in a curriculum change context in South Africa

During the time of my study South Africa was implementing an Outcomes-based curriculum, OBE as explained in the extract below:

Outcomes-based education (OBE) forms the foundation for the curriculum in South Africa. It strives to enable all learners to reach their maximum learning potential by setting the Learning Outcomes to be achieved by the end of the education process. OBE encourages a learner-centred and activity-based approach to education (Department of Education, 2003:2)

The NCS therefore, advocated teacher practices that enabled learner involvement in their own learning. Among the requirements for a learner-centred practice is learner activity, in particular the engagement of learners' ideas during teaching and learning sessions (Driver, Asoko, Leach, Mortimer, & Scott, 1994; Hewson & Hewson, 1988; Slominsky & Brodie, 2001). Working from the realization that learners are not empty vessels for teachers to fill up with information, education research has shown that effective instructional approaches are those based on learners' prior knowledge and which deliberately elicit, address and link learners' ideas to their classroom experience (e.g. Cimer, 2007; Leach & Scott, 1995).

Research further indicates that determining learners' ideas in science may increase learners' awareness of them and hence promote effective learning. Also, taking into account and building upon learners' ideas could make science education more inclusive of learners' cultural diversity and differences in ability (Cimer, 2007). However, learner-centred teaching is often quite challenging for teachers (Mercer, Wegerif, & Dawes, 1999; Taylor & Vinjevold, 1999). For instance, although research in South Africa suggests that the pace of change has been very fast and that many teachers are now in the transition stage or what is referred to as the hybrid teaching styles – moving between the teacher-centred and learner-centred practices (Brodie, et al., 2002b), many teachers remain uncertain what is expected of them (Sanders & Kasalu, 2004). In the last decade science education has turned to argumentation as a possible strategy to help teachers and learners transition to the learner-centred methods expected in the new South African curriculum. Thus, argumentation research is still new in South Africa.

So far there have been two main studies on argumentation in South Africa. One of the ongoing studies is investigating the science-indigenous knowledge (IKS) curriculum innovation: the potential for argumentation strategies in implementation of the requirement in the new curriculum for teachers to include Indigenous Knowledge (IK) in science lessons. The research has focused mainly on development of science teachers' and students' conceptual understandings of the Nature of Science (NoS) and the Nature of Indigenous Knowledge Systems (NoIKS) (Kwofie & Ogunniyi, 2011; Ogunniyi, 2005, 2006). Implementation of the new curriculum to include both science and IK concepts, poses a challenge for many South African learners (and teachers). According to Ogunniyi (2007b, 2007c) South African learners and teachers uphold a diversity of thought systems including various religious and cultural beliefs, indigenous knowledge systems, and what he terms commonsensical and intuitive notions. They therefore, often find themselves confronted with different thought systems during the course of science teaching and learning under the new curriculum. In order to explore the nature of argumentation in this context, Ogunniyi came up with a localised model of argumentation, the Contiguity Argumentation Theory or CAT.

The Contiguity Argumentation Theory is an adaptation of Toulmin's model, TAP, suited for exploring the interface between the different thought systems, particularly science and IKS. Findings from applications of Ogunniyi's CAT have established five types of adaptive co-

existence within the learner confronted with counter-intuitive school science: the dominant, suppressed, assimilated, emergent and equipollent situations. In the dominant situation, the underlying assumptions of one thought system are amenable to the teaching and learning context that the learner finds herself in. In some cases, the one system may be suppressed by or assimilated into the other. An example could be the learning of evolution by a Christian learner. Since the context is a science classroom, the learner may let the school science thought system dominate and suppress her religious belief system for the purpose of doing the science. If the evidence is compelling, her religious beliefs may be assimilated into the dominant science thought system or if the evidence is not sufficiently compelling the science thought may be assimilated into her belief system. Ogunniyi argues that in the fourth case, the emergent situation, the learner is confronted by a concept for which she does not have pre-existing schema and in that case new ones are formed. The final case is one in which two competing schema exert equipollent intellectual and emotional force or exist as parallel notions of the concept under discussion, thus alternately dominating each other during the process of meaning making. The argument is that a variety of possible interactions is to be expected if argumentation activities are to be used in South African classrooms with such a wide diversity of learner backgrounds.

Findings from Ogunniyi's work have shown positive effects of in-service professional development programmes using argumentation as a strategy in shifting teachers conceptions of NoS and NoIKS (Ogunniyi, 2007b, 2007c; Ogunniyi & Hewson, 2008). However, the research is itself still new and its findings have not yet been incorporated into existing teacher professional development programmes on the use of argumentation in the implementation of South Africa's new science curriculum. Moreover, Ogunniyi's work spans only the Western Cape province of South Africa, which comprises relatively more homogenous communities of Xhosa speakers than Gauteng, the province in which Soweto, my study area is located. Soweto is much more cosmopolitan with teachers and learners originating from various parts of the country or indeed from other African countries as well as some locals of mixed heritage. Thus, the population of Soweto is a lot more heterogenous and arguably classroom argumentation would most likely play out differently from the way it has in the Western Cape province. Further, Ogunniyi's study focused on developing argumentation skills, mainly for teachers (eventually for learners) to be able to introduce IK into the science classroom and to be able to deal with the conflict that might result from the interaction of the two world views

or thought systems. My study, on the other hand, was concerned with understanding the dynamics of teacher-learner and learner-learner argumentation, where it occurred, particularly for development of science concepts and for the purpose of meaning-making in whole class discussions. For this reason, the work of a group at the Cape Peninsula University of Technology (CPUT) in the Western Cape Province of South Africa was more relevant for my study.

Like the Ogunniyi study, the CPUT research is focussed on development of argumentation skills among science teachers, mostly student teachers enrolled for a continuous professional development programme. The findings from this study have also provided important information about the nature of interaction in small group discussions (Braund, et al., 2007; Scholtz, et al., 2004). Using the TAP model, Scholtz and her colleagues observed a unique form of engagement among teachers, which they termed inclusive argumentation (Scholtz et al., 2008). Scholtz and her team found that practicing teachers involved in a development programme in which argumentation was used as one of the teaching strategies, engaged in a unique style of argumentation which precluded rebuttals. Teachers' disagreements were either in the form of an affirmative statement followed by a counter claim/alternative warrant or they were phrased as a question. The authors explained inclusive argumentation in terms of the concept of *ubuntu*. *Ubuntu* is a way of talking in the African cultural context based on a "world-view that emphasizes the good-of-all, harmony, mutual respect, relational understanding, interdependence, interrelationships, or interconnectedness of all phenomena" (Ogunniyi 2007). It emphasises consideration for the other person, "instead of comparing and judging individual contributions on their intrinsic merit, contributions are judged in terms of the extent to which they promote harmony and reciprocity" (Scholtz, et al., 2008, p. 31).

Scholtz and her colleagues observed that teachers did not use rebuttals in the way that they are defined in Toulmin's argument structure, as clear challenges to the claim under discussion or the evidence used to support it. Instead they softened the challenge, as it were, in an effort to promote this harmony and reciprocity. The emergence of both inclusive argumentation and Ogunniyi's contiguity argumentation attest to the potential for argumentation, thus providing opportunities for research to explore its possible adaptations for and within the diverse local South African contexts (Otulaja, Cameron, & Msimanga, 2011). For example, a question could be raised as to whether argument construction is indeed always influenced by the

thought systems involved in the lesson and whether it is always guided by the principles of *ubuntu*, to maintain harmony, mutual respect and relational understanding among participants. If so, then similar patterns of interaction might be anticipated in my study as in the Ogunniyi and Scholtz studies. However, since my study focused on adult-child and child-child (teacher-learner and learner-learner) classroom interactions as opposed to adult-adult (among teachers) discussions in the Cape studies reviewed, I contend that argument construction in my sample classrooms would play out differently. Also, from the diversity of argumentation models discussed so far, it is evident that analysis of classroom argumentation data is not always straight forward and that no one model can be applied satisfactorily to all contexts. Not only are models developed for international classroom contexts inapplicable to South Africa but even those developed locally are not universally applicable to all South African situations.

Most research argumentation in South Africa has so far focussed on small group discussions by teachers and student teachers. However, since my interest was to understand how teachers facilitate talk and how learners then talk, I targeted high school whole class discussions. Also, among some of the difficulties experienced by teachers in South African classrooms in facilitating classroom discussions and/or argumentation are issues of overcrowding, learner language difficulties as well as teacher lack of adequate preparation (Msimanga & Lelliott, 2008; Stoffels, 2005a). My study aimed to understand emergence of argumentation in such teaching and learning environments where small group work is constrained. I now turn to literature on whole class discussion and how it relates to development of dialogic discourse.

2.7 Development of dialogic discourse - How to get learners talking and arguing

Literature emphasises the importance of whole class discussion to develop learner ability to dialogue (Lemke, 1990; Roth, 1996). Roth argues that in an intervention to get young children talking about engineering, whole-class interactions played a central role in development of learner discourse. “Children and teachers tied together the various experiences they shared; that is, these shared experiences ... were simultaneously topics of conversations and background against which discourse participants made sense.” (Roth, 1996, pp. 114-115) Roth says that whole class discussions can provide opportunities for developing appropriate discourse. For example, student presentations about their tasks and solutions can serve to stimulate interaction and to anchor conversations. Teacher and peer

questions, comments, and suggestions also help to sustain the conversations. These kinds of conversations also allow students to integrate personal experiences into the discussion.

Roth seems to suggest that allowing for personal experiences to be incorporated into the discussion could break the barrier between formal classroom discourse, formal science and personal experience, “In this way, the different aspects of the curriculum were not separate from each other, but were linked through their inclusion in the classroom engineering design language.” (Roth, 1996, p. 118). This links very well with Aikenhead and Jegede’s (1999) argument that for many children learning science is like navigating borders between the different sub-cultures that they belong to, particularly the everyday and the formal science cultures. Teacher pedagogical practices are critical to making this navigation non-hazardous.

Richmond and Striley (1996) argued that learning science in the socio-cultural perspective is a product of student ideas, how they are introduced, how they are debated, how they are accepted or rejected, the interactions of teachers and students as well as students’ interactions with their peers. It is the personal experiences of the learners in this interactive/dialogic discourse that shape science understanding in the classroom. Yackel (2002) on the other hand, argues that the dialogic discourse results from the negotiation of social roles which have to be taken-as-shared. In other words there has to be a level of intersubjectivity between the teacher and learners and also among the learners. This happens as the teacher validates, suppresses, recognises, reiterates, clarifies, acknowledges and emphasises learner ideas. She contends that among learners intersubjectivity is achieved through inclusiveness, involvement of as many learners as possible, co-construction of arguments (explaining and justifying own thinking), asking questions, and challenging ideas. Also important is an awareness of the norms of engagement (Driver, et al., 2000) and the norms about own thinking (Herrenkhol & Guerra, 1998) or metacognitive reflection. To facilitate metacognitive reflection teachers must guide students to learn the conventions associated with the discourse and its recognition. Yackel further argues that other social talk, such as talk about sports, relationships, events and situations outside of the classroom or school context, is also important for the establishment of intersubjectivity. This last observation relates to Denley and Bishop’s (2007) assertion made earlier in this chapter on how student engagement comes through fun, humour, unpredictability and the will to do odd things. One could argue that the norms of classroom talk are inclusive of both formal and informal forms of interaction. Yackel (2001,

p5) defines a norm as a sociological construct which “refers to understandings or interactions that become normative or taken-as-shared by the group. Thus, norm is not individual but a collective notion ... the expectations and obligations that are constituted in the classroom”. However, science is a strongly framed form of knowledge and its social mediation introduces a tension between the intellectual and the social goals or between “how students come to understand science concepts and the norms which guide science talk”, then the norms can help to describe expectations and obligations in the science classroom (Richard & Striley, 1996, p. 840).

Research with science learners for whom English is a second language suggests that since learners are struggling with the challenges of building registers for the language of instruction they cannot be expected to automatically formulate high quality arguments on science concepts (Rojas-Drummond, et al., 2001; Rojas-Drummond & Zapata, 2004). Rojas-Drummond and her colleagues worked with primary school learners in Mexico and made some interesting observations with regard to non-English speaking learners whose language of instruction is English. They argue that for these learners the first hurdle is to be able to talk at all in English in the science classroom. Only after that first hurdle has been dealt with can learners begin to struggle with formulation of structured scientific arguments (Rojas-Drummond et al., 2001). This observation influenced my decision to rather consider all talk emanating from science talk teaching initiatives so as to be able to allow for talk to emerge and if possible develop into fully fledged argumentation in time. I envisaged that learners in the township schools that I would be working with would contend with this difficulty as well as the burden of the shift in pedagogy from the familiar transmission method to one in which they are required to speak up and participate more. Hence, my definition of science talk includes all verbal interaction including argumentation. I envisaged that such verbal interaction would take place in dialogic discourse in the classroom. In the next section I review the literature that helped me to identify and describe dialogic discourse as well as determine the role of the teacher in creating and managing such a discourse.

2.7.1 Descriptions of dialogic pedagogic practices

In dialogic discourse the teacher’s role is described by Cornelius and Herrenkohl (2004) as fourfold: to problematise content, to give students authority, to hold students accountable to each other and to the norms of the discipline, and to manage resources. Engle and Conant

(2002), argue that problematising content of the subject matter in ways that represent the true nature of discipline specific inquiry requires some intentional moves by the teacher, namely encouraging “questions, proposals, challenges, and other intellectual contributions” (p. 404) from students. They also argue that in problematising the content teachers must allow students to be active participants in classroom discourse and they have to give students the authority to conduct the inquiry or investigations. Yackel (2002) argues that teachers must pay attention to and follow up on students’ ideas, recast and legitimise arguments as plausible, elicit warrants or provide warrants, revoice/repeat statements, elaborate to make implicit warrants explicit and challenge student thinking. Opening up the classroom for questions and contributions from students is a risky undertaking as it has the potential to create perceptions of a teaching and learning environment where learners can do as they please. Holding students accountable means insisting on adherence to the conventions and standards of the discipline and being accountable to their peers (Herrenkohl & Guerra, 1998). In order to be held to these high accountability standards students need requisite resources, among them adequate time to engage with the subject matter.

In defining and describing dialogic discourse I drew largely from the work of Mortimer, Scott and colleagues. Mortimer and Scott (2003) proposed a model for understanding teacher-student classroom interactions in the science classroom. Drawing from observations in British and Brazilian science classrooms they developed the framework around three categories of activities that define the role of the teacher during the lesson: focus, approach and action (Table 2.02).

Table 2.02 Analytical framework for teacher-learner interactions (From Scott & Mortimer, 2005:397)

Aspect of Analysis		
i. Focus	1. Teaching purposes	2. Content
ii. Approach	3. Communicative approach	
iii. Action	4. Patterns of discourse	5. Teacher interventions

The communicative approach that a teacher takes is central to the framework and shows whether and how the teacher interacts with students and whether or not she develops their

ideas. Meanwhile the focus of the interaction can either be the purpose of the lesson or the content, while teacher and learner actions are centred on emergent patterns of discourse and teacher interventions. Teacher focus comprises both the teaching purpose and content of the lesson or episode. Teaching purpose may include opening up the problem (engaging students emotionally and mentally in initial development of the scientific story); exploring and working with students' views (probing student views and understanding); introducing and developing the scientific story (making meanings available in the social plane of the classroom); maintaining the development of the scientific story (commentary on the developing scientific story as well as helping students follow its development and how it fits into the wider science curriculum). The content of classroom interaction is viewed at two levels: the type of knowledge focussed on (everyday versus scientific knowledge); the language used to communicate the concepts, that is, whether a description, explanation or generalisation of the concept is being presented.

According to Mortimer and Scott the central role of the communicative approach is in showing how the teacher uses various intervention strategies to shape the patterns of communication so as to achieve the focus of the lesson. Communication is thus a tool for manipulating the lesson content and getting to the teaching purposes of the day. This relates to my thinking about science talk as both a teaching strategy and a tool for meaning-making. For the purposes of my data analysis I drew from four aspects of the model; the *teaching purposes*, *teacher interventions* and how they help shape the *communicative approach* and the nature of the resultant *discourse patterns* (Figure 2.02). Since the content covered in the lessons I analysed was varied, I described the content for each lesson as I went along. I revisit this point in the discussion of my methodology in Chapter 3.

The model distinguishes dialogic from authoritative patterns of classroom interaction. In dialogic interaction the teacher opens up the teaching and learning space for different viewpoints and takes seriously learners' ideas and understandings. This involves decentralising her authority by responding elaboratively to learners' contributions (Viiri & Saari, 2006) and by inviting learners to critique each others' thinking and ideas. In authoritative interaction however, the teacher restricts interaction to engagement with the accepted scientific view and/or content. Teacher response to learner contributions is largely evaluative in authoritative interaction.

Mortimer and Scott categorised teacher-student talk along the two dimensions, the dialogic-authoritative continuum on the one hand and the interactive-noninteractive talk on the other. The former ranges from lessons where various points of view are considered (dialogic) to

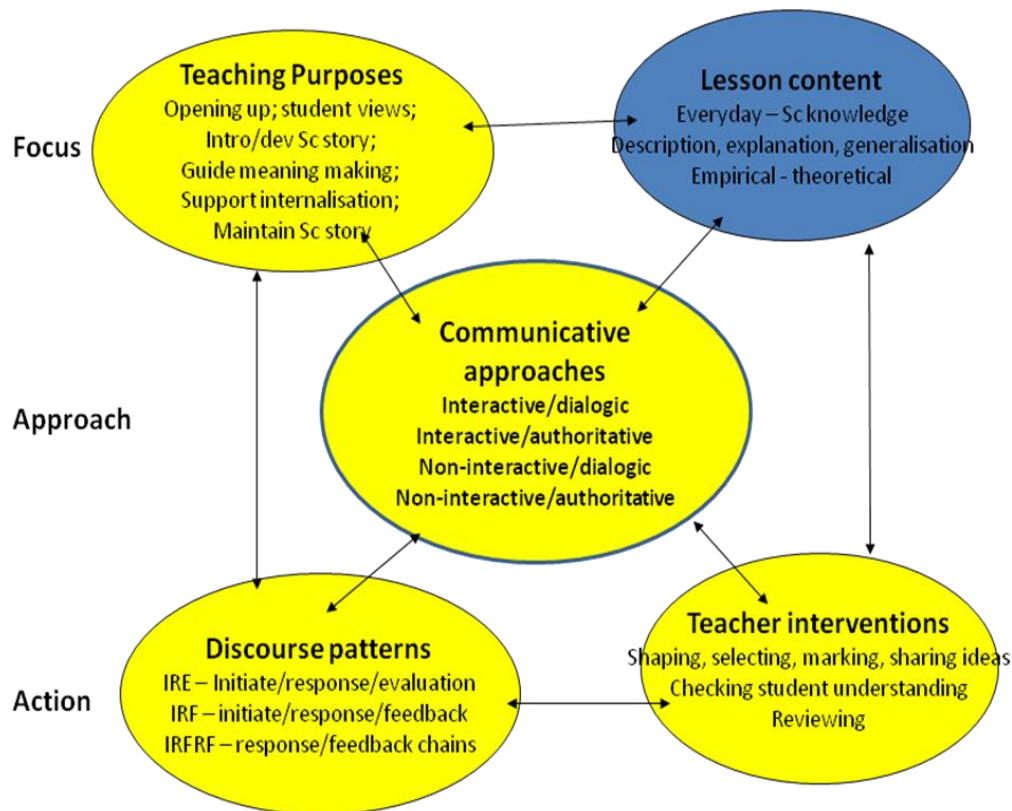


Figure 2.02: My conception of how the five aspects of the Mortimer & Scott model relate to each other.

lessons involving only the teacher's voice (authoritative approach). The latter is about affording the highest possible student participation on the one extreme (interactive) and the participation of only the teacher as in the lecturing method (non-interactive). In Fig 2.03 I provide my visual impression of the two dimensions and the four classes of communicative approach generated from them. On the top right quadrant is the Interactive-Dialogic (ID) approach in which the teacher engages students in dialogue as she explores their ideas; on the bottom right is the NonInteractive-Dialogic (NID) approach in which the teacher reviews reviews student ideas (she continues to address students' ideas but without engaging them interactively); in the NonInteractive-Authoritative approach (NIA) at the bottom left, only one point of view is expressed - the scientific view through the voice of the teacher alone, as in lecturing; and finally in the top left quadrant is the Interactive-Authoritative (IA) approach

in which the teacher pursues a specific point of view usually by engaging students in a question and answer session.

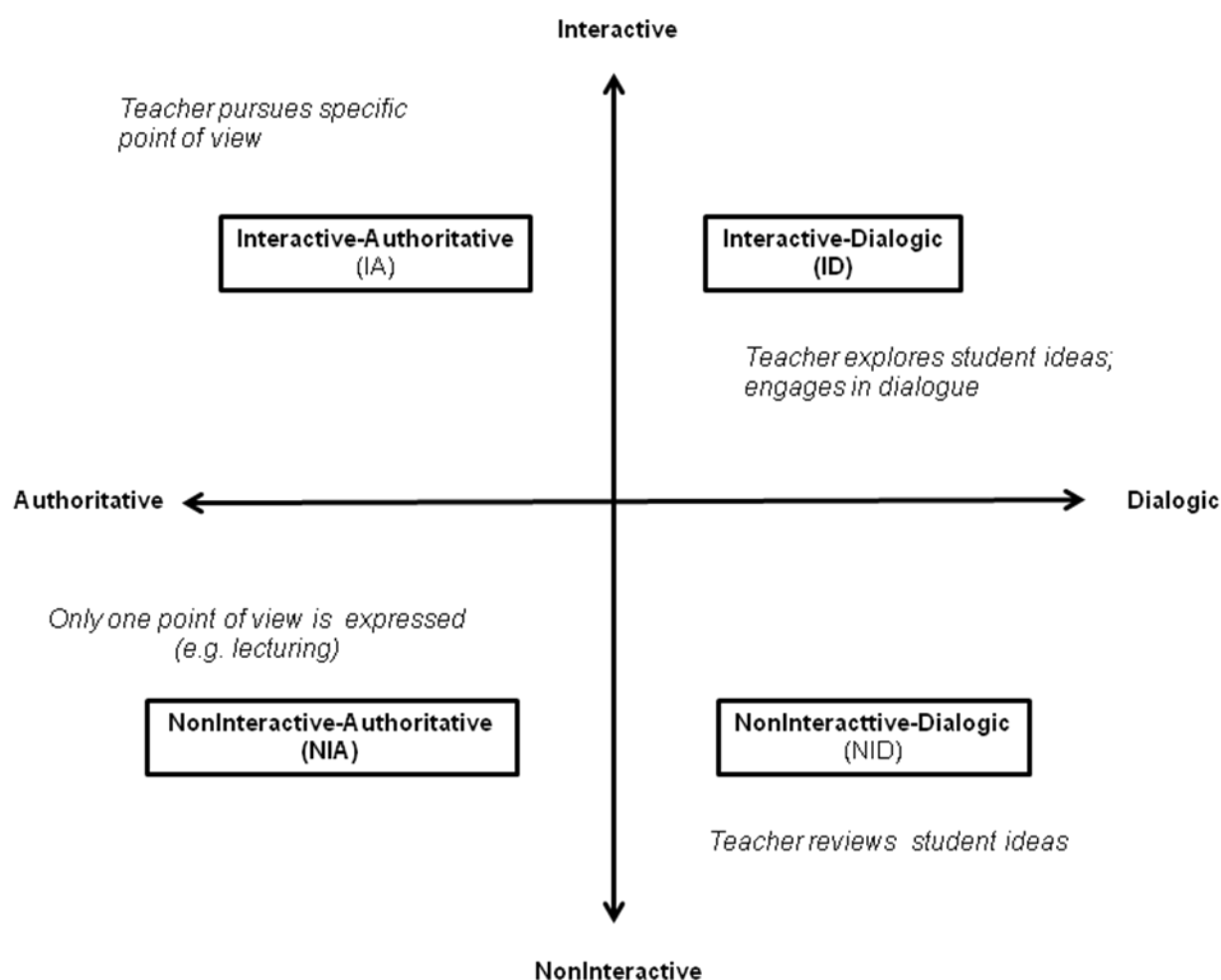


Fig. 2.03 My visual representation of Mortimer and Scott's (2003) categorisation of classroom talk along the Dialogic-Authoritative and the Interactive-NonInteractive continuums

Different combinations of communicative approaches produce the patterns of discourse that play out in the classroom. Mortimer and Scott recognise three main types of discourse. The first and most prevalent discourse type is Sinclair and Coulthard's (1975) initiation-response-evaluation/feedback triadic discourse or the traditional IRE/F triad which is strongly authoritative in nature. As discourse becomes more dialogic, the triads are replaced by more elaborate chains of utterances. In the closed IRPRP...E/F chain a series of learner responses and teacher probing interventions follows a single initiate move and culminates in a feedback or evaluation move by the teacher. In an open chain, however, the initiate move triggers a series of response moves with learners responding to each others' contributions without or

with very little intervention by the teacher. The open chain does not culminate in a feedback or evaluation move.

Teacher interventions that determine the discourse patterns include shaping ideas (new term, paraphrase, differentiate); selecting ideas (focus on or overlook student ideas); marking key ideas (repeat or ask to repeat, voice intonation); sharing ideas (report back, posters, repeating student's ideas); checking student understanding (probing, ask for clarification, check consensus); reviewing (return to ideas, summarise, recap on previous lesson, view progress so far). Scott and Mortimer argue that the teacher's decision on how to intervene is influenced by the content and teaching purposes for the lesson. If for example, the teacher's intention is to open up the discussion to explore learners' prior knowledge or existing ideas of the topic, she may take a dialogic communicative approach and so choose more elaborative and non evaluative interventions such as exploring and sharing learner ideas. In this case the teacher encourages learners to expose their thinking and in turn she simply listens to and/or captures the ideas (sometimes for interrogation later in the lesson or series of lessons). At other times, the teacher may take an authoritative communicative approach, say to develop the scientific story, in which case her interventions would be more about selecting and shaping ideas as well as checking learner understanding. The authors argue that there is always a tension between these two communicative approaches in the science classroom. Since by its very nature science is an authoritative subject (Scott, et al., 2006) it is sometimes necessary for the teacher to take an authoritative stance in order to develop the scientific story and yet to create opportunities for learner participation and engagement in a dialogic learning environment the teacher has to take a dialogic communicative approach.

A dialogic discourse is preferred in the science classroom according to Scott, Mortimer and Aguiar (2006) so as to facilitate meaning making for learners. However, as seen in Chapter 2, this form of classroom discourse is rare in science classrooms, especially at high school. Teachers need to be equipped with the skills to deliberately foster it by way of specific interventions. Scott, Mortimer and colleagues have used their model to investigate the development and nature of dialogic discourse in various science classrooms in Brazil and the UK (see for example Scott & Ametller, 2007; Scott, Ametller, Mercer, Staarman, & Dawes, 2007; Scott, Mortimer, & Ametller, 2011).

Aguiar, Mortimer and Scott argue that as discourse becomes more and more dialogic it must of necessity begin to include learner initiated questions (Aguiar, et al., 2010). How the teacher responds to learner questions will also either shut down or open up the dialogue. Similar findings have been reported in some South African classrooms (e.g. Brodie, 2007). Working in mathematics classrooms, Brodie investigated the dynamics of dialogic discourse and identified four forms of classroom interaction; question and answer, reversing IRE, learner-learner dialogue as well as whole class dialogue. In reversing IRE, the initiate move is made by a learner usually as a question and the teacher chooses which questions to respond to or how to respond to them, thus maintaining her authority. In such cases the evaluation or feedback move can be made by the teacher or another learner. She argues that this form of interaction takes the discourse beyond a simple question and answer session which may yield positive or negative consequences. In many South African classrooms question and answer sessions tend to lead to superficial engagement. The teacher may funnel the discussion, leading learners to the acceptable answer by progressively simplifying and reducing the question's cognitive demand. The teacher sometimes ignores irrelevant answers. The latter situation I see as lost opportunities for learner engagement with content and for affording learner epistemic access. With the requisite skills to foster the reversing IRE as observed by Brodie then the teacher might be better equipped to create a more dialogic environment. In whole class dialogue the interaction may be teacher led but learner talk predominates and not teacher talk as is the norm in traditional forms of whole class discussion (Brodie, 2007; Lyle, 2008; Scott, 2008).

One of the aims of my study was to determine whether classroom discourse was dialogic or not. To do this I used the intervention aspect of Mortimer and Scott's (2003, 2005) model to examine the third move in the IRE/F triad, the teacher's evaluation/feedback move. In the traditional IRE triad or sequence (Mehan, 1979; Sinclair & Coulter, 1975) the teacher initiates interaction (I) usually with an instructional question, the student responds (R) and the teacher then evaluates (E) the student response positively or negatively depending on whether it provides the answer that the teacher has in mind. This type of interaction does not always result in meaningful learner engagement. If however, the feedback move is more elaborative, foregrounding learners' ideas and encouraging others to evaluate and critique them, then a dialogic discourse results. The teacher can do this by asking thinking questions, marking and probing learners' ideas.

Mortimer & Scott's (2003, p. 25) model of analysing teacher-learner and learner-learner interactions in the classroom "is offered both as a tool for thinking about and analysing science teaching after the event, and as a model to refer to, *a priori*, in thinking about the planning and development of science teaching". The model seemed appropriate therefore for the classrooms targeted for my study as it allowed for both the development of dialogue where it did not previously occur and for development of argumentation under the constraints of untutored learners and traditionally non-dialogic classroom discourse. This way I took into account the need to allow unconstrained development of both dialogue and argumentation without the need to be compliant to a fixed pattern of argument as is the case in the TAP model. In Chapter 4 I return to this discussion and provide greater detail on how this thinking influenced the design of my data analysis tool.

2.7.2 Dialogic discourse, the outcome of pedagogic practices

Like Mortimer & Scott (2003, p. 1) I recognise two views of teaching: the "traditional view and today's view". In the traditional view the teacher stands up front and presents facts to the class while learners sit and listen or copy notes and answer the teacher's questions. In "today's view" both the teacher and the learners are "out of their seats" (p1) and work alongside each other. The latter is reminiscent of dialogic teaching. Dialogic teaching is a transformative pedagogic practice that is rooted in dialogic meaning-making (Lyle, 2008). Transformative pedagogic practices aim to bring about social justice through the valuing of student voices. They focus on the cognitive, social as well as the affective domains by employing various strategies, particularly reflective teaching and learning through open-ended questioning, elaborative feedback, fostering learner argumentation (see for example Smith & Higgins, 2006). According to Smith and Higgins it is the teacher's feedback that opens up classroom interaction in dialogic discourse. They argue that while teacher questions are important, it is the teacher's response to learners that is critical. When there is uptake of learner contributions or if the teacher takes a genuine interest or asks high level questions then a high expectation is communicated to learners. Further, when teacher responses are conversational learner interest is aroused enhancing engagement. Conversational responses include genuine exclamations, cues, wait time or drawing from the teacher's own experience. Similarly, Cullen (2002) argues that in supportive teacher talk the F-move is not only evaluative but also discoursal, both of which support learning. According to Cullen a

discoursal teacher response builds on learner contributions and focuses the dialogue on concepts. The most important of these strategies for dialogic teaching is the feedback move.

In dialogic discourse classrooms are interactive and there is high quality classroom interaction. Learners ask questions, state view points, comment on each others' ideas (Mercer, et al., 2004). Learners become each other's resource and the atmosphere is conducive for joint meaning-making and a high level of student engagement at deep levels (Nystrand & Gamoran, 1991). However, the high level of learner involvement and learners taking greater responsibility in their own learning does not suggest that teachers have abdicated responsibility for guiding the construction of knowledge; their role in enabling children to gain a better understanding of interpersonal communication and curriculum content is crucial. Rather, this kind of interaction creates conditions in which the educational purposes of classroom activities become clearer to all involved. The class atmosphere becomes more open, interested and engaging as the class gains an ethos based on shared purposes for activity and for collaboration. Such a class ethos of shared purposes is achieved through negotiated norms of interaction in the classroom (see for example Driver, et al., 2000; Osborne, et al., 2004; Yackel & Cobb, 1996; Yackel, Rasmussen, & King, 2000).

2.8 Development and uptake of dialogic pedagogical practices in a curriculum change context

Teacher uptake of new innovations and/or teaching strategies is not easy. Observations from some international studies point to certain specific individual and contextual conditions that tend to favour the uptake of new strategies during an intervention. For example, findings from the CASE study in the UK suggest that the duration of the intervention – continuous project team presence in classrooms for the first half of the project as well as continuous and consistent researcher availability to support the teachers during the course of the intervention seemed to have a positive effect (Adey, 1997; Shayer, 1999). Constant teacher support seemed to be a critical factor for the success of school based interventions together with researcher openness to critique of their own practice during the reflection sessions (Showers & Joyce, 1996, 1999). Other factors included relating as equals – where researchers did not come in as experts to teach the teachers “how to” but worked collaboratively as well as provision of workshops focusing on science content knowledge. Similar findings have been

recorded in Europe (Kuijpers 2010), the USA (e.g. Reed 2008; Garet, et al., 2001; Luft 2011; Lambson 2010) as well as in Canada (Bruce et al 2010).

2.8.1 Curriculum and institutional constraints

Since the introduction of a democratic government in 1994 the South African curriculum system has undergone a series of changes aimed at addressing the needs of learners from diverse social, cultural and economic backgrounds (Department of Education, 2003b). The new curriculum requires shifts from teacher-centred to learner-centred instructional practices (Brodie, 2005b; Jansen, 1999). Teachers must therefore, move from transmission instructional strategies to methods that promote learner participation and engagement. Research into trends in teacher change in South Africa, shows that the demands made on teachers to make such large shifts in their pedagogical practices have been overwhelming, resulting in some cases in teacher resistance to change (Brodie, et al., 2002b; Verspoor, 1989). Alternatively, some teachers who desire to change may not know how, (Aldous, 2004) or they may change at a pace much slower than envisaged by policy makers (Rogan, 2000). However, if guided and supported through the change South African teachers do take up new innovations and begin to adapt them for their contexts (Brodie, 2007, 2008).

Besides the overwhelming shifts expected of teachers, other contextual factors influence uptake of new innovations. For instance, science teachers in South Africa (in particular, those in township schools) are constrained by various socio-political and socio-economic factors, such as teaching science to large multicultural classes with learners from diverse socio-economic backgrounds; diverse learner abilities; low uptake, lack of motivation and low performance in science (Hattingh, et al., 2007; Taylor & Vinjevoold, 1999). The teachers themselves were educated in teacher-centred science classrooms; many are not grounded in science content knowledge and have to deal with new topics in the curriculum which they did not study at school or college. Yet, according to Chisholm (2005a) the new curriculum demands a high degree of knowledge and high proficiency of teachers.

Teachers themselves express concerns over the content heavy curriculum and the strict timetables that leave very little room for dialogue or classroom talk (Brodie, et al., 2002b; Stoffels, 2005a). Also, critics of dialogic approaches raise their own issues like the fact that the approach is not pragmatic, it is rather idealistic, considering the imbalances in resource

provision in schools. They also argue that by their very nature classroom power relations are not balanced; the teacher is mandated to control learner speech and action in class and is also vested with epistemological authority – the school as an institution demands learner compliance (Lyle, 2008).

Although various pre-service and in-service teacher education programmes have been instituted at tertiary institutions around the country to address this need, not all practicing teachers are able (or have the inclination) to take up such studies. Such teachers are therefore, excluded from continuous professional development programmes and from any forms of school based support during the curriculum change process. My study focused on this category of teachers.

2.8.2 Cultural constraints

Language and other cultural issues tend to constrain the uptake and use of new strategies like science talk and/or argumentation in science classrooms. For example, literature is replete with studies on the language of instruction in multi-lingual classrooms (e.g. Kamen, et al., 1997; Rojas-Drummond & Zapata, 2004; Setati, Chitera, & Essien, 2009). Jay Lemke (2001) cites learner emotions as a possible constraint to engagement in classroom talk, while Wolf Michael-Roth (1997, 2001), Aikenhead (1999) as well Ogunniyi (2007b) and Scholtz, et al. (2008) all raise the issue of conflicting world views in the science classroom. The tension between formal and informal ways of talking and learning has also been cited as a factor in the use of talk in teaching and learning of science (examples include Ash, 2004, 2007; Boylan, 2010; Hofstein, Bybee, & Legro, 1997). I now turn briefly to some of these studies and how they relate to my own study.

2.8.2.1 Talking science in their own languages

Although the issue of language in the science classroom was not the focus of my study I could not ignore it because of the obvious impact on classroom interactions it would have in the multilingual South African context. The constitution of South Africa recognises eleven official languages including English and many South African teachers and learners are fluent in more than one local language. This means that South African classrooms are by nature multilingual. The Language-in-Education policy provides for schools to choose a preferred language of teaching and learning beyond the fourth year of schooling (Department of

Education, 1997). Most South African schools in Black communities, including all the three schools I worked with choose to use English as a language of instruction, yet English is not the mother tongue of either the teachers or learners (Probyn 2006, Adler 2001). The reasons for this decision vary, including the fact that all the high stakes and exit point examinations are conducted in English and that English is viewed by teachers, learners (students) and parents as a language of privilege affording access to a good education and to social goods (Setati, Molefe & Langa 2008). Thus, for the majority of South African classrooms the language of teaching and learning (LoLT) is neither the teachers' nor the learners' home language. For many the only time they encounter the English language is in the classroom, there is no social interaction in the English language outside of the classroom. It is not surprising that one of the current debates in South Africa centres on the LoLT. My interest was not on the latter debate but on what actually happened in the classroom in terms of language and how that may influence science talk. The rationale for my thinking was that while the language in education debate rages in academic and parliamentary forums and the issue remains unresolved, science teachers and learners in my schools were already engaging with science content in their own languages. Yet, no research has been conducted to understand the dynamics of disciplinary engagement in learners' own languages and thus inform both teacher practice and teacher preparation for these multilingual classrooms.

Most research into the role of language in science teaching and learning in South African classrooms has focused on perceptions of and attitudes towards the LoLT as well as on strategies to help learners cope with learning science in English (e.g. Olugbara 2008; Pliiddemann, Mati & Mahlasela-Thusi 1998; Probyn 2006) in addition to the challenges of learning the language of science itself (e.g. Oyoo 2009). For example, it has been observed that both teachers and learners in South African multilingual classrooms use strategies like code switching and transliteration (Setati, Molefe, & Langa, 2008) as well as peer and/or teacher interpretation (Pliiddemann et al., 1998) to cope with the challenges of teaching and learning science in a language they are not proficient in. Other research in South Africa has shown how language can be used as a visible and invisible resource to facilitate epistemological access (Setati, et al., 2008). That is, how teachers and learners switch between consciously engaging with the problem of language during the lesson (visible) and the unconscious use of their own languages to engage with the mathematics (invisible). However, such inquiry has not been reported in science classrooms in South Africa yet

teachers and students do use their own languages to discuss science concepts. In this thesis I look briefly at the nature of learner engagement during discussions in which learners home languages were used.

2.8.2.2 Learner silences and the norms of social interaction

The relationship between social processes and cognition are the subject of ongoing research in education. For example, student silences have been seen to be associated with traditional ways of teaching and learning that do not afford safe spaces in which to talk about their thinking. In a study of student interactions in university mathematics classrooms, Stylianou and Blanton, showed that students who were initially reluctant to expose their thinking, became comfortable not only in giving explanations and justifications but also in expecting them from others. Students became comfortable to talk as they understood better not only the mathematical rules but also the social rules of engagement in the mathematics activities (Stylianou & Blanton, 2002). Learner talk may be constrained by personality and group dynamics, especially where there is poor understanding of the norms of social interaction. Mercer and colleagues argue that:

“providing children with ‘rules’ for talk may seem constraining. But if children agree ground rules and then implement them, this can represent a kind of freedom. The usual social conditions for talk—for example, the dominance of participants who talk most and most forcefully—are suspended. The social status of individuals can be neutralized by the ground rules, creating an intellectual environment which is more equitable—though of course it is also one in which everyone’s ideas are open to critical examination. More confident children gain the opportunity to hear a wider range of views. Quieter children find that their contribution is sincerely requested and valued. One of the simplest but most profound benefits for children is the idea that challenging each other is not just accepted but encouraged.” Mercer et al. (2004, p. 375).

For Mercer and others, a classroom culture where the norms of interaction are negotiated and clearly understood is critical in liberating learners and encouraging meaningful engagement. As explained in Chapter 3, one of the complaints that teachers in my study raised right at the beginning of the project was that their learners were not talking or they talked in ways that made it difficult to keep them focused on the science task. Mercer asserts that even quieter learners may be drawn out to talk if through an understanding of shared norms and values they feel that their contributions are valued. This resonates with other observations about learner interest (or usual lack of interest) in learning science. Research in the UK on students’ views and attitudes towards school science established a general dislike for science among students, even for those who believed that it was worth learning for its value in creating job opportunities (Jenkins & Nelson, 2005; Osborne, Simon, & Collins, 2003). The Osborne

team recommended research to establish teaching strategies and classroom environments that could raise interest in studying school science.

In other research in Canada, Wolff-Michael Roth (1996, p. 110) observed significant changes in engagement in classroom talk among students exposed to activities specifically designed to engage them in talking about engineering tasks. The teachers “managed the classroom in a very child-centred manner. Students and teachers negotiated classroom norms, planned and structured activities, and organized the classroom. The teachers' goal was to establish a ... community ... in which students worked together in small groups, shared ideas between groups, and built on each other's ideas to elaborate them. ... teachers also made sure that, when students critiqued or commented on each other's work, this was done in a positive manner; thus when such critical comments could be heard as put-downs; or were directed at a person rather than an artefact, ... teachers intervened.” Clearly, a welcoming learning environment is crucial for learner interest and engagement and teachers need to be equipped to be able to create and manage such environments.

2.8.2.3 Formal and informal ways of talking

In a study of Haitian students Cynthia Ballenger (1997) explored student engagement with science tasks using their language and their everyday ways of making sense of the task. Her interest was to understand whether students would not make any conceptual progress, simply remaining in a non-academic discourse, unable to explore science as a different way of thinking and acting. The study showed effective learning in the context.

Studies noting the continuities and points of overlap between everyday and scientific understandings link them continuously across settings (Ash, 2004; Warren, Ballenger, Ogonowski, Rosebery, & Hudicourt-Barnes, 2001). These studies position “everyday” and “scientific” language and thinking along a continuum, rather than as discontinuous or mutually exclusive cognitive states. Focusing on continuities between situated everyday and formal academic science assumes students have a chance to succeed in school science and to access the “culture of power” necessary to enter science as a professional domain. Such research also reformulates ideas about what it means to learn science. Rather than seeing science learning as just a “cognitive” task, it allows researchers to see how learning science is also a product of particular social practices and cultures, and of changing identities, values,

and culturally valued ways of thinking about the world (Barton & Hamilton, 1998; Lemke, 1990). Thus, classroom science teaching and learning can benefit from the contextual, cultural informal ways of engagement. Contextual informal ways of engagement could also include what is popularly known as social talk or talk that is not focused directly at the concept under discussion.

Science education research on classroom talk has focussed on understanding the nature of conventional forms of talk or what Luk (2004) termed “institutional talk” as opposed to “non-institutional” or social talk (Alexopoulou & Driver, 1996). Solomon and Harrison (1991, p. 291) argue that social talk is an integral part of engagement in the classroom. They state that “the purpose of social talk is to try out opinions, receive feedback, and respond to others. This necessitates taking on board others' perspectives”. Thus, social talk would draw from and be shaped by the participants’ shared experiences. The role of social talk has been explored in mathematics classrooms and talk is implicated in the establishment of intersubjectivity during discussions (Yackel, et al., 2000). Intersubjectivity or a shared common understanding of tasks and expectations is important for learner conceptual engagement and understanding. Yackel and colleagues assert that such social talk includes talk about sports, relationships, events and situations outside of the school context.

Aikenhead and Jegede (1999) saw value in the alternate uses of social and formal science talk, arguing that enculturation into school science is easier if school science harmonises with the learner’s world view. Berland and Hammer (2012) used the notion of hybrid spaces to understand unconventional forms of talk in science classrooms. They described hybrid spaces as social spaces where participants engaged in combinations of scientific and everyday context-based interactions. Engagement in hybrid spaces would thus, involve participant ability to draw from a combination of shared knowledge and understanding of the established and agreed on scientific discourse with everyday forms of interaction that are part of teacher-learner cultural capital. Cobb and colleagues suggest that both forms of interaction always play out in classrooms, that “both small group and whole class interactions typically involve these two intertwined levels of discourse” (Cobb, Yackel, & Wood, 1992, p. 108). Thus, classroom talk is likely to at all times, reflect both the collective understandings of scientific engagement as well as the collective contextual everyday ways of interaction. In other words

science classrooms are inevitably hybrid spaces, particularly so in multicultural classrooms such as are prevalent in South Africa.

2.9 Conceptual framework and research questions

In this section I draw on Prof Fatih Tasar's analogy of theory as a light that can be moved around (see image insert at the beginning of this chapter). Theory was the light that I could move around to vary the view of the shadow that I was attempting to make sense of. I made conscious choices as to what to foreground or background at different times so as to be able to sometimes see "more detail" and sometimes see in "greater detail" the selected aspects of the classroom interactions. I therefore drew mainly from two frameworks for analysing classroom interaction. On the one hand, I drew from Mortimer and Scott's model for analysing teacher-learner interactions to help me understand whether and how teachers used science talk. On the other hand, I drew from argumentation theory to analyse the quality of the science talk. In the same way that I might vary the position, intensity and probably colour of light to affect the shadow in Prof Tasar's analogy, I selected and modified aspects of the two theories in order to foreground and/or background selected aspects of classroom interaction.

2.9.1 Establishing the link between theory, the research problems and research questions

Here I show how my research questions relate to the theory that I have discussed so far and how that helped me address what I perceived to be the three problems that I was dealing with. The main question that guided my research was "How do teachers use science talk to stimulate learner participation and engagement in high school science classrooms and what is the nature and quality of ensuing teacher-learner interactions during science talk?" The question was broken into three sub-questions:

- How do teachers shape science talk in high school classrooms?
- What patterns of interaction emerge as teachers and their learners engage in science talk?
- What is the quality of the interactions that emerge with science talk?

I drew from the cognitive and socio-cultural views of learning (and teaching) as well as argumentation theories to investigate these three questions. I viewed science talk as a tool that teachers could use to facilitate learning and to mediate in the learner's ZPD as well as a

tool that the learners themselves could use to mediate their social interaction during the lesson. I therefore, wanted to understand how science talk could be used to mediate learning at three levels (Mediation 1, 2 and 3 in Fig 2.02). My study therefore, focused on three problems. The

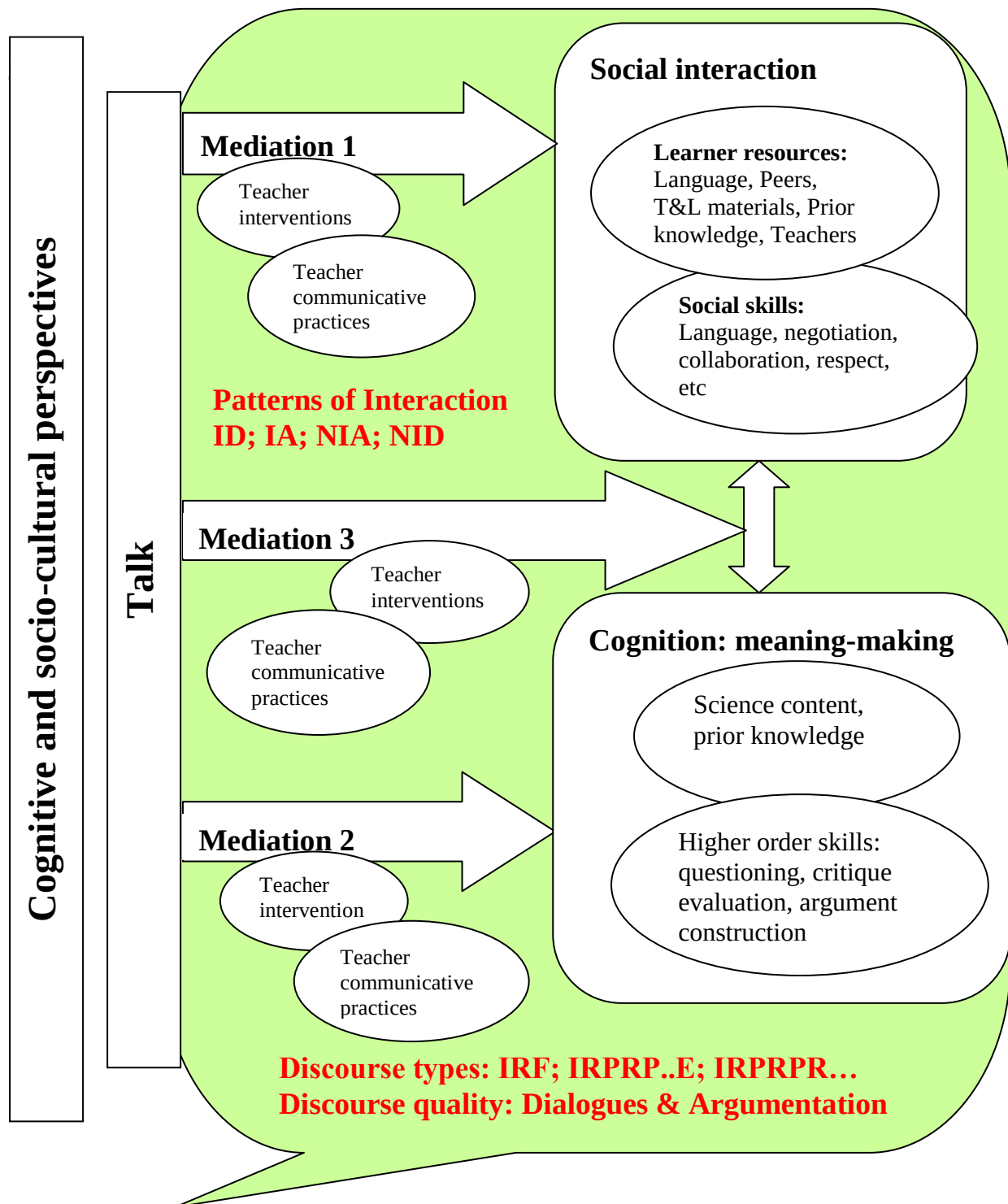


Figure 2.04: Conceptual Framework of my study

first problem was related to the nature of the pedagogical practices expected of the teacher in order to stimulate and mediate learner participation and engagement. In Figure 2.04 this would relate to the first level of mediation by the teacher using talk to facilitate social interaction as well as learner cognition (Mediation 1). The second problem was both empirical and methodological. The underlying assumption in research that focuses on the quality of talk in science classrooms is that there is meaningful talk going on in the classroom. However, research guided by such an assumption precludes those classrooms where learners may not be talking or where learner talk is not substantive. Drawing from observations from work done by the ICC project team before the commencement of my study, I realised from the outset that very few learners were actually talking at all in the classrooms that I was going to work in. I needed to understand how science talk played out as a tool for learners to participate in classroom discussions (Mediation 2 in Fig 2.04). My first question therefore, aimed to address the first two problems; to understand the patterns of teacher pedagogical practices and to understand how they stimulated learner talk. Thus, *How do teachers shape science talk in high school classrooms?* With this question I sought to understand what communicative approaches teachers adopted in order to guide and/or shape the talk so as to achieve their teaching purposes. I did this by identifying talking episodes and using teacher interventions as codes to determine the teacher's communicative approach at different stages of the lesson. My data analysis for this question was guided largely by Mortimer and Scott's model of classroom talk (see discussion of the data analysis tools in Chapter 4).

The third problem related to the fact that most argumentation research in South African science classrooms has so far focussed on construction of arguments based on socio-scientific issues and not on meaning-making about science concepts *per se*. Socio-scientific issues have both a scientific and socio-cultural aspect and have been observed to stimulate arguments of a largely informal nature. Participants tend to draw on both scientific knowledge and their own opinions and emotions (Braund, et al., 2007). However, my study targeted discussions of the more mainstream science concepts. I was guided by a personal assumption that, as in international studies reviewed in this thesis so far, talk and/or argumentation could be used in South African classrooms as a tool for meaning-making about scientific concepts (Mediation 3). My second and third research questions targeted this problem. To answer the second research question: *What patterns of interaction emerge as teachers and their learners engage*

in science talk? I identified the patterns of discourse that emerged during science talk. By mapping the sequence of teacher-student turns on the transcripts I determined whether IRE triads prevailed or whether there was evidence of emergence of the more dialogic IRFRF or IRPRPR...E chains. Emergence of Mortimer and Scott's chains of interaction would be evidence of two developments. First, that learners were talking meaningfully during the discussions and secondly, that the teacher was succeeding in moving the classroom towards a more learner-centred form of engagement as expected in the new curriculum.

Through the third research question: *What is the quality of the interactions that emerge with science talk?* I sought to understand how meaning making was negotiated between the teacher and learners and among the learners by determining whether and how the teacher guided and mediated students' justifications of their claims with evidence and/or evaluation of their own and others' arguments. Any evidence of learner justification or evaluation of ideas would suggest two possible outcomes: that the teacher was attempting (and succeeding to different levels) to engage the learners in argumentation during discussions and that argumentation was in fact a tool that could be adapted to South African contexts not only for discussions of socio-scientific issues but also for main stream science concepts. This would suggest the potential for argumentation to afford epistemological access and perhaps to enhance learner performance in science.

2.10 Conclusion

In this chapter I have shown how my study is located in literature and how my thinking is guided by a socio-cultural perspective of science learning. In doing so, I defined science talk and contextualised within a broad review of literature on classroom talk and cognition, on social interactions that characterise monologic and dialogic classroom discourses and as well as argumentation in science classrooms.

I located my study within socio-cultural theory, in particular the Vygotskian social constructivist view of learning because I wanted to understand science talk as a tool for teachers to promote participation and engagement in science lessons and for learners to construct their own understandings of scientific knowledge during classroom discussions. For me three key tenets of the socio-cultural perspective are important. First, how talk is

implicated in the notion of learning as socially mediated active construction of knowledge, since language is used between people as a tool for creation and externalisation of thoughts and since people use language to construct knowledge together. Secondly, talk is implicated in the notion of mediation of learning which happens in what Vygotsky terms the zone of proximal development. The ZPD is the region of (social) mediation in teaching and learning. Thus, thirdly, language is an important tool in this process of mediation. Science talk is therefore, a tool for both teaching and learning in the classroom.

Because I defined science talk in terms of all science related speech produced during discussions in the lesson, I reviewed literature on classroom talk as well as argumentation in science classrooms. Much of the research that has identified and developed teaching strategies to stimulate meaningful talk in science classrooms has been conducted overseas. In South Africa, such research has been reported mostly in mathematics education. Recently there has been an interest in argumentation research in South African classrooms, but mostly with pre-service and in-service teachers. No research has been reported on argumentation as a teaching and learning strategy in high school science in South Africa. Also, no research has been done in South Africa to investigate the dynamics of dialogic interaction in science classrooms. Very little is known about how learners talk (or do not) about science concepts and how talking might facilitate substantive engagement. Some research has been done on learner talk about socio-scientific issues but not core science concepts as prescribed in the new curriculum. I believe that argumentation is a potential tool for meaning-making and argue for its use to foster learner talk about conventional science concepts.

My thinking about science talk, my research questions, data gathering methods as well as analysis and interpretation of my data is guided by both Mortimer and Scott's model for analysing classroom interactions and the TAP model for analysing arguments (as defined by Erduran, et al., 2004). I ended this chapter by showing how the different aspects of my study are located within this theoretical framework. The analytical framework is presented in greater detail later in Chapter 4. In the next chapter, Chapter 3, I discuss the design of my study and the methodology that I adopted.

Chapter 3

Research design and methodology

The burden of educational work is carried by the spoken word, by its representational forms in writing, and by its attendant communicational forms such as images, diagrams, gestures, and other print and electronic symbols, mediating novices and texts – acted, spoken, printed or electronic. Education is both made up of interactions, and aimed at the enhancement and spread of certain kinds of interactions. (Freebody 2003, p90)

3.0 Introduction

In this chapter I follow up on the description of my research approach given in Chapter 1. I now give a more comprehensive description of my research design and its justification, the assumptions inherent in the research design, identification and justification of the participants; how I ensured objectivity of the data (reliability/validity) as well as how I analysed my data.

Methodology is defined variously but generally seen as a broad definition of how one goes about doing the study (Silverman, 2000, p. 77), or “...indicates frameworks for the conduct of (the) project” (Freebody, 2003, p. 74) and data from education methodologies includes observations, interviews, notes or talk. I begin with a brief description of the theoretical underpinnings of my methodology, the research paradigm and show how my methodology and data collection methods derive from it. In other words, I explain why I view my study as taking an interpretive qualitative collaborative research methodology. I then show how my research paradigm links with that of the bigger project in which my study was located.

3.1 My research paradigm and methodology

Qualitative research by its very nature points to a paradigm that connotes a way of knowing rather than “just a collection of techniques” (Freebody, 2003, p. 38). Freebody describes the qualitative research paradigm as “... a coherent collection of propositions about the world, their relative importance, and particular ways of finding out and knowing about them”. Since I believe that learning happens through social interaction and that talk is central to the interaction I wanted to understand the nature and variety of science talk within the local contexts of the teaching and learning environments of the Soweto classrooms I studied. I believe that to find out about science talk I had to be involved with the participants, observe

them talking and talk to them about the ways in which they engaged in science talk. For these reasons I located my study within socio-cultural perspectives of learning.

I took the Vygotskian social constructivist perspective of learning which is based on the notion that learning happens through social interaction (Davydov, 1995; Vygotsky, 1978). Research design for a study based on the constructivist perspective is guided by the assumption that the study involves more than just collecting observations and that the only way to make sense of the observation would be to involve and talk to the individuals (Bodner, 2007). It is impossible and undesirable for researchers to be distant and objective since co-construction of subjective reality happens through mutual engagement (Hatch, 2002). My study therefore, lent itself well to a qualitative collaborative research methodology in which the researcher is a participant-observer (Bodner & Orgill, 2007). Freebody (2003) asserts that the participant-observer role involves some level of deception, that is, a degree of pretending by the researcher to the participants not to be observing. In my case, however, my participant-observer role was fully negotiated. In other words both the teachers and the learners were aware of the fact that I was in their classrooms to observe them talking science. I will discuss the implications of this later when I talk about how I negotiated for consent to get into the classrooms. In the next two sections I briefly define what I mean by qualitative collaborative research and in particular the case study methodology.

3.1.1 Qualitative research

Qualitative research provides for an understanding of the dynamic and complex social world of humans, explaining questions relating to meaning of experiences (Darlington & Scott, 2002). Qualitative research varies depending on disciplines but in all its forms its interest is in what people say and do in the course of their various social activities (Freebody, 2003; Hatch, 2002). The methods used in qualitative research seek thick and “rich descriptions of people and interactions as they exist and unfold in their natural habitats” (Freebody 2003, p56). The richness of the data derives from the high diversity of subjects in the sample say, in terms of gender, age, new, old, and thick data results from the variation in data collection methods while depth is determined by the nature of the questions asked, probing and not superficial (Denzin & Lincoln, 2011; Opie, 2004). Qualitative methods are classified broadly into three categories; interviews of individuals or small groups, systematic observation of people’s behaviour, and analysis of documents (Darlington & Scott, 2002).

3.1.2 Collaborative research

Collaborative studies are a kind of qualitative research done in collaboration with practitioners with the principal aim of generation of knowledge and understanding of practice (Silverman, 2000). Hatch (2002) argues that collaborative qualitative research brings in both insider (participants) and outsider (researcher) perspectives to the analysis of the phenomena under investigation. In my case, the teachers' perspectives (participants) were incorporated into the research largely in the form of participation in workshops, pre- and post-teaching discussions as well as interviews.

3.1.3 The case study method

In designing my study I followed the case study methodology. The in-depth study of a case or situation using qualitative methods is referred to as a case study (Hitchcock & Hughes, 1989; Opie, 2004). This method allows for the investigation of one or a few (multiple case study) cases in order to gain an understanding of one phenomenon in depth within a limited context. Case studies can be exploratory, when conducted prior to the formulation of research questions usually as a prelude to other research; explanatory if aimed at causality; or descriptive if the research begins with a descriptive theory and aims to hypothesise about cause-effect relationships (Freebody, 2003; Silverman, 2000). My study was interpretive in nature in that I was seeking meanings and relationships between theoretical and contextual conditions. My data was collected at the end of a two year period of interaction and observation of the practice of three teachers and their Grade 10-12 learners, thus providing me with thick data on classroom interaction in their specific contexts.

Case study methodology is favoured in education as it can accommodate the messiness, uncertainty and complexity of studies of human behaviour. The classroom has all of these characteristics, since teaching and learning is contextual, topic based and the "lived conditions are indigenous to each teaching and learning event" (Freebody, 2003, p. 81). The case study focuses on instances of a specific experience with a view to understand the theoretical and professional underpinnings of the instance. I investigated the science talk so as to understand its role (and potential) as a teaching and learning strategy in specific science classrooms in the township context of Soweto. The patterns of interaction between teachers and learners were of particular interest for my study and as is typical of the case study both the teachers and myself were able to reflect on instances of our own practice through regular

structured interaction (Freebody, 2003). Data collection techniques selected were used to extract data on what teachers did and how they did it (classroom observations) as well as why they did it (interviews). The findings from case studies cannot be generalised but can provide insights into aspects of the big picture of (in this case) the possible use of science talk as a strategy for implementation of the new science curriculum at FET level, in South Africa.

3.2 The ICC Project research approach

My study was conducted under the auspices of a large scale project, the ICC Project (from hereon, the Project) focusing on the mathematics and science curriculum change process in South Africa. While my study derived its research paradigm and methodology largely from that of the Project within which it was initially located, there were significant deviations from this methodology in the later stages. The first two years of my study were conducted as part of the Project but the rest was completed independently of the Project and its design and methodology. The Project was designed on a Collaborative Action Research methodology that aimed to drive change in practice. Its main objective was to identify ways of working with education stakeholders such that opportunities for teaching and learning mathematics and science could be utilised more efficiently. The researchers in the Project were expected to work together with teachers on a long term basis (5 years) to explore and reflect on their practices, with a view to improving the ways in which learning opportunities were created within the local contexts of the targeted schools. My study on the other hand followed a qualitative and interpretive approach in which I conducted a cross sectional study of three cases, the three Physical and Life Sciences teachers reported on in this thesis. The significance of these differences will be made clearer as I discuss the actual data collection and analysis later in this chapter.

The science component of the Project involved myself as the science education researcher and 11 teachers who had volunteered to participate in the Project. However, my study focused on only three of the eleven, two Physical Sciences and one Life Sciences teacher. All three taught at least some classes at the FET level, Grades 10-12 (15-18 years old) which was the focus of the Project. As already explained in Chapters 1 and 2, my study aimed to examine how the target pedagogical practice of science talk played out in context, guided by the question, “How do teachers use science talk to stimulate learner participation and engagement in FET science classrooms and what is the nature and quality of ensuing teacher-

learner interactions during science talk?” and the sub-questions, a) How do teachers shape science talk in high school classrooms? b) What patterns of interaction emerge as teachers and their learners engage in science talk? and c) What is the quality of the interactions that emerge with science talk?

In the rest of this chapter I locate my PhD study’s methodology within the ICC Project design and then proceed to explain my data collection methods and instruments, the nature of the data that I collected and I close with a brief discussion of my analytic tools. When I joined and registered for my PhD study the Project had already been running for over a year and baseline or benchmark data had already been collected and analysed. The study commenced with an intervention (teachers workshops on science talk) and proceeded to implementation and data collection on science talk.

3.2.1 Teachers’ workshops

During the first year of the study a series of workshops on science talk were conducted under the auspices of the ICC Project. Grade 10 - 12 science teachers from township schools were invited to participate in a series of half day workshops run over a period of one year. The aims of the workshops changed as the project progressed. Initially the workshops were used as a forum to introduce teachers to the ICC Project aims and objectives and within that context both teachers and Project researchers would then explore teachers’ (and learners’) challenges with implementation of the new curriculum. The next step would be to identify teaching and learning strategies to focus on as a team. Three key concepts were identified, argumentation, critical thinking and problem solving and these were to be the focus of the team’s efforts for the duration of the Project. It was in the workshops that the science team decided to focus on argumentation as a teaching and learning strategy to explore in the volunteering teachers’ classrooms. Subsequent workshops became more technical and academic depending on the need and the phase of the Project. The phases of the Project and sequence of workshops are summarised in Fig 3.01. Data for my PhD study was collected in Phases C, E and G of the Project cycle.

The focus of workshop activities was on understanding learner-centredness and how to create interactive classrooms. I drew from local and overseas literature to introduce teachers first to the notion of science talk, and then built up to argumentation. Strategies that could promote

talk in the science classroom were considered, for example, how to stimulate learner participation in whole class and/or small group discussions and how to manage the resultant discussions (Keogh & Naylor, 2007; Simon & Maloney, 2007). We discussed questioning techniques, particularly use of questions like “how? Why? do you agree? Why do you disagree?” We also considered the role of meta-talk and the use of trigger material like prompt posters, concept cartoons, puzzles, short research projects (Braund, et al., 2007; Webb & Treagust, 2006).

To help understand argumentation, we drew largely from the work of Erduran and her colleagues. Discussion topics included the nature of scientific arguments, that is, the need to base decisions on evidence, the ability to justify own opinions and/or a willingness to consider alternative perspectives. We also discussed the structure of an argument starting with Toulmin’s Argument Pattern (TAP) (Toulmin, 1958, 1964) and progressing to its various adaptations for science classrooms (Erduran, et al., 2004; Osborne, et al., 2004) and understanding arguments as relating claims to evidence. For models of argumentation in classrooms we focused on how to design and manage science talk tasks and activities. For example, we considered what tasks would be suitable for the different grades and topics to be covered (Naylor, et al., 2007; Rojas-Drummond, et al., 2001); setting ground rules for discussion (Mercer, et al., 1999a; Wegerif, 2002); how to open and close discussions (Rojas-Drummond & Zapata, 2004; Scott & Ametller, 2007); and how to manage discussions of sensitive issues like socio-scientific issues, IK-related, cultural and ethical issues (Ogunniyi, 2007b; Zohar & Nemet, 2002). Teachers’ opinions varied the most about this aspect of classroom talk and they shared ideas on coping strategies drawn from their cultural and professional backgrounds.

During the course of the workshop interactions it became apparent that I would have to extend the agenda for workshops to an aspect that was not originally part of the Project proposal. Teachers expressed the need to engage with specific science topics which they were not confident with for various reasons, but mainly because these were new topics which they themselves had not been taught at school or college. For this I held two workshops at which I

			A				B		C		D		E		F		G	
Date	June 2006	Aug 2006	Oct 2006	Dec 2006	Feb 2007	April 2007	June 2007	Aug 2007	Oct 2007	Dec 2007	Feb 2008	April 2008	June 2008	Aug 2008	Oct 2008			
Workshops (WS)	WS June 2006				WS March 2007		WS June 2007	WS Sept 2007			WS Feb 2008	WS May 2008		WS Aug 2008				
Co-teaching (CT)					CT	CT	CT	CT	CT		CT							
Data collection for my study							Data July 2007	Data Aug 2007 Data Sept 2007			Data Feb 2008	Data April 2008 Data May 2008		Data Sept 2008	Data Oct 2008			

Note: A-G are project phases, thus:

A: Needs analysis

B: Development of materials, modelling strategies, intensive teacher support and co-teaching;

C: Adapted materials and strategies, intensive teacher support and co-teaching

D: Less intensive teacher support and co-teaching;

E: co-teaching by invitation

F: no teacher support or co-teaching

G: final data collection

Figure 3.01 Timeline for teacher workshops (WS) for the teachers observed and lesson observation and data collection (Data).

invited subject specialists from my university to present on teachers' selected topics. Some of the topics that the teachers requested were, moments of forces, semi-conductors, and the Doppler effect. Interaction during the workshops included working on examples of tasks for each topic and ideas on how to select appropriate tasks for their contexts; how to present the tasks, whether in whole class or small group sessions.

Also during the Project workshops decisions were made about adapting the Project's suggested forms of engagement and suggestions included:

1. Team teaching – teachers teach each other as a group, each doing a topic/area they feel more confident in.
2. Co-teaching – teachers agree to teach each others' classes, again each taking a topic they are more confident in.
3. Peer assisted learning – Grade 12 learners mentor & teach Grade 11s and Grade 11s in turn teach Grade 10s.
4. Integration – within and across disciplines.
 - a. Maths and Science teachers identify linked topics within the discipline
 - b. Maths and Science teachers get together with teachers of other subjects and identify topics that cut across disciplines and agree to teach them at the same time or sequence them for easy progression.
5. Remedial teachers – solicit Department of Education (DoE) to fund remedial teachers to take care of slower learners. Couple this with issues of retention (see below).

Some of the challenges identified during the workshops related to:

1. Multilingualism – recommendations from research and DoE to use teachers and learners' languages in mathematics and science classrooms. The teachers' biggest concern was that the final assessment, the matric examination, is given in English (or Afrikaans) in South Africa and so learners need time to practice the use of English during the lessons so as to be able to articulate their thinking adequately in the final examination. There were also fears that learners may not take the activities seriously if they are done in their home languages as this was not the traditional way of doing science.
2. Teachers felt under pressure to teach to examinations as they are assessed in terms of learner performance in spite of discrepancies in admission policies. Teachers in

schools that do not have a selection policy (for enrolment) are assessed like those in schools that have a selection policy.

3. In terms of the school ethos, teachers' experiences were varied. Some teachers felt that their school administration policies facilitated good teaching and learning, while others felt that it was in fact, the lack of administrative support that made it difficult to try new strategies that might make it easier to implement the new curriculum.

3.2.2 Development of teaching and learning materials

Scott and Ametller (2007, p. 77) noted that teachers who were able to use both “opening up” (dialogic) and “closing down” (authoritative) communicative approaches could initiate and sustain meaningful discussion in their classrooms. Other research in multicultural classrooms in South America (Rojas-Drummond & Zapata, 2004) and recently in South Africa, indicates that learners' “cultural capital” (Webb & Treagust, 2006) is reflected in the discussions generated in class. With these two thoughts in mind we determined to design tasks that would enable teachers to manage communication in their lessons as well as draw as much as possible from what learners already knew from previous grades/lessons and from their diverse cultural backgrounds.

Development of materials targeted selected topics and concepts according to teachers' needs but was guided by DoE curriculum documents, in particular the FET Learning Programmes Guidelines. The targeted topics and concepts were:

- Cells, tissues and molecular studies, and their application in biotechnology e.g. stem cell and cancer research, organ transplants and genetic diseases.
- Environmental studies, with special focus on ecosystems, nutrient cycling and conservation.
- Chemical systems, chemical change, balancing chemical equations
- Organic chemistry

The use of both mainstream science and IK concepts in classroom discussions of the selected content areas was considered. The materials were to include exemplars of activities that promote science talk in the classroom including concept cartoons, prompt posters and jigsaw activities. The next two sub-sections (Sections 3.2.2.1 and 3.2.2.2) are examples of activities

that were designed and later used by teachers in their lessons. Some of the illustrations of science talk in Chapters 5 – 7 relate to these two activities.

3.2.2.1 Example of chemistry activity - small group discussions on reactions of acids.

The task involved four reactions for learners to consider:

Reaction 1	Acid + metal	=	salt + gas
Reaction 2	Acid + metal oxide	=	salt + water
Reaction 3	Acid + carbonate	=	salt + water + gas
Reaction 4	Acid + base	=	salt + water (neutralisation reaction)

Learners work in small groups and groups are assigned tasks as follows:

Group(s) 1: Reactions 1 and 4

Group(s) 2: Reactions 2 and 4

Group(s) 3: Reactions 3 and 4

Instructions to learners:

- agree on the products of each of your reactions
- name the salt formed in each of your reactions
- write out and balance the equations
- all members of the group must participate in the discussion

3.2.2.2 Example of biology activity - small group discussions on indigenous knowledge of owls and conservation.

Teacher's instructions: Have learners in groups and either assign different tasks to different groups or the same task to all groups depending on lesson objectives.

Blurb for distribution to all groups: Owls are useful, harmless birds that occupy an important position on the food chain/web and therefore all members of the community must find ways to introduce owls to environments where they are not already present or to preserve their populations where they already occur.

Possible Task 1 Discuss the statement above.

(The teacher's strategy with this task: provide no information; elicit students' ideas, knowledge, opinions; expose misconceptions; identify beliefs, attitudes)

Possible Task 2

Discuss the statement above considering

- Your personal opinion on owls; Some cultural beliefs about owls
- The local communities' feelings and attitudes towards owls
- What the owl feeds on - the owl's prey
- The owl's position on the food web as both a predator and prey for other organisms
- How the presence or absence of owls may affect the food web (use examples)

(The teacher's strategy with this task: to provoke thinking about conflicting situations; may also expose student ideas, beliefs, attitudes, misconceptions)

3.2.3 The co-teaching model

The co-teaching model was informed by literature coming out of studies in the developed world which suggest that teacher uptake of innovations is implied where there is extended school-based teacher support. Research has identified some features of effective intervention programmes that incorporate teacher professional development. These include duration (programmes must be ongoing), opportunities for individual reflection and group inquiry into practice, coaching and follow up programmes, collaborative engagement with peers, recognition of teachers as professionals and adult learners. Examples from the USA include reports from the work of Garet and colleagues (Garet, et al., 2001; Ismat, 1996) (Garet, Porter, Desimore, Birman, & Yoon, 2001; Ismat, 1996). From the UK, the work of Showers and Joyce (1999) on peer coaching has produced evidence of considerable teacher uptake with systematic support. This is supported by the work of Adey and colleagues (Adey & Shayer, 1994). There was also evidence locally from mathematics research that school-based teacher support improved the chances of teacher uptake of new thinking and strategies (Brodie, 2008; Brodie, et al., 2002a, 2002b)

The co-teaching model was structured along the lines of the CASE methodology (Adey & Shayer, 1994; Shayer, 1999). The UK project, Cognitive Acceleration through Science Education (CASE, 1984-1987) involved collaborative work between teachers and researchers. Its success was largely attributed to sustained collaboration and support provided for the teachers. The model involved joint planning of lessons, post-teaching conferencing sessions for group reflection on video recorded lessons as well as turn taking in delivering the lessons. Teacher support and mentoring was intensive at first but was gradually reduced in

the second year and finally stopped in the third. Teachers were given the choice to use or not to use the strategies in their lessons after that.

3.3 My research methods and data collection instruments

In defining methodology and methods I followed Silverman (2000) who argues that methodology is the broad definition of how one goes about doing the study while methods are specific research techniques. The methods in my study included lesson observations, interviews and field notes as explained below.

3.3.1 Classroom observations

Classroom observation involves getting inside the classroom to look and listen to what teachers and learners do (Hatch, 2002; Stubbs, 1976). As a method classroom observation is well suited to exploring meaning of experiences. Observations require little effort on the part of the participants since they happen as the activity is also happening (Darlington & Scott, 2002). However, the limitation of observations lies in what can be observed. The researcher/observer can only observe the visible social phenomena and none of the cognitive and emotional processes of the participants, that is, why they do what they do and what exactly it means to them. The method is also limited to what is happening currently and none of what has already occurred or will still take place and yet these often have a bearing on what is being observed. Also the presence of the observer impacts the setting and sometimes participants may alter their behaviour because the presence of the observer (Darlington & Scott, 2002). To take these limitations of observation into consideration I combined the method with other forms of data collection. For example, I did not only make recordings of what was happening during the lessons but I also talked to the participants about what they did and why they did it. Since by the time I collected data for my PhD study I had been working with the teachers and their learners for over a year, sometimes on a daily basis for weeks, I was fairly confident that my presence no longer altered their behaviour in significant ways.

Since classroom observation is concerned with moment by moment interactions it is important for the observer to capture the events as quickly and as accurately as possible for re-examination later or for checking and refining interpretations. To do this the observer has to identify and decide on what is worth recording. Thus, observations are subjective,

dependent on the observer. That is, different observers will filter the material to be recorded differently from each other. Also, interactions are transient and unless recorded in some way they cannot be captured again (Darlington & Scott, 2002). For this reason I decided to engage multiple methods of recording my observations and in the initial stages of the project I shared the material with other ICC Project researchers and we compared observations to try and synchronise our filtering systems. I made video and/or audio recordings of lessons, meetings and interviews as well as field notes to capture the more contextual data as explained in Sections 3.3.2 and 3.3.3 below.

3.3.2 *Semi-structured interviews*

Interviews are the most commonly used method for collecting qualitative data (Darlington & Scott, 2002) mainly because they allow the researcher to hear from the participants what sense they make of their own experiences. Interviews are conversations between researchers and the respondents in order to obtain information from the respondents, to follow up on ideas and to probe further or to validate other methods (Gorard & Taylor, 2004; Silverman, 2000). Semi-structured interviews utilise open-ended questions planned in advance and are designed such that the interviewer can probe and encourage the respondent to explain and expand on their answer. This way the interview has both structure and flexibility. Darlington and Scott argue that interviews allow the interviewer and interviewee to negotiate understandings of the context and situation of the phenomena under consideration. Unlike questionnaires, interviews allow for clarification of questions and information by both parties as it is being collected. The latter is a particular strength of semi-structured interviews, which allow for conversational engagement. However, as previously mentioned in section 3.3.1, classroom talk happens in the moment during the course of the lesson and often interviews follow a few minutes or hours later. Obviously what the respondents give as interpretations or understandings of instances of talk during a lesson that has ended cannot be seen as an exact re-enactment of their experience at the time of the talk, which would give a “false sense of access to the past” (Darlington & Scott, 2002, p. 50)

An interview protocol was designed on the basis of my three research questions, that is, one open-ended question was designed to extract data specific to each of my research questions. For each question, a set of follow up, probing questions were compiled from which I would choose during the course of the interview itself (see interview schedule in Appendix 3.01). I

conducted semi-structured interviews of teachers before or after teaching depending on the lesson type, topic or events during the lesson. I wanted to hear from the teachers what their views of science talk as pedagogical and a learning tool were and how they perceived it to be unfolding in their own lessons.

3.3.3 *Field notes*

Field notes are considered to be a less obtrusive way of recording information during observations (Darlington & Scott, 2002; Denzin & Lincoln, 2011). The notes made can provide greater detail and descriptions of settings, physical or social, as well as interpretive notes and follow up questions. I used field notes to record information like date, time of the lesson, whether or not it started and ended on time, if all the learners were in class when the lesson started, and what interruptions took place during the lesson. Where possible I recorded seating plans and tried to make representative diagrams to refer to later as I watched the videos or listened to the audio recordings. I also noted interesting incidents like sudden changes in the classroom interaction or new ways of talking that I had not observed before, or reactions to breaking pieces of apparatus or a learner's mobile phone going off during the lesson. I recorded my own insights and questions that I could not answer or needed to ask the teacher or team members later. A sample of my field notes is given in Appendix 3.02.

3.4 Sampling

3.4.1 *Determining the sample*

Teachers and their classes were selected using purposive sampling, that is, deliberate selection of subjects for a particular reason (Opie, 2004) or to represent a specific population (Freebody, 2003). The teachers I worked with were already participating in the ICC Project. Their subsequent participation in my study was both voluntary (based on the teachers' willingness to participate in my study) and purposive in that only those teachers who showed consistent commitment to attempt the use of science talk as a teaching strategy in their classrooms were approached. My initial misgiving was that my sample might be biased even more by, say, gender imbalances or skewed representation of educational backgrounds and experiences, which would affect the potential richness of information that would emerge from the study. However, the three teachers who finally signed up were of comparable backgrounds and length of service in the teaching profession.

My sampling and data collection was also enriched by my long engagement with the teachers as collaborators in the ICC Project before they were recruited into my PhD study. I had worked with them for more than a year and together we had participated in the workshops, developed teaching and learning materials and co-taught some lessons in their classrooms. We had had the opportunity to critique each other's practice. Because of the long engagement with the teachers I gained a deep understanding of the context in which my study would develop and that the production of rich data.

The sample comprised one male Physical Sciences teacher and three of his classes; one female Physical Sciences teacher and two of her classes as well as one female Life Sciences teacher and three of her classes. It was the teachers' prerogative to decide which lessons I would observe for my data collection. Although I was aware of the potential bias in letting them choose which lessons they wanted me to observe I was sufficiently confident of the collaborative process thus far. All three teachers were at this stage sufficiently confident in the process to call me even on days when I was not due to go to their schools and request that I come in and help them with "difficult" lessons. I had observed several lessons in the three teachers' classrooms since the onset of the Project and I had taught at least three lessons to each of their classes. Freebody (2003) argues that in qualitative research samples are small and difficult to constitute because the researcher is seeking in-depth understandings of selected phenomena. Sampling therefore, becomes context and/or time bound. This was the case with the selection of my teachers and their classes. I sought to understand how science talk played out in those classrooms where it was actually practiced and so my selection was biased towards teachers who showed evidence of willingness to use science talk strategies.

Since my main interest was in how they stimulated and engaged with their learners in science talk I was not restricted by the topics they were addressing at the time. I made audio and video recordings of whole class (and small group discussions, where they occurred). In the final analysis my sample size was not determined only by the number of participating teachers but by the variety of interaction styles in their lessons. Since I intended to analyse all verbal interactions my ultimate sample size would be determined by my unit of analysis. I will revisit this point in Section 3.5.1 when I explain my unit of analysis. In the next section I provide the profiles of the teachers who volunteered to participate in my study.

3.4.2 Teacher profiles

I refer to the teachers as Mrs Thoba, Mr Far and Mrs Nkosi. All three teachers were quite keen to work with me and to try out the science talk strategies we had explored earlier in the Project. For two of them, Mrs Thoba and Mrs Nkosi it was an opportunity to actually try out some strategies that they had been considering and/or trying out already during the course of the ICC Project workshops. Mr Far valued more the support that he and his students received from the collaboration and co-teaching model that the ICC Project used.

Mrs Thoba was a Mathematics specialist who had taught for twenty years in three schools including the one she was in at the time of my study. Three years before the commencement of the Project she had been requested to assist with science teaching at Grade 10 – 12. In the second year of her involvement in the ICC Project she decided to enrol for a Bachelor of Science Honours degree in Mathematics (I was rather disappointed since I had hoped that she might consider enrolling for science education. Since science is not her area of specialization I thought that enrolling for a course in science might help her strengthen her science content knowledge, which was not poor at all. She had a very good grasp of science for the level that she was teaching in and she was quite diligent in reading and researching the topics that she was going to teach. However, she often struggled with some topics and would then appeal to the ICC team for support and further studies could have helped to give her good grounding in science content). Mrs Thoba shared her classes with a colleague who taught all the physics while Mrs Thoba taught all the chemistry to the two Grade 11 and two Grade 12 classes in her school. She then taught both physics and chemistry to one Grade 10 class.

Mr Far was a Physical Science and Mathematics specialist who had been teaching at Physical Science at Grade 10-12 level for 28 years (15 in the current school). However, as early as the first year on the Project his responsibilities steadily increased to include Computer Application Systems (CAT) for Grade 11-12 as well as Mathematics for Grade 7-9. He was also the Head of Departments (HoD) of Science and Computer technology and also sat on the school's Senior Management Team (SMT) in which he did a lot of administrative work as discussed in Section 5.1.3. His school was in a transition, changing from Afrikaans to English language as the medium of teaching and learning. Mr Far was bilingual and said that most of his learners were too. He was quite comfortable teaching in English although he still taught some of his classes in Afrikaans because "they struggle with English". Learners had the

option to take their examinations in English or Afrikaans. I only worked with him in those classes where the medium of communication was English. Mr Far's highest qualification was a Master of Education degree following an Honours degree in Science Education and Mathematics.

Mrs Nkosi had 25 years teaching experience, eight of which she taught Life Sciences. She was one of four Life Sciences (Biology) teachers in a school with an enrolment of about 1500 learners, about the same size as Mrs Thoba's. She did not only teach Life Sciences but also taught Natural Science to two Grade 8 and two Grade 9 classes as well as Life Sciences to two Grade 11 and two Grade 12 classes. She also taught Life Orientation at Grade 10 – 12. Mrs Nkosi held a Bachelors degree in Life Orientation with a minor in Natural Sciences which she had obtained following a Higher Diploma in Education obtained after an initial three year teaching certificate before 1994. When she took on Life Sciences teaching she studied for the Advanced Certificate of Education (ACE) which was her highest qualification in Biology when she volunteered onto the project. During the course of the Project she enrolled for another ACE programme with specialisation in Life Science education so as to proceed to an Honours degree in Life Science education. She was HoD for Life Sciences as well as member of the Senior Management Team (SMT). Probably because of her Life Orientation training, Mrs Nkosi held a few other positions in the school including sitting in the HIV/AIDS, disciplinary and weekend tuition committees. All these duties were assigned over and above her quite heavy teaching load.

3.5 Analysis of data

3.5.1 *The analytic tools*

Literature identifies a variety of approaches to classroom interaction analysis depending on the purpose and theoretical base of the study. These in turn influence the methodology and depending on their logic, studies look in different places for classroom interaction and/or focus at different features of the interactions (Bodner & Orgill, 2007; Darlington & Scott, 2002). My data analysis was guided largely by Mortimer & Scott's (2003) framework for analysis of classroom interactions as well as models of argumentation, in particular Erduran et al's adaptation of Toulmin's (Erduran, et al., 2004; Toulmin, 1958, 1964). Mortimer and Scott's model was useful in the analysis of how teachers stimulated learner participation and how it played out in their varied contexts. I used the model to determine teacher

communicative approaches and the resulting discourse patterns while the argumentation theories helped me determine the nature and quality of teacher-learner and learner-learner engagement.

I engaged in an iterative process of data collection and analysis at the beginning of the study and as the data built up I engaged in more focused coding and memoing so as to determine themes from the data. Attaching codes to sections of data is a form of data reduction and transformation. It is a classification process that creates named sets of segments of data that are more manageable and can later be retrieved or further analysed (Miles & Huberman, 1994). Memoing is defined by Silverman (2000) as the record of analysis, thoughts, questions and interpretations of the data. Memos helped me extract and keep a record of thoughts and ideas to be used later to come up with conclusions from my findings.

3.5.2 *The unit of analysis*

Since the main interest of my study was to understand patterns of science talk, all speech produced during discussions of the selected lessons was the focus of my analysis and thus, the unit of analysis. As will be explained in Chapter 4, episodes of science talk were identified as sections of the discussions focusing on a specific activity or aspect of a concept. This method is consistent with that used by Rojas-Drummond and Zapata (2004) in the analysis of exploratory talk by primary school learners in Mexico and that of Mortimer and Scott (Mortimer & Scott, 2003; Scott & Mortimer, 2005) with learner discussions in Brazilian and the UK high school science classrooms. Mortimer and Machado (2000) used what they called classroom episodes as the unit of analysis and identified verbal interactions in each unit. To determine the quality of the science talk I identified and characterised arguments in different science talk episodes using the components of arguments as defined in the TAPping analysis techniques as codes (Erduran, et al., 2004). In this case, the science talk episode was the unit of analysis at the macro level while the argument was my unit of analysis at the micro-level. This reiterates the point I made in Section 3.4.1 that when the unit of analysis is considered the sample size changes considerably so that although mine was a case study of three teachers it was actually a sample of all talk episodes, which translates into a much larger number than the three teachers concerned.

3.6 Rigour in the research

3.6.1 *Validity and reliability*

According to Silverman (2000) validity is another word for truth – the extent to which an account accurately represents the social phenomena to which it refers, while reliability is the degree of consistency with which instances are assigned to the same category by different observers or by the same observer on different occasions. A method is therefore, not valid if it always misses the target although it always gives the same results. A method that is not reliable on the other hand, hits the target only some of the time. There is too much scatter of the data points. In qualitative research design validity and reliability are replaced by terms such as credibility, transferability, dependability and conformability (Hatch, 2002).

In reporting qualitative research findings the temptation sometimes arises to exclude contrary cases and give a few exemplary cases (well-chosen examples) and researchers seldom give criteria or grounds for including certain instances and not others, they simply choose for representativeness of instances and their findings. Hence method and data triangulation or respondent validation is suggested to ensure trustworthiness and credibility (Miles & Huberman, 1994; Silverman, 2000). Triangulation is defined by Silverman (2000) as an attempt to get a true gaze on a situation by combining different ways of looking at it or different findings. I used Silverman's definition of triangulation in combination with Gorard and Taylor's view that triangulation cannot be used as a form of mutual confirmation or validation of the different methods. Rather "it is about complementarity, and nothing at all about mutual validation. The two observations or methods must be directed at different aspects of the wider phenomenon to be investigated" (Gorard & Taylor, 2004, p. 45). I used the different data collection methods (e.g. lesson observations, interviews and field notes) to complement each other to enhance the trustworthiness of the analysis by a fuller, more rounded account. Also, to check the validity of my methods I had an independent researcher use my analytic tools on similar samples of data to see if they produced similar results to mine (see samples of inter-rater analyses in Appendices 3.03 - 3.06).

3.6.2 *Respondent validation or member checking*

The collaborative nature of my study made continual respondent validation or member checking possible (Bodner, 2007). The teachers and I were able to review and reflect on emerging trends, themes and/or arguments as the lessons were analysed. In some cases this

necessitated a re-examination of the episodes or whole lessons to refine my observations in light of the teachers' reactions. Often evidence emerged that seemed to lead in an interesting direction and the teachers were able to provide a context or alternative view that may not point in the same direction. Silverman refers to this as the refutability principle (Silverman, 2000), a need to be conscious of how knowledge is always provisional and so avoid the temptation to jump to conclusions just because there is interesting evidence.

Silverman (2000) recommends subjecting data to repeated tests and analyses, the constant comparative method. In this method of validation the researcher must always find another case through which to test out the provisional hypothesis, that is, begin analysis on small parts of data and generate categories and use them to test out emerging hypotheses as data extends. This is challenging if all parts of data will finally be inspected and analysed. However, in my case the collaborative nature of the project as well as the iterative approach to data collection and analysis made it possible to work from small chunks of data to progressively larger ones as more data was collected.

3.7 Ethical considerations

One of the challenges of qualitative research studies is the dual aim of on the one hand, engaging in the academic development of knowledge and on the other delivery of service (Freebody, 2003). In the case of my study one could argue that there were in fact three goals: teacher support and professional development (delivery of service) within the curriculum implementation context; the ICC Project objectives and responsibilities to EdQual and DfID, the donor organisations; and an academic qualification, my PhD study. As Freebody observes, working at the interface of these goals has significant ethical implications in terms of the blurring of boundaries of researcher, practitioner and student roles as well as in terms of the participants' roles. The research "process is shaped by the interests and relative power of the various stakeholders" (p22) and in my case, the EdQual and thus ICC Project timelines, the requirements and expectations in terms of the DfID funding, my responsibilities as the ICC Project science researcher, the University of the Witwatersrand timelines for PhD students, teachers' expectations and workloads all combine to shape the process. Several measures were put into place to manage the implications of this interface, including applications for permission and ethics clearance from both the Gauteng Department of Education (GDE) and the University of the Witwatersrand's Ethics Committee. The results

of this study have been communicated to the schools on an ongoing basis and will also be made available to the University (in the form of this PhD thesis), to the GDE and the ICC Project sponsors (by copy of the thesis). Also, various stages of the PhD process have been presented for discussion in PhD weekends organised regularly by my university for students to present their work in progress for peer review. Further, some of the findings have been presented at local and international conferences on science education as well published in peer reviewed journals (see list of publications and presentations from my PhD study in Appendix 3.07)

3.7.1 Ethics clearance

In terms of the legal and ethical considerations stipulated for research involving human subjects I applied for and obtained ethics clearance from the following bodies:

- Human Ethics Research Committee (Non-medical) of the University of the Witwatersrand. See clearance details in Appendix 3.08.
- Gauteng Department of Education (GDE) – since the research was conducted in schools within Gauteng (Appendix 3.09)
- Administrators of the schools in which the teachers and learners volunteering onto the research were practicing (Appendix 3.10).

3.7.2 Participant information

Further, the participants (both teachers and learners) were informed beforehand of the purpose of the research and how the data would be collected. Participants' informed consent was sought for the use of the audio and video recordings for purposes of data analysis for my research and for other academic purposes including conference presentation (See Appendices 3.10 – 3.15). I also assured them that the material would be stored according to stipulated regulations of the University and that the data, including audio and video tapes would be destroyed after the five years stipulated by the University.

3.7.3 Confidentiality and communication of findings

It is not always easy to ensure confidentiality in qualitative research (Freebody, 2003; Miles & Huberman, 1994). Although the intention may be to disguise case data so as to protect the identity of the setting and participants it may not be possible to disguise them completely especially from those who are familiar with the contexts in which the study was conducted.

My study was conducted in Soweto, a well-known township in Gauteng and some of the surroundings in which I worked may be familiar to some local and international prospective readers of this thesis. Be that as it may, I made every effort to ensure confidentiality and protection of the identities of the teachers and learners in my study. For instance, I have used pseudonyms for the schools and teachers themselves.

It has been suggested that another way of ensuring confidentiality might be to disaggregate data from cases and report it in bits and pieces at different stages of the thesis (Freebody, 2003). Freebody is quick to state that while this would increase the disguise of participants it may defeat the purpose of showing the holistic picture of the research findings.

A further ethical risk is in the inability of the researcher to control the ultimate use made of the final published reports from the study by others. This creates a tension between the need for the researcher to be selective of what to make public and the need to “disseminate the voices of those previously unheard in the public domain in ways in which privacy is protected” (Freebody, 2003, p. 30). To this end as selected data sets are used in conference presentations, journal publications and other public dissemination formats, the identity of the schools, teachers and learners will always be protected through the use of pseudonyms.

3.8 Chapter summary

In this chapter I set out to provide a detailed description of my research design and methodology. I defined methodology broadly after two authorities, Freebody and Silverman first, as how I went about doing my study and secondly, as an indication of the frameworks for the conduct of my study. With these definitions in mind I first provided a brief discussion of the theoretical foundations of my study and then showed how my research design links to the theory provided. I then identified the participating schools and teachers and justified their selection for participation in my study. I also showed how my design was influenced by the bigger project, the ICC Project in which my study was located. I linked the data collection methods that I used with my research questions and described the nature of the data that I collected. Further, I discussed how I handled issues of validity and reliability as well as ethical considerations in my data collection, analysis and dissemination.

I continue the discussion of my data analysis and analytic tools in Chapter Four where I show in greater detail how the two models were adapted for my data analysis. I refer to Mortimer and Scott's model for the analysis of teacher-student classroom interactions and meaning making as well as the TAP (Toulmin's Argument Pattern) model for argument construction and show how I used each to analyse different sets of data to answer my three research questions.

Chapter 4

My data analysis tools and data summaries



http://www.nytimes.com/imagepages/2010/03/07/magazine/07Teachers-t_span.html

4.0 Introduction

This chapter provides a description of the tools that I used to analyse my data and how I used them. First, I explain how theory shaped my thinking about both my data analysis and my decisions on what to foreground or background in the process of data analysis. I explain how I drew from two models for analysis of verbal classroom interactions; Mortimer & Scott's (2003) framework for analysing classroom interactions and argumentation theories as used in some UK, USA and South African classrooms (Berland & Reiser, 2008; e.g. Erduran, et al., 2004; Ogunniyi, 2007b). Then, I explain how I developed my analytic framework and analytic tools from these two sets of theories to suit the context of my study. Also how my analytic framework relates to my research questions and how it helped me select relevant data to answer the questions. Finally, I give a brief summary of the data that I analysed as well as an outline of how I used my analytic tools to analysis and interpret my data.

4.1 Background information about my study

As noted in Chapters 1 and 2, the main aim of my study was to investigate the use of science talk as a teaching strategy to stimulate student participation and engagement in science lessons. I defined science talk as all science related verbal interaction between the teacher and students or among students during a science lesson (Chapter 2, Section 2.1.1). I explained how I viewed science talk as both a teaching strategy and a tool for learning science. Therefore, my focus was on how teachers stimulate and shape science talk in their classrooms. However, I could not know this for sure unless I looked at what the students then did in response to teacher interventions. My analytic tools targeted both the teacher's

activities involving talk as a teaching strategy and the students' responses as evident in the way they used (or did not use) talk to construct meaning. Thus, in line with the definition of my unit of analysis as the "collective activity of a group of adults and children" (Section 2.3.2) or "all speech produced during discussions of the selected lessons" (Section 3.5.2.) I analysed all teacher-learner and learner-learner utterances in the lessons observed. To do this I categorised the science talk into episodes, identified as sections of the discussion focusing on a specific activity or aspect of a concept. I took cognisance of the fact that the verbal interactions I was targeting happened within semiotic, linguistic and conceptual contexts. By this I mean that the interactions took place within established classroom cultures or in specific ways of engaging socially or through established language patterns and were intended to address specific topics or concepts. As Bakhtin argues (quoted in Mortimer & Scott, 2003), words are not non-contextual. They derive their meaning from the contexts in which they are uttered, in that they relate to other words said before or after them, or to gestures and body language or voice intonation. However, because I was interested more in whether and how science talk was used and also because of the scope of my study I had to make decisions to foreground only the verbal interaction and background the gestures, intonation, pitch and other linguistic and semiotic factors.

In my data analysis I sought to do three things: to identify and describe teachers' interventions that stimulated learner talk; to determine patterns of teacher-learner interaction as seen from learner responses elicited by the teacher interventions; and to characterise the resultant process of negotiating understandings of scientific concepts.

My data analysis model derived from both Mortimer & Scott's (2003) framework for analysing classroom interactions as well as from argumentation theories, particularly the TAPping model by Erduran and colleagues (Erduran, et al., 2004). While the Mortimer & Scott's model was informed to a large extent by similar classrooms in the developing world in Brazil, it has never been used in South African classrooms its use in my study was thus exploratory of its potential in analysis of classroom interaction in South African contexts. Argumentation theories, on the other hand, have recently been adapted for use in South Africa, first with trainee teachers enrolled at tertiary institutions for formal teacher professional development and later with these teachers' students in high school classrooms (e.g. Braund et. al., 2007; Ogunniyi, 2007; Scholtz et. al., 2004). However, I used the theory

of argumentation for the first time in South African in classrooms where the participating teachers were practicing teachers who were not enrolled for any study programme when they joined the project. I now explain how I drew from Mortimer & Scott's framework a tool to identify and describe the classroom verbal interactions and from argumentation theories a tool to determine the nature of those interactions.

4.2 How my analytic framework is informed by Mortimer & Scott's (2003) model

Mortimer and Scott's model was appropriate for identifying evidence of teacher use of science talk to foster student talk because it is premised on the central role of the teacher's communicative approach as she intervenes and shapes the classroom interactions in order to achieve specific teaching purposes and cover the intended content of the lesson. The emerging patterns of discourse describe the action of the classroom; how the teacher and student interaction plays out.

For the purposes of my data analysis I drew from four aspects of the model; the *teaching purposes*, *teacher interventions* and how they help shape the *communicative approach* and the nature of the resultant *discourse patterns*. Since the content covered in the lessons I analysed was varied, I described the content for each lesson as I went along. Also, since I did not intend to compare the effect of talk on how different types of science content are learned I decided not to focus on this aspect of the model in the analysis itself. I draw on the content aspect to help me interpret the emerging trends from my data.

As described in Chapter 2 Mortimer and Scott's model distinguishes dialogic from authoritative teacher communicative approaches and characterises patterns of communication resulting with each teacher approach. Communication is Interactive-Dialogic (ID), Interactive-Authoritative (IA), NonInteractive-Dialogic (NID) or NonInteractive-Authoritative (NIA) (Figure 2.03, Chapter 2). Since my interest was in determining whether lessons were interactive and whether discourse tended to be dialogic, the ID and IA aspects of the model were useful for describing the nature of the interactive and/or dialogic interactions. The teacher interventions that produced each communicative approach could be used to characterise the interaction in each lesson. By examining emerging patterns of teacher-student interaction I would be able to determine the structure of student participation and the patterns of teacher's intervention that produced it.

The challenge was in determining an appropriate list of codes to use to characterise the teacher interventions and the resulting patterns of interaction. Like all models described in published work, the details of the actual coding are not always available to the reader. In describing their model in various publications Mortimer and Scott only list the teacher interventions that are likely to produce each of the four communicative approaches. They then illustrate the approaches using talk episodes from the lesson and for each episode they provide a general analysis of what the teacher and students were doing in relation to the overall teaching purpose. The excerpt and quotation below from one of the published articles illustrating the model demonstrate how the teacher's approach in this particular episode was identified as interactive/authoritative:

"1. Let's just ignore the sparks..."

Teacher: Do you remember the electric bell?

Students: Yes! [*in chorus*]

Teacher: OK! Did any of you notice, did any of you actually hold onto the bell after it had...been working? What did you notice?

Suzanne: Vibration

Teacher: Well, the arm vibrated, yes. Sound. What else did you notice?

Tom: It was loud.

Teacher: That's not quite what I'm getting at. Remember the bell. There's the bell [*holding up a bell in front of the class*]. You did the experiment. If you held onto this bit here where the wires were [*indicating*], did you notice anything there?

Jason: There were sparks there.

Teacher: Heat, did you notice some heat?

Jason: There were sparks from there.

Teacher: There were?

Jason: Sparks.

Teacher: There were some sparks, yes. Let's just ignore the sparks a minute...some heat. There was a little bit of heat there with that one.

In this sequence, it is clear that the teacher is focusing his attention exclusively on the production of heat by the electric bell. He reminds the students about the activities of the previous lesson, and asks, '*What did you notice?*' Suzanne replies with a single word, '*Vibration*'. The teacher acknowledges her answer, '*Well, the arm vibrated, yes. Sound*'. It is clear, however, that this is not what the teacher wants to hear and he moves on, discounting in turn the students' suggestions, '*it was loud*' and '*there were sparks*'. This is an *authoritative interaction*, where the teacher's sole aim is to arrive at the idea that the bell heats up as it is working. The teacher's interventions are based on instructional questions for which he has in mind only one answer. If the students do not come up with the required answer, their suggestions are put to one side: '*That's not quite what I'm getting at*'; '*Let's just ignore*'. The students' contributions are limited to single brief assertions '*vibration*', '*it was loud*', '*there*'

were sparks’, made in response to the teacher’s questions. This kind of interaction, where the teacher leads students through a sequence of instructional questions and answers with the aim of reaching one specific point of view, is typical of an interactive/authoritative communicative approach” (Scott & Mortimer, 2005, pp. 398-399)

Clearly, the description in the quotation of the teacher-learner interaction in the excerpt was an interpretation of an analysis that is not reported in the article. To be able to perform my own analysis I had to compile a set of codes by inferring from such excerpts. This was important too for purposes of validation and/or repeatability of my methods. Initially I thought I would use the indicators of teacher interventions as codes for the analysis and I therefore, extracted and tabulated all the indicators from various publications by the authors (see Table 4.01). Then I realised that some teacher interventions were indicated in more than one communicative approach and could not therefore, be used to distinguish between the communicative approaches. For example, in Table 4.01 under “Indicators for possible teacher interventions” (in the second column from the right) the teacher action “Shaping ideas” is listed for all four communicative approaches. The distinction seemed to depend on what other actions it was combined with or what teaching purposes the teacher was targeting.

I had to decide on those indicators that were most specific to each communicative approach and could thus be used to characterise the approaches. I used the codes derived directly from the Mortimer & Scott model deductively for a first parse of the data. The rest of my codes were derived inductively from the data as descriptions of those emerging trends that were not described in Mortimer & Scott’s list of indicators (See Table 4.02).

A few indicators (now codes) that were unavoidably similar for more than one communicative approach were maintained for both and identified as 1 or 2 respectively. It seemed to me that they served different purposes in each case. For example, in Table 4.02 the code T explains appears in both the IA and the ID communicative approaches. In the IA communicative approach it is designated T explains1 which refers to the teacher’s explanation of a student’s own idea for the benefit of the rest of the class while in the ID communicative approach a similar intervention codenamed T explains2 refers to a conventional scientific or textbook explanation.

Table 4.01 Indicators of the aspects of Mortimer and Scott's model used to characterise teacher-learner talk in lesson transcripts

Descriptions of Teacher communicative approaches		Possible discourse	Indicators for possible teaching purposes		Indicators for possible teacher interventions	
Approach	Description		Teaching purpose	Indicators	Intervention	Indicators
Interactive-Dialogic	Teacher and students explore ideas, generate new meanings, pose genuine questions, offer, listen to and work on different points of view	IRE/IRF IRFRFRF IRPRPR...E IRPRPR- IRRR-	Opening up the problem	Engaging learners mentally in initial development of Sc story	Shaping ideas	New term
			Exploring and probing students' views	Probing learner's views and understanding	Sharing ideas	Paraphrasing
			Introducing and developing the scientific story	Making meanings available in social plane of classroom	Checking student understanding	Repeating student ideas
			Guiding students to apply, and expand on the use of the scientific view and handing over responsibility for its use.	Providing opportunities to talk and think individually, in groups or whole class. Learners apply new meanings in various contexts; take responsibility for using the new meanings		Probing Asking for clarification
Non-interactive-Dialogic	Teacher considers various points of view, different perspectives	Lecture	Introducing and developing the scientific story	Making meanings available in social plane of classroom	Shaping ideas	Differentiate Return to ideas, summarise, recap previous lesson
			Maintaining the development of the scientific story	Comment on the Sc story, fit into science curriculum	Reviewing	
Interactive-Authoritative	Lead students through questions and answers to specific point of view	IRE/IRF or IRFRFRF IRPRPRE IRPRPR- IRRR-??	Opening up the problem	Engaging learners mentally in initial development of Sc story	Shaping ideas	New term
			Introducing and developing the scientific story	Probing learner's views and understanding	Sharing ideas	Paraphrasing Repeating student ideas
			Guiding students to work with scientific ideas and supporting internalisation	Making meanings available in social plane of classroom	Checking student understanding	Probing Asking for clarification
			Maintaining the development of the scientific story	Comment on the Sc story, fit into science curriculum	Reviewing	Differentiate Return to ideas, summarise, recap previous lesson
NonInteractive-Authoritative	Pursue only the scientific view	Only teacher voice	Developing scientific story	Presenting one view of the concept	Telling	New term Expalin Differentiate Summarise, recap

(From Mortimer & Scott (2003, pp. 28-45) and Scott et. al.(2006, pp. 609-613)

I used the codes in Table 4.02 to characterise teacher utterances in ATLAS.ti. Next I formed each set of codes (teacher interventions) into a Code Family named after the communicative approach that they described. By using the “Use as a filter” function in Code Manager mode, I was able to map out the distribution of the communicative approaches on a timeline of each lesson.

Table 4.02 List of all codes used as indicators of teacher communicative approaches.

Approach/Code family	Description of approach	Indicators of approach (T = teacher; S = student/learner)
Interactive/ dialogic	Teacher and students explore ideas, generate new meanings, pose genuine questions, offer, listen to and work on different points of view. The teacher checks student views and/or understanding (of multiple views under discussion).	T accepts correction by S T asks open ended question T asks S to repeat own idea T explains1 T laughs / T light talk T paraphrases1 T probing T repeats S response1 T summarises1 T inclusive (we, us, our)
Interactive/ authoritative	Teacher leads students through questions and answers to specific point of view. The teacher checks student views and/or understanding (of the targeted scientific content or perspective).	T affirms T asks closed question T asks S to repeat T asks for S questions T checks consensus T checks progress so far T directs T explains2 T gives cue T over looks T paraphrases2 T probing T recaps T redirects T refocusing T repeats S response2 T returns to idea2 T summarises2

Analysis using the codes in Table 4.02 targeted my first research question which focused on the way teachers guided the development of talk in the classroom. I now give three examples of how I used this analytic tool to analyse my data

4.3 Examples of how I used my analytical model to determine teacher-student interactions

4.3.1 Example 1: Interactive-Dialogic communicative approach

The excerpt in Table 4.03 is an example of an Interactive-Dialogic teacher communicative approach. This was an introduction lesson in a series of Chemistry lessons on “Chemical

Systems” and prior to this excerpt learners had been talking in groups of four about different terms the teacher had put up on the board, that is, “System”, “Cycle” and “Global”. They were to answer the question “What comes to your mind when you hear the word.....?” and all the students’ ideas (everyday knowledge of the terms) were captured and put up on the board. In the excerpt below the teacher and students had just finished an episode on defining a system. The class was now moving on to define global cycles as types of chemical systems.

Table 4.03 Example of Interactive-Dialogic communicative approach – From transcript of lesson on Chemical systems in Mrs Thoba’s Grade 10 class

T-S turns in the excerpt		Code for communicative approach
86	T: Ok. Now we come to our Global cycles, then. So, in a way we are saying our Global cycles are systems that are in operation. Yes?	T inclusive (we)
87	Ss: Yes	
88	T: But what are they? What are these Global Cycles? First of all ... C-y-c-l-e. What does it mean to cycle? What is your understanding of cycle? What comes to mind when you see the word “cycle”? What ... one thing that immediately comes to mind. ... Let’s see if we can get different hands.	T asks open question T asks open question
89	T: Yes gentleman ... cycle... cycle... what do you think of when I say “cycle”? Anything that comes to mind	
90	S1: (inaudible)	
91	T: You think of something like... he says when ... when he hears “cycle” he thinks of something like a circle ... that’s what he thinks about. What comes into mind when you hear of “cycle”? Yes Maam ...	T paraphrases1
92	S2: A procedure whereby something is continuous	
93	T: Ahah. A procedure where something is continuing and continuing and continuing. Yes, Sir	T paraphrases1
94	S3: What goes around comes around	
95	T: ok (General laughter)	
96	T: Right, so we all agree that cycle has to do with ... (moving hand around in a circle)	T inclusive (we)
97	Ss: Continuous	
98	T: ... continuous. Like a circle ... no start no end ... continuously. Ok, and so we are looking at Global Cycles. “G-l-o-b-a-l” what do we mean there? Global ... global? Yes, Sir	T repeats S response1 T paraphrases1 T inclusive (we) T asks open question
99	L2: Around us	
100	T: Around us. Ok, he says around us. Yes, Sir	T repeats S response1
101	S3: In the world	
102	T: In the world. Yes, Sir	T repeats S response1
103	S4: All the earth	
104	T: All the earth. Yes, Sir ... G-l-o-b-a-l?	T repeats S response1
105	S5: Global is ... er ... map of the world	
106	T: Ok, he thinks of the map of the world. G-l-o-b-a-l?	T paraphrases1
107	S6: Nature	
108	T: Nature ... ok, anything else about Global?	T repeats S response1
109	T: Ok, so we all seem to agree that when we talk of Global cycles, we are talking about a c-o-n-t-i-n-u-o-u-s process ... continuous process on earth. It has to do with continuous ... it has to do with the earth.	T inclusive (we) T summarises1

In turn 86 on Table 4.04 the teacher set the tone of the discussion by adopting an Interactive-Dialogic communicative approach. It was interactive in that both teacher and learners talked and it was dialogic in that the ideas of both parties were considered. She indicated to the learners that this was a dialogic phase by using inclusive terms like “we must keep them in mind as we look at our Global cycle”. This implied that the learners and teacher would engage as “equals” in this phase of the talk – multiple perspectives would be explored. The teacher would not draw on her authority as a teacher nor as a scientist but would engage with learners’ ideas. This was evident in most of the discussion that followed, turns 86-95 and then also in turns 99-108. The students’ ideas were captured mostly without modification except just repeating or paraphrasing them. The teacher’s focus was not on the scientific story yet but on capturing student thinking for later use in developing the scientific idea of a Global cycle, although she guided student thinking and made links between the concepts, as in turns 96-98 and 109. For example, in turn 98 she repeated and then paraphrased a student’s response and then moved the discussion from “cycles” to “global” stating “... *Like a circle ... no start no end ... continuously. Ok, and so we are looking at Global Cycles. “G-l-o-b-a-l” what do we mean there? Global ... global?*”.

In the next example I illustrate the Interactive-Authoritative teacher communicative approach.

4.3.2 Examples 2: Interactive-Authoritative communicative approach

The Interactive-Authoritative teacher communicative approach illustrated in Table 4.04 took place within a discussion in which the teacher had been taking a largely Interactive-Dialogic in the same chemistry lesson as described in Example 1 above. The learners had put up their diagrams of the water cycle (as an example of a Global cycle) on the board and they were to now identify the three characteristics of a system in the water cycle. At this point there was disagreement on whether the diagram should have both a dam and an ocean. The teacher then took an authoritative stance, funnelling the ideas towards consensus on inclusion of all water bodies in the water cycle. At the same time she allowed the students to advance their own thinking about the problem and thus maintained some of the dialogic mode of the talk.

Table 4.04 Example of Interactive-Authoritative approach from transcript of the lesson on Chemical systems in Mrs Thoba's classroom

Teacher student turns in the excerpt		Codes for T communicative approach
197	T: We cannot have an ocean and a dam in the cycle. Why?	T repeats S response1
198	S7: They do the same job.	
199	T: Because they do the same job, he says. They all keep water. Ok.	T repeats S response1 T paraphrases/T affirms
200	Ss: Yes	
205	T: Is there evaporation in the ocean, at all. Does evaporation happen in the ocean?	T asks question T probing
206	Ss: (Commotion)	
207	T: Hang on Guys hang on let's have your attention. He is talking to us. Yes, Sir?	
208	S8: Because from the sun the sun heats the water the ocean then the water rise up to the sky ...	
209	Ss: (Commotion)	
210	T: Hang on hang on. Does the sun heat the ocean?	T asks closed questions
211	Ss: Yes ... no	
212	T: Does the sun heat the dam?	T probing ; T cue
213	Ss: Yes	
214	T: Does the sun heat the river?	T cue
215	Ss: Yes	
216	T: Does the sun heat your reservoir with water?	
217	Ss: Yes	
218	T: Does the sun would the sun heat my beaker of water if I left it outside? (<i>T holds up beaker</i>)	T cue
219	Ss: Yes	
220	T: So the sun would heat all of them?	
221	Ss: Yes	
222	T: When the sun heats the water what happens to the water?	T cue
223	Ss: Evaporation	
224	T: When the water evaporates from the ocean, does the ocean tell the river not to evaporate?	
225	Ss: No ... (Laughter)	
226	T: Hang on can water evaporate from both the ocean and the river and my beaker at the same time?	T cue
227	Ss: Yes	
228	T: Ok so we can have evaporation from all of them at the same time?	T seeks consensus T inclusive (we)
229	S: yes	
230	T: So, we can have all of them in the diagram	T summarises1
231	Ls: (Commotion) ... yes ... no	

The episode started with the teacher repeating a learner's response which had been accepted in the previous ID episode but was now being questioned and presented for discussion. To do this she took up an IA communicative approach. In response to S7's response that these water bodies all did the same job the teacher asked a series of closed, leading questions meant to guide the learners to a specific understanding as intended by the teacher. She offered cues and made the questions simpler and was clearly funnelling until the class "saw" the teacher's

point in turns 225 as they all laugh together. Then the teacher drew in some of the learners' ideas to make her point in turn 230.

4.3.3 *Example of Interactive-Authoritative communicative approach and its discourse patterns*

The next example illustrates another episode of IA communicative approach with instances of teacher telling which resembled the NonInteractive-Authoritative (NIA) communicative approach (Table 4.05). for the most part the teacher asked closed questions with one or a small range of acceptable answers. She was in fact engaging in some formative assessment to determine how much of the targeted content the learners already knew or could remember from previous lessons. Although she tended to repeat student responses she seemed to be doing something different from what she was doing in Table 4.04. By repeating learner responses the teacher in Table 4.04 was in fact affirming the respondents and confirming the acceptability of the answer or science knowledge presented by the speaker, whereas in the

Table 4.05 Example of Interactive-Authoritative communicative approach Version2 – From transcript of Mrs Thoba's lesson of 20May2008

Teacher-student turns in the excerpt		Codes for Tr communicative approach	Codes for pattern of discourse
25	T: Ok let us talk about energy changes during covalent bonding Ok what do you think are the types of energy that are going to take place during this bonding?	T closed question	I
26	S4: kinetic energy	T repeats S response2	R
27	T: Kinetic energy what is kinetic energy?	T asks closed question	E, I
28	S4: (inaudible)	T repeats S response2	R
29	T: The energy of the body by virtue of its movement... Please speak loud ... ne? Ok ...What else?...What else?...	T probing	E
30	S5: I think ionisation energy	T repeats S response2	I
31	T: Ionisation energy...what is ionisation energy?	T focuses (looks like probing)	R
32	S5: Ionisation energy is the energy required to remove an electron...	T repeats S response2	F
33	T: Energy is the energy required to remove...an electron...remember we are talking about covalent bonding. No electrons are removed in covalent bonding but electrons are...shared. Do we understand each other there?	T refocuses	
		T checks consensus	I
34	Ss: Yes	T summarises	R
35	T: So ionisation energy...does not apply to covalent bonding		F

excerpt in Table 4.04 she was merely indicating that she accepted student responses. In Table 4.05 the teacher also did what I call focusing and refocusing. In focusing she drew attention to a wrong answer (Turn 31) while probing the learner's thinking. She then asked some leading questions for the learners to resolve the error themselves, whereas in refocusing (Turn 33) she guided the discussion back from addressing an error to the original point of discussion. Finally she checked for consensus. Because her goal was to get across a specific scientific story she checked to see if the students had actually "got" the story. Thus turn 33: "Do we understand each other there?" followed in 35 by a summary or review of what it is that they should understand each other on, "So ionisation energy...does not apply to covalent bonding".

For my second research question I needed to construct sequences of teacher-student turns so as to determine the patterns of discourse. I coded all teacher and student turns as Initiation, Evaluation, Feedback, Probing (the I, E, F, P) moves by the teacher or Responses (R) by the learners. In Table 4.05 above the discourse pattern was in the form IRE/IRF throughout. This is typical of the IA communicative approach in which the teacher's focus is developing the scientific story, guiding learners to a specific view of the content under discussion.

4.4 Analysis of the nature of teacher-learner, learner-learner interactions: Determining argument construction

In my third research question I sought to understand the nature and quality of the interactions by characterising argument formation. I wanted to see how teachers might model argumentation, as well as whether and how students then constructed and/or supported their own and other's arguments. To do this I used Erduran's model of Toulmin's Argument Pattern (TAP) (Erduran, et al., 2004) as explained in Chapter 2 (Section 2.6.1 and 2.6.2). I used the argument components as codes in characterising arguments in the discussions. That is, the claim, C (an assertion or conclusion); evidence that supports the claim, D (data, scientific information, observation); the grounds, justification or relevance of evidence - consisting of warrants, W (the link between C and D) and backings, B (Scientific information that supports W or D); and rebuttals, R which are situations where the claim does not hold true. Since I wanted to understand if learners were critical of their own and others' arguments I included an additional code, evaluation, E. Evaluation included reconsidering own claims and/or grounds, providing (additional) support of others' claims and/or grounds as well as

opposition of others' claims and/or grounds. I had two categories of evaluation, E (agree) which was evaluation in agreement with Claim or Evidence as well as E (disagree) which was evaluation in disagreement with Claim, Evidence or Grounds under discussion.

To address the limitations of TAP in terms of identification of the components of an argument I drew from the explanations of the components designed by von Aufschnaiter and her team (von Aufschnaiter et. al., 2008) (see Table 4.06)

Table 4.06 Definitions of argument components (adapted from van Aufschnaiter et al., 2008)

Component of Toulmin argument	Description	Indicators/hints
Claim (C)	Position taking: Assertion/decision /prediction	Contextual; Choose / agree statement, prediction, hypothesis
C-claim (CC)	Counter position to a claim	Disagreement; alternative claim; contradiction
Data (D)	"Fact", "evidence"	Fact; Observation; event; an authority;
Warrant (W)	Why/how data relates to claim	Explicit / implicit
Backing (B)	Why D/W/R is appropriate to explain relation of claim & data	e.g. Law, theory, other additional information

Berland and Reiser (2008) also modified the model of argument formation to cater for other weaknesses. For example, they described the claim, evidence and reasoning as follows: a claim is a "description of what happened or an identification of the critical causal factor ... *the piece of information in the scientific explanation that the other two components – the evidence and reasoning – will defend*" (Berland & Reiser, 2008: 34, my emphasis). They regarded evidence as the scientific data which could be in the form of numerical data, observations, facts from reading and discussions. Berland and Reiser did not distinguish warrants, backings and rebuttals, but talked about all of these as reasoning. Reasoning for them was about students moving further than just providing claims and/or stating evidence, to being able to articulate why the evidence is important or relevant. This the students would do by including background knowledge or scientific theories and by describing the connections between evidence and their claim, including inferences.

Drawing from the above I examined justified statements to determine first, if the justification included the grounds on which the claim is made or supported. Secondly, I determined if the learners included an evaluation of their own or others' claims, evidence and/or grounding.

Table 4.07 Example of analysis of argument construction

T: She says that...if they come closer the hydrogen is going to become negative because of the attraction force. What do you think about that?	Claim, C1: if they come closer the hydrogen is going to become negative Evidence/Data, D1: because of the attraction force.
L8: Er...Maam I much agree...	E1, Evaluation of C1: I much agree
T: You agree?	
L8: Yes Maam...	
T: ok	
L8: coz Maam...when they bond covalently they are bonding to achieve what the nearest noble gas...	W1, warrant providing grounds for C1: when they bond covalently <i>they are bonding to achieve what the nearest noble gas</i>
L11: Madam...I disagree with the statement Maam coz Maam I think when the two atoms come closer Maam the the chemical potential energy...will increase	E2, Evaluation of C1 and/or W1: <i>I disagree with the statement</i> W2, grounds for E2 (=new Claim? C2?): <i>coz Maam I think when the two atoms (inaudible) Maam...the...the...chemical potential energy...will increase</i>
T: Why...(inaudible)...why do you disagree with the statement?	<i>(Teacher redirects the argument to C1 and probes S11 to provide grounds for his disagreement with C1)</i>
L11: Its because Maam when the the the two atoms Maam interact its impossible for them to be negatively charged.	B1, grounds for W2: when...the two atoms Maam interact its impossible for them to be negatively charged.

Unlike in traditional analyses of arguments, where the arguments components are identified from the same speaker, in this case the components were provided by different participants. For example, the claim, C1 was made by one student just before this excerpt and L8 is attempting to provide evidence and grounds for the claim. I shall now briefly show how my analytic model relates to my research questions.

4.5 Relating analytic model to research questions.

Fig 4.01 provides a visual representation of the relationship between my research questions, the data collected and the tools for analysing it. My data analysis focused on extracting the following information for each research question:

Research question 1: How do teachers shape science talk in high school classrooms?

Here I wanted to understand what communicative approaches teachers adopted in order to guide and/or shape the talk so as to achieve their teaching purposes. I did this by:

- Drawing up timelines for the lessons to determine which communication approach the teacher uses at different stages of the lesson.
- Identifying the teacher's interventions that led to these communication patterns
(This is the T-S Communication patterns box in Fig 4.01)

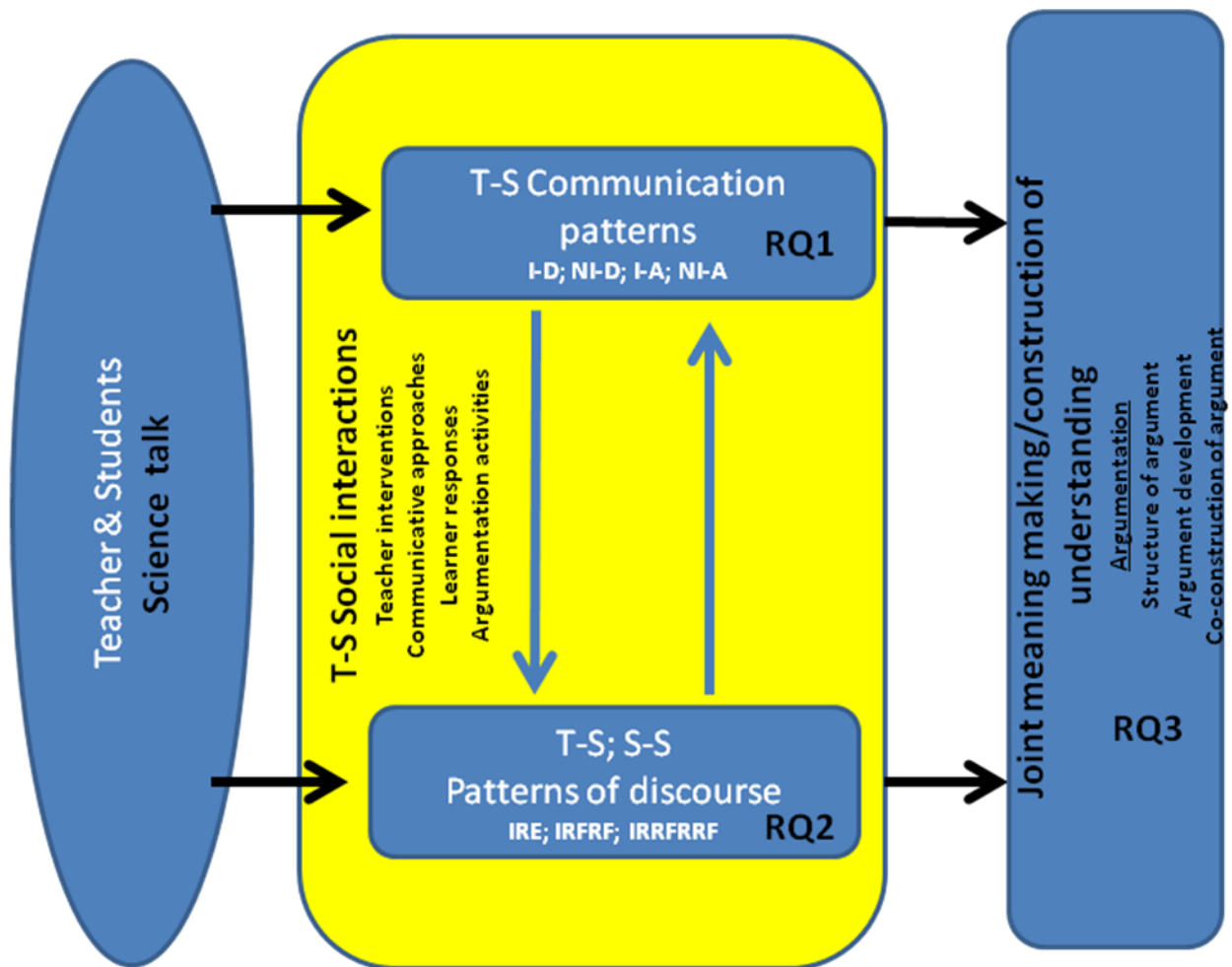


Figure 4.01 How my analytic tool relates to my Research Questions

Research question 2: What patterns of interaction emerge as teachers and their learners engage in science talk?

- I identified the patterns of discourse that emerged during science talk (whether it is IRE or IRFRF or IRPRPR... E).
- This would also characterise student participation. (This is the T-S; S-S Patterns of discourse box in Fig 4.01)

Research question 3: What is the nature of the interactions that emerge with science talk? In this case I wanted to understand how meaning making is negotiated between the teacher and learners and among the learners by determining:

- Whether and how students justified their claims (Evidence and grounds).
- Whether and how students reasoned through their own as well as others' claims/grounds (Evaluation).

- Who was responsible for initiating, supporting and/or justifying arguments; whether the meaning making process was a shared experience or it was monopolised by some students. (This is the Joint knowledge construction box in Fig 4.01)

I now provide a summary of the data that I analysed and show how analysis began to reveal some trends in science talk which I elaborate on in Chapters 5, 6 and 7.

4.6 Data summaries

I start with summaries of the lessons analysed for each of the three teachers, both those that I video or audio recorded and those that I sat in and only made field notes. I then present a summary of the discourse types identified in each teacher's lessons and finally a summary of the teacher communicative patterns identified in each lesson. For each teacher I present eleven lessons. To determine the number of lessons to report on I was guided by least number of lessons observed for any one teachers, in this case, Mr Far. I decided to take all of his eleven lessons for which I had both audio or video recordings and field notes. For the other two teachers I then selected the top eleven in terms of richness of data.

4.6.1 Lesson observations in Mrs Thoba's classrooms

As explained earlier Mrs Thoba only taught chemistry at Grades 11 and 12 and both physics and chemistry at Grade 10. However, Table 4.08 shows only Grade 10 and 11 lessons. This is because initially I was not going to observe Grade 12 lessons so as not to interfere with their preparations for the final examinations. I was only going to work with Grade 10 classes and continue with them in Grade 11 the following year. However, both Mr Far and Mrs Nkosi later requested support for Grade 12 classes and for them I did get data for Grade 12 classes.

Table 4.08 Summary of Physical Science (PS) lessons observed in Mrs Thoba's classrooms

Lesson	Date	Topic	Subject	Grade	Recording**
T1	19-07-07	Waves – Pulse	Physics	10	V*
T2	22-04-08	Waves – introduction	Physics	10	FN
T3	05-05-08	Sound waves	Physics	10	FN
T4	04-09-08	Water cycle	Physics	10	FN
T5	19-07-07	Quantitative analysis: Test for anions	Chemistry	11	FN
T6	04-09-07	Titration – calculation of concentration	Chemistry	11	FN*
T7	20-05-08	Bond energy - Energy changes	Chemistry	11	V

Lesson	Date	Topic	Subject	Grade	Recording**
		covalent bonding			
T8	14-10-08	Properties of acids	Chemistry	11	A*
T9	14-10-08	Reactions of acids – whole class discussion only	Chemistry	11	V
T10	15-10-08	Reactions of acids	Chemistry	11	V*
T11	17-10-08	Titration	Chemistry	11	A*

Total = 11 lessons, each 50minutes long

* Learners in small groups for parts of the lesson.

** In the last column V means that the lesson was video recorded; A means that it was audio recorded and FN means only field notes were made.

The eleven lessons given for Mrs Thoba are only part of what I observed in her classroom. As mentioned in the narratives, Mrs Thoba opened up to classroom observation much earlier than the other teachers and throughout the course of the project she was enthusiastic about having her lessons observed. In Table 4.08 I am presenting only those of her lessons for which I was able to make video or audio recordings and those for which I made the most extensive field notes. It was difficult to make extensive field notes for all the lessons since in terms of the project's co-teaching model that we had adopted I sometimes taught or supported the teacher in her lessons. It became easier to make recordings once I reduced teacher support in the last two phases of the project hence more video/audio material from the later lessons. The situation was the same for Mr Far's classrooms as seen in Table 4.09 below.

4.6.2 Lesson observations in Mr Far's classrooms

Table 4.09 Summary of some Physical Science (PS) lessons observed in Mr Far's classrooms

Lesson	Date	Topic	Subject	Grade	Recording
F1	27-08-07	Valency	Chemistry	10	FN
F2	16-10-07	Properties of compounds	Chemistry	10	V
F3	28-08-07	Acids and bases	Chemistry	11	FN
F4	17-08-07	Isotopes	Chemistry	11	FN
F5	17-08-07	Oxidation	Chemistry	12	FN
F6	05-09-07	Mining	Chemistry	12	V*
F7	08-02-08	Momentum	Physics	12	V
F8	15-10-08	Organic chemistry	Chemistry	12	A*
F9	17-10-08	Organic chemistry	Chemistry	12	A*
F10	21-10-08	Organic chemistry	Chemistry	12	A*
F11	23-10-08	Organic chemistry	Chemistry	12	FN*

(Total = 11 lessons, each 50minutes)

*Learners in small groups for parts of the lesson.

When I first started working with Mr Far in 2007 he was teaching only one class each at Grades 10 and 11 so I observed him teach those classes. In 2008 however, as he took on more and more administrative duties, he often requested another teacher to teach his Grade 11 classes (which I had observed at Grade 10 in 2007) as he focused whatever teaching time he had on the Grade 12 class (which I had observed as Grade 11s the previous year). He thus, needed my presence more in his Grade 12 classes and that was how I came to record his Grade12 lessons in 2008.

4.6.3 Lesson observations from Mrs Nkosi's classrooms

Mrs Nkosi's situation was different in that she taught Life Sciences to all the three FET grades (Grades 10-12) and it was possible to get a more even spread of lessons across the three grades (Table 4.10).

Table 4.10 Summary of some Life Sciences (LS) lessons observed in Mrs Nkosi's classrooms

Lesson	Date	Topic	Grade	Recording
N1	17-10-07	Cells and tissues	10	V
N2	28-04-08	Nutrients – disaccharides	10	FN
N3	29-04-08	Organic substances- vitamins	10	FN
N4	28-04-08	Evolution	12	FN
N5	29-04-08	Evolution	12	FN
N6	04-09-08	Plant tissue	10	FN
N7	13-08-07	Population dynamics	11	V
N8	04-09-07	Breathing	11	V
N9	14-10-08	Human circulation	11	FN
N10	21-10-08	Respiratory diseases	11	V
N11	22-10-08	Owl IK and conservation	12	V

(Total = 11 lessons: Grade10 lessons, 40 minutes each; Grade11&12 lessons, 50 minutes)

Mrs Nkosi experienced a lot of interruptions to her teaching. Her lessons were often cut short because she had to attend to a sudden disciplinary matter. This often caused interruptions of recordings of her lessons as was the case with the lesson on Respiratory diseases. The lesson was interrupted a few minutes after she had started but because it was a double lesson she was able to come back and continue after the disciplinary hearing. Fortunately I was still at the school and was able to record the remaining part of the lesson. The topic that she was addressing in this lesson was one of those that teachers had identified as challenging for them

and I was keen to see how Mrs Nkosi used talk strategies to handle this topic. In the next section I present the emerging trends from the analysis of all the lessons whether video or audio recorded or just based on field notes.

4.7 Emerging patterns from data analysis

First, I summarise the communicative approaches identified in each teacher's eleven lessons (Table 4.11). In Chapters 6 and 7 I will only draw from audio and/or video recorded lessons to elaborate and illustrate the results summarised in this chapter. The lessons are codenamed with the first letter of the teacher's name, that is, Mrs Thoba's first lesson is lesson T1 and Mr Far's eighth lesson is lesson F8.

4.7.1 Trends in teacher communicative approaches and discourse types

The communicative approaches were determined from indicators of teacher interventions listed in Table 4.02 and the emerging discourses were identified according to indicators in Table 4.06. For example, in the Interactive-Dialogic (ID) approach the teacher seeks to elicit and/or explore learners' ideas and thus takes an open non-evaluative stance to learner contributions. This results in genuine teacher-learner (T-L) dialogue (Table 4.11). However, some learner-learner interactions can also be dialogic (L-L dialogues in Table 4.11) if properly facilitated.

Since the discourse types were identified as episodes in each lesson, the lessons appear in every discourse category that was identified. This explains the repeated appearance of some lessons. For example, in Mrs Thoba's first lesson (T1) six of the eight discourse types were identified and as a result lesson T1 appears in all categories except learner presentations and drill. Also, although writing and reading are not talk I included them here to obtain a full picture of all the types of interaction that took place in each lesson.

In all three cases there were several episodes of teacher exposition or what I termed *telling* as well as the traditional question and answer (IRE) sequences in every lesson (see Table 4.11). It is worth noting however, that there were also episodes of dialogic interaction in more than half the lessons for all the teachers. This is interesting in light of observations in literature that most science classrooms around the world are quiet, that teachers do not afford learners

the chance to talk about their ideas (Lemke, 1990; Mortimer & Scott, 2003). Although dialogic interaction was the target type of interaction for the project it was not my expectation

Table 4.11 Summary of teacher communicative approaches and discourse types in the three teacher's lessons observed

Predominant communicative approach	Discourse type	Mrs Thoba's lessons	Mr Far's lessons	Mrs Nkosi's lessons
NIA	Exposition/ Telling	T1; T2; T3; T4; T5; T6; T7; T8; T9; T10; T11 (11)	F1; F2; F3; F4; F5; F6; F7; F8; F9; F10; F11 (11)	N1; N2; N3; N4; N5; N6; N7; N8; N9; N10; N11 (11)
IA	Question and answer (IRE)	T1; T2; T3 ; T4 ;T5 ; T6 ; T7 ; T8 ; T9 ; T10 ; T11 (11)	F1; F2; F3; F4; F5; F6; F7; F8; F9; F10; F11 (11)	N1; N2; N3; N4; N5; N6; N7; N8; N9; N10; N11 (11)
ID and NID	Teacher-learner dialogue (IRR...F chains)	T1; T2; T3; T7; T8 (5)	F1; F2; F4; F5; F7; F8 (6)	N3; N4; N7; N8; N10; N11 (5)
ID	Learner-Learner dialogue	T1; T3; T8; T9; T10; T11 (6)	F2; F3; F6; F7; F8; F9; F10; F11 (8)	N3; N11 (2)
ID	Learner questions (Reversed IRE)	T1; T3; T7; T10 (4)	F2; F6; F7; F11 (4)	N3; N11 (2)
ID	Learner presentations	T10 (1)	F1; F4; F6*; F7; F9; F10 (6)	
Look alike IA	Drill			N5; N8 (2)
	Practical activity	T1; T2 (2)	F2; F3; F5; F7; (4)	N8; N10 (2)
	Reading	T10; T11 (2)		N1; N3; N7; N8; N10; N11 (6)
	Writing	T1; T3; T4; T6; T8 ; T10 ; T11 (7)	F1; F2; F4; F5; F6; F7; F8; F9; F10 (9)	N2; N5; N6; N7 (4)

* Lessons code named with each teacher's initials: Mrs Thoba's are T1, T2, etc; Mr Far's lessons are F1, F2, etc and Mrs Nkosi's lessons are N1, N2, etc.

** Communicative approaches: IA is Interact-Authoritative; ID is Interactive Dialogic; NIA is NonInteractiveAuthoritative and NID is NonInteractiveDialogic

that classroom interaction should be completely dialogic. As Scott and colleagues noted (Scott, et al., 2006) there has to be a mix of interaction styles so as to facilitate for both the cognitive goals of learning science and the social requirements for classroom interaction.

Some differences in the teachers' pedagogical practices are evident in the data presented in Table 4.11. For example, Mrs Nkosi almost always got her learners to read in her lessons. The reading was either a passage taken directly from a textbook or a media statement or a role play that she herself had designed. The class discussion would then be guided by the text. However, she was also the only teacher who used drill as a teaching strategy and in whose lessons I never observed learner presentations. By presentations here I mean all activities that required a learner to be in front of the class including reporting from a research project or going up to the board to solve a problem or write up something. Mrs Nkosi's learners were always in their seats. Although she did get her learners to write, this happened less often than in Mr Far's lessons, for example.

Similarly learner involvement in Mrs Thoba lessons was largely through teacher-learner talk in the form of question and answer sessions and whole class discussions not as learner presentations. However, there was significant learner-learner interaction in six of the eleven lessons, two of which included small group discussions (lessons T1 and T10 in Table 4.11). The learner presentations in lesson T10 were part of a debriefing session at the end of a small group discussion session. Each group had a representative put up their solutions on the board, after which the teacher led a whole class discussion of the various answers on the board. Mrs Thoba seldom gave instructions for the learners to write, but her tasks were usually designed such that learners had to write down either just the answers or the method they used to get to the answer. However, since the tasks were usually meant for group discussions not all the learners did get to write.

Mr Far on the other hand, involved his learners a lot more both in practical activities and up at the board. He often conducted demonstrations and some of these were done by learners themselves under his guidance. For example, in the lesson on properties of compounds, lesson F2 in Table 4.09 he called up two learners to ignite the magnesium ribbon and demonstrate to the rest of the class the changes that took place when it ignited. Also, in the lesson on momentum he got learners to simulate various types of collisions and describe their observations. For the lessons on valency and isotopes he called learners up to the board to draw the different representations of atoms and their isotopes.

4.7.2 *Distribution patterns of teacher communicative approaches in the three teachers' lessons*

Table 4.12 shows the lessons in which each of the four of Mortimer and Scott's communicative approaches were identified. Three communicative approaches; IA, NID and NIA were identified in all eleven lessons for each of the three teachers, while various combinations of dialogic discourse were observed in some of each teacher's lessons, with

Table 4.12 Distribution of teacher communicative approaches in the lessons observed

Teacher communicative approach**	Mrs Thoba	Mr Far	Mrs Nkosi
NIA	T1; T2; T3; T4; T5; T6; T7; T8; T9; T10; T11 (All 11 lessons) Exposition/ Telling	F1; F2; F3; F4; F5; F6; F7; F8; F9; F10; F11 (All 11 lessons) Exposition/ Telling	N1; N2; N3; N4; N5; N6; N7; N8; N9; N10; N11 (All 11 lessons) Exposition/Telling N5; N8 (2 lessons) Drill
NID	T1; T2; T3; T4; T5; T6; T7; T8; T9; T10; T11 (All 11 lessons) Uptake/ Explaining	F1; F2; F3; F4; F5; F6; F7; F8; F9; F10; F11 (All 11 lessons) Uptake/ Explaining	N1; N2; N3; N4; N5; N6; N7; N8; N9; N10; N11 (All 11 lessons) Uptake/ Explaining
IA	T1; T2; T3 ; T4 ;T5 ; T6 ; T7 ; T8 ; T9 ; T10 ; T11 (All 11 lessons) Question and answer (Traditional IRE)	F1; F2; F3; F4;F5; F6; F7; F8;F9; F10; F11 (All 11 lessons) Question and answer (Traditional IRE)	N1; N2; N3; N4; N5; N6; N7; N8; N9; N10; N11 (All 11 lessons) Question and answer (Traditional IRE)
ID	T1; T2; T3; T7; T8 (5 lessons) T-L dialogue T1*; T3; T8; T9; T10*; T11 (6 lessons) L-L dialogue T1; T3; T7; T10 (4 lessons) L questions (Reversed IRE) T10 (1 lesson)L presentations	F1; F2; F4; F5; F7; F8 (6 lessons) T-L dialogue F2; F3; F6*; F7; F8*; F9*; F10*; F11* (8 lessons) L-L dialogue F2; F6; F7; F11 (4 lessons) L questions (Reversed IRE) F1; F4; F6*; F7; F9; F10 (6 lessons) L presentations	N3; N4; N7; N8; N10; N11 (5 lessons) T-L dialogue N3; N11 (2 lessons) L-L dialogue N3; N11 (2 lessons) L questions (Reversed IRE)

*Learners in small groups for parts of the lesson.

**Teacher communicative approach abbreviations:

ID	Interactive-Dialogic
IA	Interactive-Authoritative
NID	NonInteractive-Dialogic
NIA	NonInteractive-Authoritative

teacher-learner dialogues dominating in all three cases. Both Mrs Thoba and Mr Far attempted to engage learners in small groups, hence the higher number of lessons with learner-learner dialogues. They also recorded the highest number of lessons with learner initiated questions. Learner questions were only observed in two of Mrs Nkosi's lessons and

she never had learners present their work to the rest of the class. This is consonant with the fact that she tended not to use group work as a teaching strategy. I pursue these trends in the findings chapters that follow. I now present a summary of lessons in which I found evidence for the emergence of argumentation.

4.7.3 *Emergence of argumentation in the three teachers' lessons*

Tables 4.13-4.15 show the lessons in which some attempts at argument construction were detected. Mostly simple claim and data (Erduran's Level 1) arguments were constructed during the IA and ID communication episodes. This was the trend particularly in Mr Far's lessons. However, in Mrs Thoba and Mrs Nkosi's cases there was at least one lesson in which the teacher and her learners co-constructed some well supported, sometimes very elaborate arguments. As seen in Table 4.13 and Table 4.15, argumentation was clearly identified in the bond energy as well as the IK and conservation lessons, in Mrs Thoba and Mrs Nkosi classrooms, respectively. In Chapter 6, I follow up on these lessons and discuss in greater detail the nature of the argument construction processes in the each of the two lessons and illustrate how the two teachers and their learners co-constructed and supported each other's arguments.

Table 4.13 Lessons in which argumentation was observed during discussions in Mrs Thoba's classrooms

Lesson topic	Interaction types	Argument components
T1*Waves : introduction	Largely question and answer (Traditional IRE) Some T-L dialogue Some L questions	Claims, C 4 Data/evidence, D 4 Warrant, W 4 Backings, B 0 Qualifiers, Q 0 Rebuttals, R 0
T7 Bond energy	Largely question and answer (Traditional IRE) Some T-L dialogue Some L questions	Claims, C 18 Data/evidence, D 20 Warrant, W 17 Backings, B 4 Qualifiers, Q 1 Rebuttals, R 5
T10* Reactions of acids	Largely question and answer (Traditional IRE) Some T-L dialogue Some L-L dialogue Some L questions	Claims, C 11 Data/evidence, D 9 Warrant, W 9 Backings, B 1 Qualifiers, Q 0 Rebuttals, R 1

*Learners in small groups for parts of the lesson.

Of the eleven lessons reported for Mrs Thoba, there was evidence of argumentation in three (Table 4.13). In fact, of the three teachers, Mrs Thoba achieved the highest levels of

argumentation in these three lessons. The three lessons were about six months apart, in the order in which they are presented in Table 4.13, that is, the waves lesson happened first followed by the bond energy and then the acid reactions lessons, respectively. The acid reactions lesson involved both whole class and small group discussions and only the arguments constructed during the whole class session are reported in Table 4.13. Since I used argumentation as a measure of the nature and quality of teacher-learner and learner-learner interactions, the level of argument construction in these three lessons could therefore be regarded as indicative of progression in the nature of learner engagement in Mrs Thoba's classroom over time. I elaborate on these observations in Chapter 6 where I compare the nature of argumentation in the three teachers' classrooms.

I now present a summary of argumentation observed in Mr Far's classroom.

Table 4.14 Lessons in which argumentation was observed during discussions in Mr Far's classroom

Lesson topic	Interaction types	Argument components	
F2** Properties of compounds	Largely question and answer (Traditional IRE)	Claims, C	8
	Some T-L dialogue	Data/evidence, D	6
	Some L-L dialogue	Warrant, W	5
	Some L questions (Reversed IRE)	Backings, B	0
		Qualifiers, Q	0
		Rebuttals, R	1
F6 *** Mining	Largely question and answer (Traditional IRE)	Claims, C	5
	Some T-L dialogue	Data/evidence, D	4
	Some L questions (Reversed IRE)	Warrant, W	0
	Some L presentations	Backings, B	0
		Qualifiers, Q	0
		Rebuttals, R	0
F7** Momentum	Largely question and answer (Traditional IRE)	Claims, C	3
	Some T-L dialogue	Data/evidence, D	4
	Some L questions (Reversed IRE)	Warrant, W	1
		Backings, B	0
		Qualifiers, Q	0
		Rebuttals, R	0

*Learners in small groups for parts of the lesson.

**Learners doing some practical activity for parts of the lesson.

***Learners reporting from investigations on the chemistry of mining.

Of the three teachers, there was the least evidence of argumentation in Mr Far lessons. In the lesson on mining, for instance, there was evidence of only the lowest level of argumentation. Of the five claims that were supported, only four pieces of evidence were provided, making them into Level 1 arguments according to Erduran et al. (2004). Similarly, in the lesson on mining, the arguments were a series of claim and data pairs, again making them mainly Level 1 with one Level 2 argument in which the only warrant was given. Only in one lesson, the lesson on properties of compounds, were there almost similar numbers of warrants as the data pieces they supported. As in the case of Mrs Thoba the lessons are presented in the table in the sequence in which they were taught, suggesting that there was no clear trend in the development of argumentation in Mr Far's classrooms. In Chapter 6 I present some excerpts to illustrate the few arguments constructed in Mr Far's lessons. The next table summarises arguments observed in Mrs Nkosi's lessons.

Table 4.15 Lessons in which argumentation was observed during discussions in Mrs Nkosi's classrooms

Lesson topic	Interaction types	Argument components
N7 Population dynamics	Largely question and answer (Traditional IRE)	Claims, C 7 Data/evidence, D 5 Warrant, W 1 Backings, B 1 Qualifiers, Q 0 Rebuttals, R 0
N8 Breathing	Largely question and answer (Traditional IRE) Some T-L dialogue Some L-L dialogue Some recitation/chanting	Claims, C 5 Data/evidence, D 3 Warrant, W 2 Backings, B 1 Qualifiers, Q 0 Rebuttals, R 1
N10 Respiratory diseases	Largely question and answer (Traditional IRE) Some T-L dialogue	Claims, C 8 Data/evidence, D 7 Warrant, W 1 Backings, B 1 Qualifiers, Q 0 Rebuttals, R 2
N11 IK and conservation	Some question and answer (Traditional IRE) Some T-L dialogue Some L-L dialogue Some L questions (Reversed IRE)	Claims, C 12 Data/evidence, D 12 Warrant, W 7 Backings, B 5 Qualifiers, Q 4 Rebuttals, R 10

*Learners in small groups for parts of the lesson.

As in Mrs Thoba's case, there seems to have been an increased in engagement in Mrs Nkosi's lessons over time. The trend in the number of argument components identified in each lesson also suggests a change in then ature and quality of interactions with time. Also, although

there were more claims made in each lesson, more supporting evidence was provided in later lessons suggesting a change in the level of arguments constructed over time. Not only was the highest number of arguments recorded in the lesson on indigenous knowledge and conservation but also the highest level of argumentation occurred in that lesson. According to Erduran et al. (2004) the number of rebuttals is a measure of the complexity of arguments and thus of the participants' competency levels of argumentation. The ten rebuttals in the IK and conservation lesson attest to a high level of engagement in this lesson. I revisit this point in Chapter 6 when I discuss the different types of arguments identified in this lesson and how they were co-constricted by the teacher and her learners.

4.8 Conclusion

In this chapter I have outlined the analytic tools that I used and how they were derived from two models, Mortimer & Scott's analytic model for classroom interactions and TAPping, an adaptation of Toulmin's Argument Pattern, TAP. I illustrated how I used a coding system in ATLAS.ti software to determine the teacher interventions that shaped the different communicative approaches and discourse patterns in the lessons. I included illustrations of how the tools were used to analyse actual data from my study and they relate to my research questions. Finally, I provided a summary of the data that I analysed for this thesis and highlighted some of the trends emerging from the data analysis. The rest of this thesis is a presentation of evidence from selected lessons to illustrate the trends in teacher communicative approaches, patterns of interaction emanating from those approaches as well as emergence of argumentation in some of the ID and IA episodes. I start in the next chapter, Chapter 5 with a discussion of the teacher communicative approaches.

Chapter 5

Opening up and shutting down talk: Teacher communicative approaches

“An important element in educational work is enthusiasm ... The archbishop of Canterbury (once asked) why actors in a play affect their audiences so powerfully by speaking of things imaginary, while ministers of the gospel often affect theirs so little by speaking of things real. ‘With due submission to your grace,’ replied a famous actor, ‘permit me to say that the reason is plain: it lies in the power of enthusiasm. We on the stage speak of things imaginary as if they were real, and you in the pulpit speak of things real as if they were imaginary’ ... The teacher in his work is dealing with things real, and he should speak of them with all the force and enthusiasm which a knowledge of their reality and importance can inspire” (White, 1903, 1952, p. 233).

5.0 Introduction

In my first research question I sought to understand the ways in which teachers stimulated and guided student talk so as to create an interactive discourse in their classrooms. The question that guided my analysis was “How do teachers shape science talk in high school classrooms?” In other words, “What communicative approaches do teachers adopt to foster talk in their classrooms?” However, the communicative approaches could not be described outside of the teachers’ intervention that created them and analysis of teacher interventions led to description of the patterns of interaction as they emerged with each communicative approach. Therefore, in the course of establishing the answers to my first question I was also addressing my second research question, which was, “What patterns of interaction emerge as teachers and their learners engage in science talk?”

In this chapter I focus on the data that answered my first two research questions for the teachers I worked with. The data analysed for this chapter was in the form of transcripts of audio and video recordings of teacher-led whole class discussions. I present a case-by-case analysis of the data which seeks to understand the uniqueness of each case (Miles & Huberman, 1994). A case-by-case analysis aims to answer three questions: the *what*, *how* and *why* of each case. In other words, it is both descriptive and explanatory in nature and the two are usually intertwined. To answer the *what*, question I identified and described the teacher’s communicative approaches, the resultant patterns of discourse as well as the teacher interventions that produced both. To answer the *how* question I characterised each teacher’s interventions that led to different communicative approaches to determine the relationships between the two. For the *why* question I did a thematic analysis of the data working

iteratively both deductively and inductively. First I used pre-determined themes from my theoretical framework and other literature and read through all the episodes of interactive discourse seeking out these pre-determined trends in teacher intervention. Any data that did not fit into the pre-determined themes were then categorised into new themes. I then re-read the data using this new set of themes (comprising the themes emerging from the data) together with the pre-determined themes in an iterative data analysis process. According to Miles and Huberman (1994: 143) such an analysis would help me surmise *how come* particular teacher interventions and communicative approaches did or did not produce the desired form of interaction for the lesson. For instance, I could determine whether the teacher's interventions created only Mehan's (1979) traditional IRE sequences or whether they opened up for the extended IRPRP chains of interaction which have the potential to create a dialogic discourse that is desirable for meaning-making in the classroom (Mortimer & Scott, 2003). However, before embarking on a discussion of the data analysis for the *what*, *how* and *why* of my cases I would like to give the reader a brief idea of the contexts under which the interactions reported in this chapter occurred in the form of narratives of the teachers' profiles.

5.1 Narratives of the cases: the context for the development of science talk

By narratives, I mean stories that I have constructed about each teacher from some of the personal and demographic data that I collected, from personal conversations with the teachers, from my own observations of their day to day activities and their school contexts and in some cases from interactions with the school management (See Table 5.01). According to Polkinghorne (1995) narratives in education research can either be constructed by the respondents themselves, which in my case would have been stories by the teachers themselves or they can be constructed by the researcher/observer, which is what I have done. In the former case of Polkinghorne's narratives, the stories originate from the respondents and are therefore part of the data collected for the study and would be subject to what he calls narrative analysis. In other words they would be subjected to data analysis just like all the other data collected during the study. I have used narratives in the latter sense where I construct stories to transform some of the data and try to paint for the reader a mental picture of each teacher and their circumstances.

Table 5.01 Teacher personal and contextual information

Teacher	Demographic and personal data	Academic and professional qualifications	Views about teaching and learning	Contextual issues	Other duties
Mrs Thoba	Black female 38years old; speaks English, isiZulu and seSotho; married mother of 2; lives within 5km of the school; postgraduate student	Holds BEd Maths major with Physical Science minor; 15years experience (5 in Physical Sciences) in same school; Has enrolled for BEd Hons Maths	Controlled learner participation to balance learner understanding with content coverage within school calendar.	One of 3 Maths and 2Physical Sciences teachers; Maths Gr10-12, Physical Sciences Gr10, Chemistry only Gr11-12 (2 classes each but Gr11 first half of year and Gr12 second half of year)	Disciplinary committee; Maths advisory committee.
Mrs Nkosi	Black female 49years old; speaks English and isiZulu; married mother of 3; lives within 20km of the school; postgraduate student	Holds TCE, HDE, ACE, BEd (LO major); 25years experience (8 in Life Sciences in same school); Has enrolled for ACE in Life Sciences	Teaching must accommodate learners' different capacities for understanding	HoD Life Science Dept; One of 4 Life teachers; Natural Science Gr8-9, Life Sciences Gr11-12 (2 classes each)	Disciplinary committee; SMT member; HIV/AIDS counsellor; Liaison person for Weekend tuition project
Mr Far	Coloured male 50years old; speaks English and Afrikaans; married father of 2; lives within 15km of the school	Holds MEd in Leadership & BEd Maths and Physical Sciences; 28years experience in both (15 in current school); Computer Technology (2 years)	Teaching for social transformation.	HoD Physical Science & Computer Technology Depts; One of 4 Maths teachers (Gr7, 11-12 Maths); one of 4 Physical Sc teachers (Gr10-12, Computer Technology Gr11-12)	Disciplinary committee; SMT member; Physical Sciences and Computer Technology facilitator for school cluster.

According to Miles and Huberman (1994) qualitative data is obtained by watching, asking and examining. This is corroborated by Froggatt (2001) who describes the three sources of qualitative data as experience (observation), enquiry (interviews) and examination (documents and materials). My data came mainly from watching or observation, with a little asking during formal and informal discussions and during workshops and was therefore subjected to my continual interpretation and incorporated into my own personal understanding of the contexts (Froggatt, 2001). Thus the stories I am telling about the cases I have studied are not objective presentations of “facts” but they are partly analytic and partly interpretative of my experiences of the teachers’ situations. For instance, the data that I used to reconstruct my experiences was already in predetermined categories either in terms of the questions I asked, or from the focus of my observations, or they were influenced by the theoretical framework that guided my study and/or by my own personal world view (see Table 5.01 for the data). Another example is in transcribing the video and audio recordings of lessons where I often referred to episodes in which learners talked in loud voices all at the same time and the teacher seemed (to me) not to be in control of the lesson as “commotion” or “noise” and this was informed by my personal perception of what constitutes commotion or noise in a classroom situation.

5.1.1 Case 1: Mrs Thoba (Mathematics and Physical Sciences)

Mrs Thoba was an experienced educator who had been teaching Mathematics for fifteen years at the commencement of my study. Five years before, she had been requested by the school’s administration to teach science to help alleviate the shortage of Physical Sciences teachers in her school. Within the five years she had also been appointed as a marker for the matriculation science examinations, the national exit examination for high school taken at the end of Grade 12.

Mrs Thoba said that when she was asked to teach Physical Sciences she did not feel confident enough to teach it to Grade 12, especially the physics component. It turned out that the other Physical Sciences teacher with whom she was to share the Grade 10-12 classes was more confident in physics than in chemistry. They then decided to split the Grade 11 and Grade 12 classes so that they each taught the Physical Sciences component they were comfortable with. This was how Mrs Thoba came to teach only chemistry at Grade 11 and 12 although she still taught both the physics and chemistry to the Grade 10 class that she was responsible for. This

however, meant that she met the Grades 11s and 12s for only half of the year. She met her two Grade 12 classes for chemistry in the first half of the year (Term 1 and part of the Term 2) and the physics teacher had them for the second part of the year (part of Term 2 and all of Term 3). In South Africa the fourth term is when Grade 12 learners take the national final examinations for matriculation. Mrs Thoba would then take the Grade 11 classes for chemistry in the third and fourth terms. This is in addition to her Mathematics teaching for Grade 10-12. Mrs Thoba's workload was quite high and although she was keen to use the science talk strategies, she was anxious about how successful she would be in light of her workload. While she felt that talk would help her learners engage with the science content and enhance their learning opportunities, she was also anxious about not having sufficient time to cover the content heavy chemistry syllabus with her classes. Since she was teaching large classes of 45-50 learners, she was particularly concerned that learners might talk for too long and she would be unable to control the class so as to move the lesson forward. She had this to say in one of our discussions during a visit to her school:

It (*talk*) does provide for effective learning but the only thing is it takes time so if your learners are involved they may talk and talk and it's sometimes difficult to move on with the lesson then you fall behind the time frame to cover all the content in time for exams.

(Transcript of interview 14 October 2008)

Mrs Thoba's concern about time was partly due to the other responsibilities that she had at school. She was a member of the school's disciplinary committee which met quite frequently, sometimes three times a week. This would obviously take away from her teaching time. The school seemed to me to be quite orderly, though. The learners in this school were far more disciplined than in the other two schools that I worked with, probably as a result of these efforts by the teachers and administration. In addition to the disciplinary committee duties Mrs Thoba was also a member of both the mathematics and the science advisory committees to the school's administration which met once every two weeks for an entire afternoon. This meant that Mrs Thoba attended every week since she sat in two committees.

Another one of Mrs Thoba's concerns was the challenge for her (and her learners) of teaching and learning science in a language that they all were not confident in. Although she spoke English relatively well she was not a native speaker of the language. She and most of the learners in her school spoke isiZulu and seSotho. In fact the community within which the

school was located was predominantly Zulu and Sotho, although there were families that spoke other local South African languages like Tsonga and Venda. Mrs Thoba and her family lived within five kilometres of the school. She and her colleagues switched easily between the various local languages. The teachers hardly spoke to each other in English, not even in the staff room. However, in class Mrs Thoba spoke only in English although she allowed her learners to code switch. She said that she did this on purpose so as to afford her learners access to the English language since they were expected to write their final examination in English. Mrs Thoba's argument was consistent with literature on perceptions of some South African parents, teachers and students about English as a language of power (see for example, Setati, Adler, Reed, & Bapoo, 2002). She felt that language was a barrier for learner talk in class. She had this to say about challenges with language in her classroom:

- 27 Mrs Thoba: I have observed that outside class they talk a lot maybe it's
because they talk in their own language
Me: Do you sometimes allow them to speak in their own language?
30 Mrs Thoba: yes I do but then I have to translate for the rest of the class.
Me: You have so many learners with different languages do you
understand all the languages?
Mrs Thoba: No, like Tsonga I only understand a little. So I sometimes ask
another learner to translate.
(Lines 27-34 of interview 14 October 2008)

In spite of all these challenges Mrs Thoba remained enthusiastic about participating in the project and about trying out science talk strategies and having me critique her lessons. When she first volunteered onto the project Mrs Thoba's highest qualification was a Bachelors degree majoring in Mathematics education with Physical Sciences as a minor subject. A year later she decided to enrol for postgraduate studies which the project encouraged the teachers to do. Since most of the teachers in the project held degrees in other subjects with science only as a minor subject their science content knowledge was usually inadequate especially for teaching up to Grade 12. However, in spite of her enthusiasm about the science talk strategies that we were working with in her classroom she wanted to pursue further studies in Mathematics rather than in Physical Science, so she enrolled for an Honours degree in Mathematics education. Although it made perfect sense for her to want to further her studies in her major subject I was a little perturbed by her decision. My fear was that should the school's situation change so that they needed her services more in Mathematics it would now be even more likely for her to be moved back to teaching only Mathematics and she would then drop out of my study. Fortunately her school needed her services as a science teacher for

the duration of my study and her enthusiasm about participating in the science talk project did not wane either. She was keen to try out the science talk strategies and for me to continue to observe her lessons and critique her practice.

One of the requirements for participation in the project was attendance at professional development workshops. The first two workshops were aimed at raising awareness of the project goals and strategies and getting teachers to volunteer to participate in the project. The next series of five workshops focused on refinement of the strategies and collaborative development of teaching and learning materials. To her credit Mrs Thoba attended all seven workshops. This might be an indication of the level of Mrs Thoba's commitment to the programme. She was also one of the first teachers to open up for the team to observe and critique her lessons. From the outset teachers were informed that one of the goals of the project was to document their practice and this meant that I would sit in the teachers' lessons and observe them teach.

At first the teachers were not comfortable allowing me into their classrooms. When I (and the other researchers in the project) volunteered to teach some lessons and have the teachers observe and critique my practice, Mrs Thoba was one of two teachers who immediately volunteered to have me teach in her classroom so that she could observe and be the next to teach and have her own lessons critiqued. As a result I visited Mrs Thoba's classroom at least twice a month throughout the duration of my study and she often tried out science talk in teacher-led whole class discussion as well as in small group discussions. According to project rules, she then decided that I critique and analyse the eight lessons presented in this thesis (five of which I refer to in this chapter). The lessons that I analysed were spread over fifteen calendar months, about ten teaching months. For a Mathematics major, Mrs Thoba's sustained interest in the science talk strategies was quite commendable.

5.1.2 Case 2: Mr Far (Physical Sciences, Mathematics, Computer Applications and Technology)

Of the three teachers that I worked with, Mr Far was the only one that taught in his area of expertise. He was an experienced Physical Science teacher with 28 years of teaching (15 in the current school). His highest qualification was a Master of Education following an Honours degree in Science Education and Mathematics. Over the years because of his interest

in computers he had obtained an introductory qualification computer studies. When he volunteered into my project Mr Far was teaching Physical Science at Grade 10-12 and Mathematics at Grade 7 and Grade 11-12 as well as Computer Application Systems (CAT) to Grade 11-12. He was also responsible for the school's internet and maintenance of all the school's computers. Mr Far was therefore, the head of both Physical Science and Computer Technology departments and sat on the school's Senior Management Team (SMT). However, Mr Far seemed to do much more than just his duties as a member of the SMT. He performed some of the duties of a deputy principal. He was often called out of class to attend to administrative issues and it was not unusual for the principal to interrupt Mr Far's lessons to consult about an administrative matter. Sometimes Mr Far would call and stop me from going to his school because he had to reschedule his classes so as to attend to some or other administrative crisis in the school. Mr Far was not only a highly qualified member of staff but was also dedicated to the welfare of the learners and the school. It was not surprising that about 18 months into my study Mr Far was promoted to principal of a school not too far from the one he was in.

My understanding of Mr Far's commitment came partly as a result of an experience I had very early on in my interaction with him, in fact on the very first day I went to his school with the other project team members. As we approached his school we were confronted with a scene that would remain etched in my memory for the duration of my study in that school. Like other schools in the area this school was fenced with the usual 3m high net wire and had a lockable gate manned by security personnel. However, as we approached the school I could not make out the fence. All I saw were pieces of paper and other litter as if pasted onto the entire surface of the fence. It was as if the school was surrounded with a high wall of litter. There was litter everywhere in the school grounds. As we alighted a slight wind blew the litter up and we had to shield ourselves from pieces of paper flying all over the place. I still recall our conversation in the car on the way back as we marvelled at the state of that school.

Other than the litter something else struck me that day about that school. Learners were milling about and talking noisily. Some were at the entrance to the administration offices, some in the corridors; others were out in the playing fields while some were standing outside the school gate. Meanwhile classes were going on inside the classrooms. As we sat in Mr Far's class it was hard to follow his lesson because of the noise that was coming from

outside. This was not surprising as this was a big school comprising both a primary and a secondary section from Grade 1 to 12 on the same premises. The school had a total enrolment of about 2500 learners and perhaps this was why the impact of having learners loitering outside was so significant.

As we were preparing to leave that day Mr Far remarked that he and a few other teachers had met and decided on a course of action to change the situation in the school and he had been tasked by his colleagues to approach the school's administration with their suggestions. He was not sure how administration would react but he was prepared to try. The school remained in that state for the rest of that term.

As a rule we did not go to the schools at the beginning of the new term. We gave the teachers time, about two weeks, to settle down and take care of the administrative requirements from the district offices. So we only went back to Mr Far's school about three weeks into the new term. As we approached the school we all fell silent in the car. I could not believe the transformation that had taken place in the school. There was not a single piece of paper, on the fence or on the school grounds. The school grounds and the corridors were empty and the school was quiet. When we commented to Mr Far about the change in the school grounds and the absence of learners in the corridors during class time he explained that the teachers had met with school management over the holidays and tabled some strategies about maintaining discipline and litter removal from the school grounds. Evidently, Mr Far and his colleagues had made a breakthrough and had transformed their school.

Mr Far was keen to try out the science talk strategies in his lessons. However his workload and his other responsibilities made it quite a challenge not just to try out the talk strategies but to meet regularly with his classes. He was also faced with some of the challenges that the other two teachers in my study met with, including the problem of large class sizes and overcrowding. For instance, in the Grade 11 class in which the lesson on formation of compounds was recorded there were 48 learners in a laboratory designed for 25 learners. Another challenge was the language barrier. Mr Far and most of his learners spoke Afrikaans but the language of teaching and learning in his school was English. Like Mrs Nkosi, Mr Far did not code switch in class but unlike Mrs Nkosi's learners his learners did not code switch either. Mr Far often said that his mission was to afford his learners access to a sound

education because this would help them change their situations and break out of the poverty that was prevalent in their community. He too like Mrs Nkosi incorporated the teaching of values into the teaching of science.

5.1.3 Case 3: Mrs Nkosi (Life Orientation and Life Sciences)

Mrs Nkosi an experienced teacher with 25 years in the teaching profession was one of four Life Science (Biology) teachers in a school with an enrolment of about 1500 learners, about the same size as Mrs Thoba's school. Mrs Nkosi's initial qualification was a three year teaching certificate from the days of Bantu education. So, by current South African standards her initial training was inadequate for her to teach to Grade 12. With the advent of the democratic government in 1994 she decided to go back to school to upgrade first to a Higher Diploma in Education and then to a Bachelors degree in Life Orientation with a minor in Natural sciences. Due to the shortage of Life Sciences teachers she found herself in the same situation as Mrs Thoba when in the year 2000 she was requested to teach Life Science to Grades 10 to 12. To upgrade her qualifications she then enrolled for the Advanced Certificate of Education (ACE) programme with specialisation in Life Science education. Probably because of her large range of qualifications Mrs Nkosi had many responsibilities at school.

Mrs Nkosi was the Head of Department for Life Sciences and chair person of the school's HIV/AIDS committee which provided support for learners living with or affected by HIV and AIDS. Because of her Life Orientation training she was also the HIV/AIDS counsellor. As head of department she also sat in the school's Senior Management Team (SMT) which met for two afternoons every week. She was the school's Liaison officer for the Weekend tuition project which was run by a group of non-governmental organisations to help provide extra tuition for selected mathematics and science learners in her district on weekends. Mrs Nkosi was also in the school's disciplinary committee which also met quite frequently to address disciplinary issues in the school. Again because of her life skills qualification she was assigned the duty of liaising with parents and guardians of learners with recurring disciplinary cases as well as counselling the learners themselves. All these duties were assigned over and above her quite heavy teaching load. She and three other Life Sciences teachers shared the Grade 8-12 classes such that she taught Natural Science to two Grades 8 and two Grade 9 classes and Life Sciences to two Grade 11 and two Grade 12 classes. She also taught Life Orientation at Grade 10 to Grade 12.

Although Mrs Nkosi expressed concerns about using the science talk strategies with the big classes that she taught, her bigger concern was the diversity of her learners' capabilities which made it difficult to manage classroom talk. In the excerpt below taken from one of my conversations with her after the lesson on population dynamics she explained what I thought was her philosophy of teaching – that teaching must accommodate learners' different capacities for understanding:

- Mrs Nkosi: I think you know learners differ yah there are those you might have noticed who are always talking and some are average but er just pointing at them asking them to say something irrespective of whether the answer is correct or incorrect but at least it gives them you know that confidence that I am recognised as well I am part of the class interaction because sometimes if you just focus on those who are always talking then the others end up inactive and feeling you know that they are not important
- Me: Hhm
- Mrs Nkosi: and a low self esteem as well develops but when you give them that opportunity they actually talk
- (Turns 20-22 Informal interview after the lesson on Population dynamics 19Aug2008)*

For Mrs Nkosi it was not always the answer that was important but that the learners feel that their participation in the lesson discussion was important. However, she said that one of the challenges in trying to include all learners was the language barrier:

- Mrs Nkosi: well language is obviously a barrier
- Me: Hhm
- Mrs Nkosi: it is it is a barrier I think it needs a lot of practice. One area you know one area that maybe we have lost you know the issue of debate in high school those were the things you know that actually helped us as students. You know not talking mother tongue when you are at school
- Me: Hhm
- Mrs Nkosi: It was the thing during our times you wouldn't speak in Zulu but now .. Yah and the issue of knowing we used to write summaries you knew that I must write ten summaries I must read ten books in English ten books in Afrikaans ten books in Zulu
- Me: Hhm
- Mrs Nkosi: so those I think are the things that developed us which are no longer done presently but if we can go back there it would help a lot. So maybe if you let them get into groups yah to work in groups yah depending on the type of er activity that you are doing
- (Turns 30-36 Informal interview after the lesson on Population dynamics 19Aug2008)*

In the third turn of this excerpt one may get the impression that Mrs Nkosi was opposed to the use of the home language in the classroom. However, later in the same conversation she explained that she did actually encourage code switching because it enabled learners to express their ideas without hindrance:

Mrs Nkosi: when they code switch you let it happen so that a person can be able to express what she wants to say and thereafter if she has to present now it has to be in English

Me: and how well do they do that the presentation in English?

Mrs Nkosi: well these are a good class actually yah the 11As are a good class very committed

Me: Hhm

Mrs Nkosi: In fact most of them work even harder than our Grade12

Me: ok

Mrs Nkosi: yah so its all about encouraging and motivating them to do that all the time
(Turns 38-44 Informal interview after the lesson on Population dynamics 19Aug2008)

It seemed that like Mrs Thoba, Mrs Nkosi's concern was that learners needed to be confident in the English language. This was because their examinations which are taken in English, again a point raised by Setati's research on perceptions of English as the language of power (Setati, et al., 2009). Mrs Nkosi believed that with encouragement and motivation learners could gain the confidence to talk about their ideas in spite of the language barrier. This could be a skill that she drew from her Life Orientation qualification, but it enabled her to adapt the science talk strategies in interesting ways for her lessons as I will show later.

5.2 Analysis of observations of teacher-learner whole class interactions

Having painted a picture of the teachers contexts I will now proceed to discuss my analysis of how Mrs Thoba, Mrs Nkosi and Mr Far worked with talk in their lessons and what subsequent patterns of communication emerged as they interacted with their learners in whole class discussions.

To get to my conclusions I was guided by my conceptual and analytical framework which was derived from Mortimer and Scott's (2003) model for analysing classroom interactions. As discussed in Chapter 2 (Section 2.7.1), the model categorises teacher-student talk along the dialogic-authoritative and the interactive-noninteractive continuums, recognising four teacher communicative approaches; the interactive/dialogic, the non-interactive/dialogic, the interactive/authoritative and the non-interactive/authoritative approaches (Figure 2.03 reproduced here as Fig 5.01 to refresh the reader's memory).

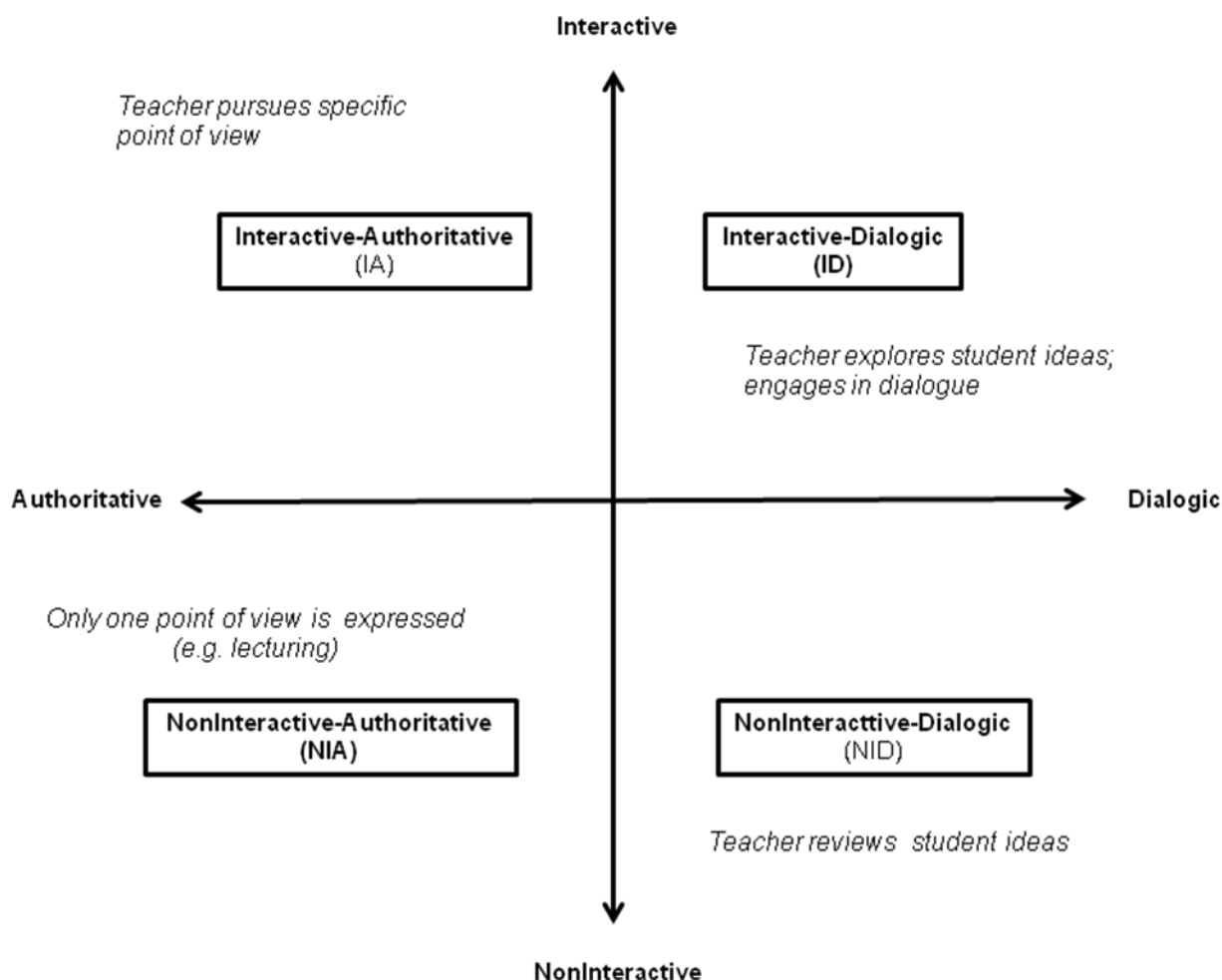


Fig. 5.01 My visual impression of categorisation of classroom talk along the dialogic-authoritative and the interactive-noninteractive continuums (Adapted from Mortimer & Scott, 2003)

Using this model I derived the following observations from my data:

1. All the teachers' lessons were interactive – the teachers involved the learners in the lesson, albeit with varying levels of participation and engagement. In most of Mrs Thoba and Mr Far's lessons only a few learners were talking while in Mrs Nkosi's lessons a large proportion of the learners were talking. However, much as Mrs Nkosi's lessons were highly interactive, learner engagement was in many cases only superficial. This suggests therefore, that while interactive classroom discourse presupposes student participation which is one of the requirements for learner-centred teaching and learning it does not necessarily provide for effective learning. Similar observations of teacher uptake of the forms and not the substance of curriculum innovation have been reported in South

African classrooms (Brodie, et al., 2002b). I will discuss this point further in Chapter 6 when I discuss the emerging dialogic practices in each teacher's lessons.

2. I identified episodes of dialogic and authoritative discourse in all the lessons. All the teachers alternated between dialogic and authoritative approaches in different ways as they shaped the science talk. Dialogic discourse draws learners in, exposes their views and legitimises their talking and thinking – it opens up for genuine learner involvement (Mortimer & Scott 2003). Thus, extended dialogues facilitate meaning making for learners providing opportunities for learning science (Scott, et al., 2006). Authoritative discourse on the other hand may be used to maintain focus on the scientific story. The occurrence of both forms of communication in the lessons speaks to the tension between the nature of science as an authoritative discourse and need to engage students' ideas as well as afford the social space for the construction of scientific meaning (Scott & Mortimer, 2005).
3. Of the four communicative approaches the Interactive-Authoritative approach was the most prevalent with a tendency towards Interactive-Dialogic communication for all the teachers. There were interesting variations of NonInteractive-Dialogic communication in both Mrs Nkosi and Mrs Thoba's lessons and in one of Mrs Nkosi's lessons I identified an imitation of Interactive-Authoritative communication which in effect was a veiled NonInteractive-Authoritative communication. These communicative approaches were explained in Chapter 2.
4. For each teacher I characterised the interactive discourse to determine learner participation. In interactive discourse the teacher leads the discussion usually in a question and answer sequence so as to involve learners in the talk. There was evidence in the lessons for all the three patterns of interaction as described in Chapter 2 (Section 8.2.2); the traditional IRE/F sequences, the IRPRP...E closed chains and the IRPRP open chains. The predominant discourse was the traditional IRE/F with some instances of both open and closed IRPRP chains which according to Aguiar et. al. (2010) would be the closest to a true conversation. I identified some IRPRP chains in two of Mrs Thoba's lessons, the one on Bond energy and the one on Waves; in Mrs Nkosi's lesson on Conservation and in Mr Far's lesson on Momentum. There was variation in the extent to which each teacher achieved this open discourse in each lesson.
5. From interactive discourse episodes I pulled out the themes or trends in teacher interventions as follows:

- a) Teacher questioning both facilitated and constrained interaction. Teachers asked a mix of closed with only one possible answer with some open and authentic questions with several possible answers which tended to open up for more learner interaction. Both Mrs Thoba and Mrs Nkosi asked mostly closed questions and often did not allow for wait time for their learners to think and respond. They often provided answers to their own questions thus shutting down learner participation. Mr Far questioned more and used more open questions often persistently prodding the learner until he got a response.
- b) Teachers often took learners' ideas and understandings seriously – although they ignored some learners' contributions they generally valued learners' ideas and used them to direct the course of the lesson. This was particularly true in Mrs Thoba and Mr Far's lessons. There was wide variation in the extent to which the teacher exercised genuine uptake of learners' ideas.
- c) The teacher interventions that produced the different teachers' communication styles were a mix of elaborative and evaluative teacher responses to learner contributions (refer to Table 4.01 for descriptions of teacher interventions). Both Mrs Thoba and Mr Far responded more elaboratively to learners' contributions while Mrs Nkosi used mostly evaluative interventions.
- d) Teachers encouraged learners to evaluate and critique their peers' ideas, often foregrounding learners' ideas for interrogation by their peers. This created the potential for increased student participation as learners gained confidence in evaluating each other's ideas.
- e) Teachers solicited learner questions at different intervals during their lessons. In addition I identified some unsolicited learner contributions in some of Mrs Thoba and Mrs Nkosi's lessons.

5.2.1 Characterisation of teacher-learner interaction in Mrs Thoba's whole class lessons

All of Mrs Thoba's lessons were interactive (details in Appendix 5.01). In other words, she involved her learners in the discussion mostly by asking questions but also by getting them to ask their own questions. In the lesson on waves she also got the learners to conduct a practical exercise in which they generated and described their own pulses. I will show later when I discuss the patterns of interaction emerging in Mrs Thoba's how her questioning either opened up or shut down talk during the lesson.

Mrs Thoba's communication style was largely authoritative in that she tended to maintain the focus of the discussions on the generally accepted scientific view of the topic under discussion. The purpose of the interaction in her classroom was for the most part to get to the science content. She did not always open up for genuine exploration of the learners' personal views of concepts. There were times when she opened up for dialogue, though. For example in the lesson on waves she opened with a dialogic discussion of learners' experiences with how the Doctor "takes the pulse" of a patient and discussed with the learners how that pulse was different from the pulse they would be generating with the slinky spring. She then got the learners to describe in their own words the pulses they had generated with a slinky spring. Also in the lesson on bond energy she engaged the learners in several episodes of dialogic interaction when she led the class through a series of question and answer episodes to get them to interrogate one of their peers' misconceptions on the circumstances under which negative ions formed. In the process she unearthed common misunderstandings among several other learners in the class. She therefore, alternated between dialogic and authoritative discourse in the way that she shaped interaction in her lessons.

Mrs Thoba's communication style therefore, incorporated mostly interactive, authoritative and dialogic episodes making her communicative approach largely Interactive-Authoritative (IA) with a tendency to Interactive-Dialogic, particularly in the lessons on waves and on bond energy. These were often interspersed with episodes of NonInteractive-Authoritative communication where the teacher engaged in telling or exposition episodes. Some of the latter episodes happened in the lesson introduction when she provided new concepts or information that the learners would need later to engage with the rest of the lesson. Most however, happened during the course of the lesson and it seemed that Mrs Thoba used this approach even where a more open dialogic approach would have served the purpose of the lesson better. I will illustrate this teacher-learner interaction in the next few paragraphs as I discuss Mrs Thoba's communicative approach.

Characterisation of the interactive discourse to determine the nature of teacher-learner interaction and the level of learner participation yielded discourse patterns ranging from the traditional IRE (Mehan, 1979; Sinclair & Coulter, 1975) to the IRPRP chains as described by Mortimer and his colleagues (Scott & Mortimer, 2005; Scott et al., 2006). In the IRPRP

chains the teacher initiates the interaction and then follows up on learner responses in an elaborative manner by probing learner ideas further in a series of turns. If such an interaction ends with an evaluation move then it is a closed chain. An open chain can end with a learner contribution or with teacher feedback that is not evaluative but which provides further clarification or additional information. There was more evidence for more IRPRPR ...E closed chains than there was for the IRPRPR open chains in Mrs Thoba's lessons as will be illustrated shortly. Another type of interaction that I observed in Mrs Thoba's lessons has been described in mathematics classrooms in South Africa. In the IRRR ...E chain described by Brodie (2007) one initiation move triggers a series of learner responses as they engage with each other's ideas directly. In one of Mrs Thoba's lessons this interaction took a slightly different form in that as learners responded to each other's ideas they did not direct their talk at each other but used the teacher as a point of reference.

In the next few paragraphs I present excerpts from Mrs Thoba's lessons on waves and on bond energy to illustrate both the interactive nature of the lessons and the teacher's communicative approaches in each case. In the process I also discuss for each episode the resultant discourse type and the teacher interventions that shape the discourse.

The first two excerpts are taken from the lesson on waves. After introducing the concept of the pulse by referring to a visit to the doctor and how the doctor takes a pulse, the teacher then put the learners into small groups and gave each group a slinky spring to create and observe a single pulse. The excerpts below are based on the interaction between the teacher and the learners during the course of this practical exercise. In the first excerpt the learners were busy trying to create their own pulse on the slinky spring and the teacher walked around checking progress and helping with manipulation of the spring. In the second excerpt the teacher stopped the activity and took the class through a teacher-led discussion in which learners had to describe what they had observed. In both excerpts the teacher interventions that shaped the discourse were mostly evaluative with some elaboration as the teacher probed learners thinking. The teacher used open questions to open up the dialogue and closed questions to funnel towards the scientific concepts. As a result the interaction shifted between episodes of IRF and IRPRP...E patterns of interaction:

10	Teacher:	hold it firmly. One person holds it. Hold it firmly. Once, move it sharply
	Learners:	<i>(move the spring)</i>

- Teacher: Do it again. Observe.
 Learners: *(move the spring again)*
 Teacher: There you are. What did you observe? *(moves to the next group)*
 15 Learners: *(the second group of learners move their spring)*
 Teacher: There you are. What did you observe? *(moves to the next group)*
 Learners: *(a third group of learners move their spring)*
 Teacher: there you are
(Turns 10-18 from transcript of lesson on Waves)

In this episode the learners had to move the spring such that it created a pulse. Then they were to observe and try to describe the pulse. Meanwhile the teacher mediated the interaction, showing and telling them how to move the spring so as to get the desired effect. She wanted the learners not only to engage in the physical exercise of creating the pulse but also to think and talk about it among themselves. This created an interactive discourse with both teacher-learner and learner-learner interaction.

The episode was also dialogic in that the teacher allowed the learners to make their own observations. Although the learners did not give direct answers to her question, “What do you observe?” they did move the spring in response to the teacher’s instruction and did observe what was happening. The teacher initiated (I) the intervention with a brief explanation of how to manipulate the spring and then gave an instruction to “.. move it sharply” to which the learners responded (R) by moving the spring. All of the teacher’s subsequent interventions, “There you are” were evaluative (E) but also elaborative (P) in that the question “What did you observe?” to which the teacher did not demand an immediate answer seemed to be an injunction to learners to think about what they observed. The emerging pattern of interaction therefore, shifted from a simple IRE to include some IRP triads giving it the feel of an IRPRP...E discourse. The effect was that learners engaged with the activity and talked animatedly among themselves about their observations. In the process of this social interaction they would be formulating individual understandings of what they were doing. This type of interaction could be viewed in the light of the Vygotskian (1978) notion that meaning making happens first in the external inter-psychological plane and then becomes internalised into the intra-psychological plane as the individual makes sense of the concept. The teacher’s Interactive/Dialogic approach in this episode opened up the interactional space for learner involvement and the potential for individual formulation of their own views of what they observed. In the next excerpt the teacher switched to a mixed approach alternating between Interactive/Dialogic and Interactive/Authoritative communication.

After writing the question “What moves along the length of the spring?” on the board the teacher led the class in a discussion of what they had observed:

- 44 Teacher: ok what moves along the length of the spring? What is it that moves?
- 45 Thami: *(inaudible)*
Teacher: we call it a pulse. A pulse moves along the ...? Length of the spring.
Class: length of the spring
Teacher: ok can we discuss that movement? How was it?
Class: *(talking at the same time)*
- 50 Nosipho: *(inaudible)* ... it goes left and right the . . *(inaudible)*
Teacher: *(ignores Nosipho and addresses another learner)* no we are not talking about the heart beat here we are talking about the movement of the pulse. How does it move?
Tebogo: like Maam if uyagijima kakhulu *(it is like when you run a long distance Maam)*
Teacher: yah but just discuss the movement. How does it move? Does it move straight?
Class: Nooo *(Excitement, commotion, talking at the same time)*
- 55 Teacher: *(points to a male learner)*
Sandile: its like a wave Maam its like a wave
Teacher: its like a wave?
Class: amanzi ... *(water...) (Inaudible)*
Teacher: how does it move? Like a frog? *(making movements with her hand)*
- 60 Class: *(more excited talking all at the same time)*
Teacher: ok others say it moves like a snake. How does a snake move? *(Teacher and learners together imitate movement with hands).*
Teacher: ok lets say this is our spring *(drawing a horizontal line on the board with two vertical lines at either end)* ok we create a pulse it is going to move up down up down to that ... direction
(Lines 44 – 62 from transcript of lesson on Waves)

In this episode the teaching purpose was again to explore learners’ perspectives of the practical exercise by getting them to articulate their understanding of what they had observed. The teacher opened the discussion in turn 44 with the question “What moves along the length of the spring?” which sounded like a genuine elicitation question for learners’ ideas. However, from the teacher’s intervention in response to Thami’s answer it becomes apparent that the teacher’s intentions were not completely dialogic. While she wanted to know Thami’s thinking about what he had observed she also now wanted to pursue the scientific story of the lesson. To do this she responded elaboratively inserting a scientific explanation of Thami’s answer. This was an authoritative move that funnelled the interaction towards a desired scientific answer. Thus the teacher was now moving from her initial Interactive/Dialogic approach and while maintaining the interaction she was now taking a more authoritative stance, adopting an Interactive/Authoritative communication approach. Her intervention style also shifted. For example, her next question “... can we discuss that

movement? How was it?”, which sounds like a genuine call for open dialogue was in fact a funnelling question. This is evident in her response to Tebogo “Yah but just discuss the movement how does it move?”, which would indicate to the learners that there was a preferred answer to the teacher’s question. The effect (and perhaps the teacher’s intention) may be to shut out some ideas that are not likely to meet the teacher’s expectations. Mrs Thoba’s next question seemed to confirm this as she now played devil’s advocate and deliberately described the movement inappropriately, “ ... does it move straight?” and again in turn 59 “How does it move? Like a frog?” Although this would provoke learner thinking it would also suggest to them the direction in which the teacher wanted that thinking to proceed. This might also provide learners with a sense of the goals of this discussion and it could serve to mediate for the learners the expected norms of engagement. This was evident as the interaction proceeded from turn 60 where some learners suggested that the pulse moved like a snake. The teacher was open to this idea which she took up and used to make her final point about the pulse movement thus bringing back the dialogic tone to the interaction.

Scott and his colleagues (2006) argued that this tension will always exist in science lessons due to the inherent tension between the lesson’s goal of presenting the science (an authoritative discourse) and the teacher’s desire to engage students’ ideas to facilitate meaning making (dialogic discourse). They argued that science is by nature an authoritative subject and the teacher is compelled to take on an authoritative stance so as to achieve the goal of the lesson which ultimately is about mastery of an established body of knowledge. However, learners need to engage with the science content in order to make sense of it and construct their own understandings of the concepts. To allow for this meaning-making the teacher has to open up for dialogic discourse, hence creating a tension between the two seemingly opposing styles of communication.

This tension between Interactive/Dialogic and Interactive/Authoritative communication was evident also in Mrs Thoba’s other lessons. The excerpts below taken from her lesson on bond energy illustrate how Mrs Thoba’s approach alternated between the dialogic and authoritative as she sought on the one hand to maintain focus on the objectives of the lesson and to deal with erroneous learner understanding, on the other.

- 121 Teacher: She says that if they come closer the hydrogen is going to become negative because of the attraction force. What do you think about that?
 Vuma: Er Maam I much agree
 Teacher: You agree?
 Vuma: Yes Maam coz Maam when they bond covalently they are bonding to achieve the nearest noble gas right?
- 125 Class: Yes yes
 Vuma: ok then, so ...
 Class: *(general laughter)*
 Vuma: soon as they reach the noble the nearest noble gas both of them what they share and then soon as they are sharing er both of these er they become negatively charged
- (Lines 121-128 Transcript of Bond Energy lesson)*

The interaction in this episode takes on Brodie's (2007) IRR...E pattern. In the first turn, the teacher's initiate (I) move, she repeated a learner's response to an earlier question, "What do you think will happens as the two atoms (*involved in formation of a covalent bond*) come closer to each other?" A learner, Tahari, had responded that the two atoms would become negatively charged. Although the teacher's question had been phrased like an open thinking question it was actually a closed question, designed to funnel learner thinking in a specific direction, the change in potential energy. Tahari's response had surfaced a misunderstanding of either the concept under discussion, changes in potential energy or of how negative ions are formed. Thus, the teacher's question at the beginning of this episode (turn 121) served to foreground Tahari's thinking for interrogation by her peers which might expose other learners' thinking. The teacher first took a dialogic and then an authoritative communicative approach in an attempt to balance the two goals of genuinely exploring learner thinking about Tahari's response and funnelling their thinking towards an acceptable scientific view. In the eight turns in the episode above the teacher only asked two questions, the opening question and the "Why?" question as a follow up to Vuma's claim that he agreed with Tahari's statement. The resultant interaction appeared to be an IRPRRR as the teacher allowed Vuma three uninterrupted turns to express his understanding of the statement. Clearly Vuma's thinking about formation of the covalent bond was a bit muddled as is evident from his attempt to use two pieces of contradictory evidence to justify his position. The episode closed seemingly without any evaluation from the teacher. However, the opening statement in the very next episode suggests an evaluation of the previous episode's interaction. The teacher initiated the interaction in the next episode with a direct question "When does an atom become negatively charged?" (turn 151) which can be interpreted as an evaluation of the learners previous responses which had failed to provide a solution for the problem under discussion. At this point two learners entered the conversation, Thinta, a new entrant who

disagreed with Tahari's statement as well as Tahari herself who now provided justification for her thinking. The previous Interactive/Dialogic interaction seemed to have opened up the interactional space for these learners to join the discussion.

- 151 Teacher: When does an atom become negatively charged?
Teacher: (*pointing to a boy*) Let me give you a chance
Thinta: Maaam I disagree with the statement coz Maam I think when the two atoms (*inaudible*) the chemical potential energy will increase
Teacher: Why do you disagree with the statement?
155 Thinta: Its because Maam when the the two atoms interact its impossible for them to be negatively charged.
Tahari: Maam didn't you say...?
Teacher: Why?
Thinta: They are not yet touching Maam.
Class: Yes yes yes
160 Tahari: Maam didn't you say when they er when they get closer to each other when they attract each other the potential energy it will decrease
Thinta: Its like this... (*Holding a pen and set square in each hand and moving them towards each other*)
Tahari: It will decrease...
Thinta: They are not yet touching Maam.
Tahari: Maam you said you said the potential energy will decrease and therefore those atoms are going to be negatively charged

(Lines 151-164 Transcript of Bond Energy lesson)

The teacher's communicative approach shifted in this episode to an authoritative one. In his opening statement Thinta pulled in evidence of the potential energy changes. However, the teacher ignored that evidence and instead asked Thinta to justify his claim that he disagreed with Tahari's statement. Again this was an interesting form of teacher uptake of learners' ideas. On the one hand, the teacher's approach served to maintain Tahari's idea in the public space of classroom interaction for further interrogation within the context of Thinta's disagreement with it. On the other hand, by insisting that Thinta explain why he disagreed with the statement the teacher might send out a message to the rest of the class that Thinta's could be the acceptable scientific way of thinking about the issue at hand. Clearly, the teaching purpose here was no longer just to explore learner thinking as in the dialogic episode in the previous excerpt but more to mediate learner understanding of the concept. This is evident in the way the teacher continued her interaction with Thinta. In response to the teacher's demand for him to justify his initial statement Thinta simply stated that it was impossible for the two atoms to be negatively charged. When Tahari attempted to bring in evidence from what the teacher had said earlier on the teacher ignored her contribution and again asked Thinta a "Why?" question, another call for him to justify his statement. In this decidedly authoritative approach the teacher seemed to be funnelling Thinta's thinking

towards a realisation or recall of the fact that in covalent bonding atoms did not acquire a charge. The teacher then allowed the dialogue between Tahari and Thinta and the rest of the class to proceed uninterrupted.

The teacher, taking an IA approach, then moved the discussion towards a conclusion, restating the statement under discussion and then asking a direct question as to whether the atoms would become negatively charged in such a situation. From the mixed responses in the chorus answer it was clear that learner understanding was still variable:

- 166 Teacher: Ok the statement is if the potential energy decreases then the hydrogen atoms are going to be negatively charged. Are they going to be negatively charged?
Class: No no yes no yes no
Teacher: When does a negative ion form?
Vuma: Its whereby Maam it gains er electrons
170 Teacher: Do we have any gaining of electrons here?
Class: No
Teacher: So how can a negative ion form?
Sabelo: Yes
(Lines 166-173 Transcript of Bond Energy lesson)

Following the chorus answer the teacher then took the class through an IRPRPRE sequence. However, this seemed to be a low level IRPRPE interaction in which the teacher reduced the cognitive demand of the question to a simpler, “When does a negative ion form?” to which Vuma immediately gave the correct answer. It was as if the teacher sabotaged her own efforts at creating the level of participation and engagement that she had achieved so far. Brodie (2007) argued that many teachers in mathematics classrooms in South Africa tended to reduce the cognitive demand of their questions in this way. However, it is possible that the teacher made a conscious decision to bring the discussion to an end and return to the day’s lesson from which she had digressed to attend to Tahari’s error. She continued with her initial explanation of how the potential energy would decrease of the two atoms would continue to decrease as they approached each other during bond formation.

The excerpts above illustrate the teacher and her learners’ movement back and forth between dialogic and authoritative communication styles and how this facilitated for learner participation in the classroom talk. Also how the teacher facilitated both for some learners to externalise their erroneous thinking and for the resolution of their cognitive conflict. To get to the bottom of the problem the teacher would have to engage these learners in the kinds of

extended interactions as seen above. In the process however, the conversation tended to be restricted or limited to only a few participants and tended to shut out other learners. The challenge for the teacher is how to focus on resolving a particular learner's misunderstanding without "forgetting" the rest of the class. This may be an area for further research to determine the dynamics of teacher intervention in relation to teaching purposes in classrooms with learners of multiple abilities and educational backgrounds as was the case for Mrs Thoba and the other teachers. It is important for science education research, for pre-service teacher education and other teacher professional development programmes to take cognisance of the need for teachers to be conscious of this tension and come up with ways to help teachers handle it such that both the goals of addressing individual learner understanding and of including other learners are achievable.

Another question that emerges from these observations is the question of effective learner engagement with the content. It is not clear for instance, whether the misconception in the bond energy lesson was resolved and if so whether it was resolved for all the learners who verbally expressed their misunderstanding as well as those who were silent. I take this up again in Chapter 6 when I discuss learner engagement (or lack thereof) during dialogic discourse. This suggests the existence of another kind of tension, between the complex need to balance dialogic discourse that seeks to explore learners' understandings as well as mediate meaning making with dialogic discourse that in turn seeks to invite as many learners as possible to participate in the discussion.

5.2.2 Characterisation of teacher-learner interaction in Mr Far's whole class lessons

All of Mr Far's lessons were also interactive (see details in Appendix 5.02) with considerable learner involvement in the discussion through question and answer sessions. The two lessons considered in this chapter are typical of Mr Far's style of involving learners. In the lesson on properties of compounds he had learners perform a demonstration of the reaction of magnesium with oxygen to form a compound magnesium oxide. Observations from other science classrooms that I worked in during the course of my study as well as from literature indicate that this is not a common practice of science teachers in township schools. First, most science teachers tend not to use practical activities in their teaching, especially those that involve the use of real scientific equipment or where the classrooms are as crowded as Mr Far's was in this case. That Mr Far actually used the science kit to show learners how

magnesium changed during a chemical reaction was quite commendable. Secondly, where the physical environment is conducive to small group work teachers are known to perform demonstrations themselves rather than involve learners (Hattingh, et al., 2007; Stoffels, 2005b). Mr Far actually had the learners conduct the practical exercise themselves. Similarly in the lesson on momentum, the learners were involved in simulating collisions and in attempts to provide explanations for their observations. Once again Mr Far was quite creative in having learners use whatever objects were available to them to engage with the concept of momentum. in which they generated and described their own pulses. I will now illustrate how Mr Far's style of communication afforded the forms of learner engagement just described and the patterns of interaction that emerged in the lessons.

Although like Mrs Thoba, Mr Far maintained a largely authoritative communication style focussing on maintaining the scientific story, he often made interesting shifts towards dialogic communication. In doing so, he drew alternately on formal ways of science talk and informal forms of engagement with learners opening up for dialogue in his lessons. Mr Far's communicative approach was mainly a mix of Interactive-Authoritative (IA) and Interactive-Dialogic (ID) with a considerable incidence of NonInteractive-Dialogic (NID) and NonInteractive-Authoritative (NIA) communication episodes. The NID and NIA communication occurred as telling or exposition episodes in the lesson introduction and during the development of the scientific story and in where the teacher engaged in episodes.

In the next few paragraphs I present excerpts from Mr Far's lessons on compounds and on momentum to illustrate both the interactive nature of the lessons and the teacher's communicative approaches in each case. In the process I also discuss for each episode the resultant discourse type and the teacher interventions that shape the discourse.

The first set of excerpts are taken in sequence from the beginning, the middle and towards the end of the lesson on properties of compounds. With these excerpts I illustrate the tension between ID and IA communication approaches as Mr Far introduced the topic for the day, led the class to the demonstration and then onto engaging with and developing the scientific story. His interventions were largely in the form of open and closed questions, probing and foregrounding learners' ideas. I illustrate Mr Far's uptake of learner contributions as well as attempts to get his learners to evaluate each others' ideas.

My first example is taken from the lesson on properties of compounds. In the first excerpt the teacher was introducing the topic for the day. Mr Far did a few interesting things in this opening episode including exploring learners' ideas and checking prior knowledge of some of the key concepts for the day. Through a question and answer session he extracted specific information, particularly definitions of terms. However, he also did what Scott, Mortimer and Amettler call link-making for continuity (Scott, et al., 2011). Link-making describes pedagogic moves to mediate learner understanding of current concepts (link-making for knowledge building) or to make connections with concepts and/or topics covered before, in past lessons or earlier in the current lesson (link-making for continuity) as well as stimulating learner interest, motivation or change of attitude (link-making for emotional engagement). In this case Mr Far facilitated link-making for continuity as he called on learners not only to recall the definitions but to remember how they had worked with the same terms in the previous lesson:

- 5 Teacher: they are elements what else? They are elements they are gases
 what else do you know about hydrogen and oxygen? So we are
 using the terms now elements we are using the term gases we are
 using what else? If you think about hydrogen ... Tebogo?
- Tebogo: I would say Sir compound
- Teacher: Now you are using another word. We are saying we know what is
 an element (*teacher writing words on the board*) we know what is
 a compound a chemical compound ... Now just briefly is there
 anyone in this class who can refresh our memory with regard to
 an element? Definition? What do you understand by the word
 or concept element? Simphiwe?
- Simphiwe: a substance that cannot be broken up into smaller particles
- Teacher: He says a substance that cannot be broken up into smaller
 particles. Right so that is one definition that you are supposed to
 know. Remember that Monday we struggled to find this. Any
 other person that can tell us the definition of compound?

(Lesson on properties of compounds, turns 5 - 9)

The episode above opened with Mr Far exploring learners' ideas of elements, compounds and mixtures through a question and answer session in the form of a traditional IRE/F discourse type. When Tebogo (turn 6) introduced with the word "compound" the teacher responded with evaluative feedback, affirming Tebogo with "Now you are using another word" and then proceeding to write the word on the board together with the word "element". His feedback then switched from evaluative to elaborative as he continued to foreground the two words and asked if there was "anyone in this class who can refresh our memory". This link-making move by the teacher suggests that the class should remember these concepts from previous lessons and this was confirmed in turn 9 when the teacher made reference to how they had

struggled with the concepts the previous Monday. Mr Far took this approach in most of his lessons, drawing learners' attention to related concepts and principles within and between lessons. In the present lesson he made these links again during the body of the lesson as he developed the scientific story as well as towards the end of the lesson as he summarised the key concepts for the learners.

As this episode opened it seemed that Mr Far might be taking a dialogic approach eliciting learners' ideas, but it quickly became evident that he was taking an authoritative stance. His communicative approach was clearly Interactive-Authoritative (IA) as he asked a series of closed questions and offered evaluative feedback. In the rest of the lesson he took on both dialogic and authoritative approaches. During the demonstration of the burning magnesium he allowed for a largely dialogic communication between himself and the learners as well as between the learners. Talk ranged from formal science talk about the science of magnesium oxide formation to a mix of formal and informal talk about laboratory rules and how to make the current experiment work. There was also completely informal talk (teasing and jeering) about the way the volunteers were conducting the experiment and/or about personal matters. The next excerpt is taken from a discussion much later in this lesson as the class waited for the volunteers to start the magnesium burning:

- 74 Teacher: *(to the class in general)* And while they are still struggling to ignite it I assume all of you observed the symbol on the bottle?
- 75 Class: Yes... No...
- Teacher: *(to class as volunteers struggle to ignite the magnesium ribbon)* Right so then we must think on our feet. Use a piece of paper and use the paper as the ... *(the boys find a piece of paper 2.5min)*
- Class: *(learners calling out)* Make it smaller ... use small paper
- Teacher: right so as small as possible. He doesn't think look at the girls giving instructions it means they are thinking and that is what the doctor said. He said to me one day it is so nice to see girls doing science. Equal opportunity
- Class: *(Jeering at the volunteers following the teacher's statement)*
- 80 Sobuka: *(one of the volunteers)* Hayi mina ngi famous *(Oh I am famous)*
- Class: *(general laughter)*
- Teacher: Right can we have two other volunteers it seems as if Sobuka is wasting your time *(next 5 lines talk by learners to each other)*
- Mandla: Girls never win they should try to win
- Stella: *(jeering at Mandla)*
- 85 Alan: *(to Sobuka)* uyabona lento yakho yokugophiphepha umlilo uyaphela *(your idea of folding the paper puts the flame out)*
- Sebuka: ayikho lento *(there is no such thing)*
- Sonto: Ikhona *(yes there is)*
- Teacher: *(to Sobuka)* Right so just take another piece and go clean it.
- Teacher: *(to the rest of the class)* Right in symbol form. Where is the bottle of the Magnesium powder? Lets have a look at it.
- (Lesson on properties of compounds Lines 74-89)*

As the two volunteers struggled to get the magnesium to ignite, the teacher talked them through the procedure while at the same engaging the rest of the class in a discussion of laboratory rules and the nature of chemical symbols (turn 74). He had passed the container of magnesium around with an instruction for the class to read the name and familiarise themselves with the chemical symbol. Meanwhile he and the learners engaged in other forms of talk like the jeering and teasing in turns 76-84. The class also offered suggestions to the volunteers on how to get the experiment to work and these were made in typical informal friendship talk. In turns 85-87, for example, Alan and Sonto's suggestion about folding the paper was made in teasing manner and Sobuka played along. When the magnesium did burn the discussion shifted as the teacher now focused on developing the scientific story of properties of compounds.

- 134 Class: Ohhh Ahhh (*as magnesium ribbon ignites*)
 135 Teacher: Right there we are. Please don't shake it just turn your hand around a little bit. I just want you to have a look at it. This is I don't want to use the word. But this is something that was formed after magnesium and oxygen have reacted (*laugh*) have reacted I can't use another word for now. So please look at this colour of it and write it down as well. So this becomes that word that I want of magnesium and oxygen
 Smitherson: what is that word?
 Teacher: If any of you start to cook at home and then you have poured all the ingredients in the pot
 Smitherson: a mixed ingredient
 Teacher: It's a mixed ingredient? It is a salad?
 140 Smitherson: mixture of ingredients
 Teacher: I am not gonna waste my time I'm not gonna waste my time. I am gonna say it is the product of, the product of. So now I already have this part of the word. When magnesium and oxygen react we get a product. So the right hand side of the chemical equation is called the product or products. Now what do we call the left hand side? If that gives us the product what will cause us to have a product?
 Smitherson: mixture
 Neliswa: ingredients
 Dana: (*inaudible*)
 145 Teacher: he says a ... say that again
 (*Lesson on properties of compounds turns 134-145*)

Amidst the learners Ohs and Ahs at the bright flame of the burning magnesium ribbon, Mr Far shifted the discourse to commence development of the scientific story linking what they had just seen with the previous discussion and moving on to the focus of the day's lesson, properties of compounds. The episode started off seemingly with an ID communicative approach but soon became an obvious IA. Some ID communication was implied in the statement, "I just want you to have a look at it ... So please look at this colour of it and write

it down as well” (turn 135). This approach was common in Mr Far’s lessons and not in the other two teachers’ lessons. Mr Far always instructed his learners to write something in their books and he mediated the writing by modelling it on the board and/or providing the correct words or spellings. In this excerpt he wanted the learners to write down the colour of the flame. In other excerpts discussed later he had the learners write their own hypotheses or record their observations during simulations of collisions in the lesson on momentum.

As the discussion continued, the teacher adopted an IA communicative approach and took the class through a question and answer session in a typical IRE discourse type taking full control of the direction of the discussion from that point onwards. For example, although the teacher intervention style seemed to suggest the teaching purpose of opening for learner ideas by eliciting, it was evident from the teacher’s approach in turn 135 that the real teaching purpose was developing and maintaining a scientific story. The teacher was targeting a specific word to describe the outcome of the chemical reaction, “But this is something that was formed after magnesium and oxygen have reacted ... I can’t use another word for now ... So this becomes that word that I want of magnesium and oxygen”. He wanted to get the learners to come up with the word “product” by getting them to think of a word that describes the outcome of the mixing of ingredients. He attempted to use a metaphor on cooking, providing clues for the learners while funnelling their thinking in the intended direction. When the learners could not come up with the correct answer he provided the answer himself, “I am not gonna waste my time I’m not gonna waste my time. I am gonna say it is the product of, the product of” (turn 141). This was another teacher intervention that was unique to Mr Far, the way he handled learner responses to his questions. After offering the learners some time to attempt to answer the question he would often say, “ I am not going to waste time”.

I observed this form of intervention often in Mr Far’s communication in this lesson. In the next excerpt I give another example of this form of intervention from earlier on in this same lesson on properties of compounds:

102	Teacher:	If there is a positive it is in between those two variables. What else makes it an equation? Right so we have term1 term2 what else? Because we are saying there is a sign between it becomes two different terms. What else makes an equation an equation? If I have to balance a mathematical equation what do I need to do?
	Phila:	formula ... (<i>inaudible</i>)
	Teacher:	Which formula?
105	Phila:	... how to calculate (<i>inaudible</i>)

- Teacher: I don't wanna waste time. I'm gonna help you. In mathematics a mathematical sentence is not a sentence unless there is an equal sign in it for our purpose because it can be greater than less than less greater or equal to. If there is no equal sign then it doesn't become a sentence. That is mathematics. So in mathematics it means an equation will have a sign and it must have an equal sign. But look at what I am doing instead of an equal sign I put a ...?
- Class: arrow
- Teacher: Arrow. So in a chemical equation we are not using an equal sign but a ...?
- Class: Arrow
- 110 Teacher: Arrow.

(Lesson on properties of compounds, turns 102-110)

At this point Mr Far and his learners were constructing a word equation for the chemical reaction of magnesium with oxygen while waiting for the demonstration to work. In turn 102 the teacher provided the learners with clues for the answer that he wanted. When two attempts by Phila (turns 103 & 105) to provide an answer failed, the teacher again declared, “I am not going to waste time. I am going to help you” (turn 106), and went on to provide the answer. He then engaged in a brief telling session, explaining the role of the equal sign. This was followed by an IA episode in which he drew an arrow into the chemical equation and through a brief question and answer session led the learners to the correct answer, “Arrow. So in a chemical equation we are not using an equal sign but a ...?” (turn 108). Thus, in developing the scientific story the teacher was also highlighting some conventions for learners to be aware of and in this case it was the distinction between a mathematical and a chemical equation. Other conventions were similarly highlighted in other episodes. In the excerpt below also from earlier in the same lesson the teacher worked with the concept of hypothesis formulation as part of doing science:

- 43 Teacher: So I will need two volunteers two people to assist me with the experiment but before we come to the experiment remember I'm saying we are performing the experiment with regard to magnesium and air. So write down your hypothesis. What do you think is going to happen if those two chemicals react? If those two chemicals react what do you expect to see? So that will be your hypothesis
- Class: *(writing - 17sec)*
- 45 Teacher: So please write down what do you think is going to happen? What you expect to see? And please think about how fast it will happen if possible or how slow it will be if possible. Musa are you done? Because I need a volunteer, Musa.
- (Teacher and 2 learners prepare the experiment while the others write their hypotheses 32sec)*

(Lesson on properties of compounds, turns 43-45)

It seems that Mr Far's learners were familiar with the concept of a hypothesis since he did not have them first define the word as he usually did with unfamiliar terms. What he was more concerned about was the actual process of formulating a hypothesis and for that he provided such guiding questions like "What do you think will happen if those two chemicals react? If those two chemicals react what do you expect to see? So that will be your hypothesis" (turn 45). Again this is not a common practice of science teachers in South African classrooms. Literature records cases of teacher difficulties in engaging effectively with either the procedural or epistemological aspects of practical work. For example, Stoffels reported in separate studies of uncritical use of textbooks by teachers in both well resourced and under resourced schools in guiding practical work in their classrooms. While the two teachers in one study both espoused the merits of OBE, which implies a measure of learner autonomy, they tended to revert back to traditional recipe style practical work (Stoffels, 2005a, 2005b).

Also in the excerpt above, the learners were again writing in their books, which as I said earlier was a more common practice in Mr Far's lessons than in the other two teachers'. Later in this lesson he had learners on the board writing out the chemical equation in symbols:

- 166 Teacher: are you ready? Here is the board. They are not ...phew... Zama?
you wanna try? Here you are
Zama: *(teacher gives chalk to Zama)*
Teacher: Remember I asked you to write the symbol of magnesium and
oxygen. Now our product is magnesium oxide. Now you need to
write in symbol form for me.
Learners: *(Kgotso and Zama at the board)*
170 Teacher: and while he is doing that I will walk around and see if anyone in
the class has completed it and I see some have not even started.
Kgotso: *(indicates that he has finished)*
Teacher: Thank you Kgotso. We will have a look at it just now. I am
having a look at some of the girls. Right so I have noticed that
most except for these girls they
haven't started writing yet.
Class: *(talking softly as they write their equations in their books)*
(Lesson on properties of compounds Lines 166-173)

Two learners, Kgotso and Zama were called up to the board to put up the chemical equation for the reaction. From the teacher's instructions it was clear that he wanted them to make a connection between what they had started writing in their books earlier and the discussion that had just taken place to identify and name the product of the reaction. The teacher made the link clear in turn168, "Remember I asked you to write the symbol of magnesium and

oxygen. Now our product is magnesium oxide. Now you need to write in symbol form for me.” Meanwhile he was walking around checking that the others were writing in their books. As he walked around he was able to identify learners who were not writing and one, Noni, who seemed to have got the equation wrong (turns 172-174):

Teacher: (to Noni) Why do you have water?
 Class: water?
 Teacher: (to Noni) Magnesium oxide it's Magnesium oxide

Noni was one of the learners who did not talk in this and other lessons and it would therefore be hard for the teacher to know if she and the others understood the concepts under discussion. It is only as learners used talk as a tool to externalise their thinking that the teacher could know what was going on inside their heads. Writing was another way for learners to externalise their thoughts and Mr Far took the time to make them write and then walked around to look at what they had written. If he had not done that he would not have been able to identify their misconceptions and errors as they were silent in class. I illustrate this approach again later in this chapter from Mr Far's lesson on momentum.

The last excerpt from the lesson on properties of compounds comes from a discussion at the end of the lesson. This excerpt illustrates how Mr Far worked with the tension between IA and ID to mediate all three forms of link-making; link-making for knowledge building, link-making for continuity as well as link-making for emotional engagement. At the beginning of the lesson the teacher had the learners recall definitions of the terms molecule, element, mixture and compound and in turn 37 he said “Why am I doing this again? Because I'm gonna come back to the molecule later ...” in the excerpt below in turn 345 he makes the link to that earlier conversation. The equation under discussion was $\text{Mg} + \text{O}_2 \rightarrow \text{MgO}_2$.

177 Class: Mg Mg
 Teacher: Right so the symbol for Magnesium is Mg
 Thabisile: plus O-2
 180 Teacher: what are you saying Thabisile? Say that again
 Thabisile: (silent)
 Teacher: hah? Why are we writing it as O-2 and not as O? Why are we writing it as O-2 and not as O? Remember I said when I started that I will come back to the specific definition a specific term
 Kgotso: oxygen is diatomic
 Teacher: Thank you very much so oxygen is a diatomic molecule. Is there anyone else that will explain to us what we mean by the term molecules? Raesibe?
 185 Raesibe: tiny units ...(inaudible)
 Teacher: say that again

- Raesibe: tiny units made of atoms
Teacher: He says tiny units made up of atoms. It's acceptable because it is a number of atoms So a molecule it is the amount of atoms that we are having. The amount of atoms that we are working with? Now what is a diatomic molecule? What does the word diatomic refer to? Kabelo? Shake your head(inaudible)
Teacher: Lerato what does the word diatomic stand for?
Lerato: *(muttering)*
190 Teacher: She is asking you Melo she is saying you will give us the answer
Melo: *(muttering)*
Teacher: What does di- mean?
Melo: *(muttering)*
195 Teacher: someone is screaming it out. They are afraid. Why are you afraid? Bongani? Have confidence and say that it is two.
Teacher: *(to Bongani)* So diatomic means?
Bongani: two
Teacher: So if Magnesium reacts with oxygen Kgotso wrote this down.
(Lesson on properties of compounds, turns 177-198)

The episode above came from an interesting discourse type in the form of a (I)RRPRPRE closed chain. Mr Far was now reviewing the equations that Kgotso and Zama had put up on the board. The teacher had made the initiate, I, move earlier, to which the class now responded, R, by providing the symbol for magnesium (turn 177) and before he could continue Thabisile made another (unsolicited), R move calling out "Plus O-2". This was an unsolicited learner contribution but appropriately presented as the next term in the equation that they were constructing. Thabisile's reaction to the teacher's intervention in turn 181 is interesting. Her reluctance to repeat her answer implies that she may have interpreted the teacher response in turn 180 as negative evaluative feedback. However, the teacher's follow up in turn 182 suggests that he was genuinely probing (another P move), for Thabisile's understanding of the difference between the molecule of oxygen, O₂ and its atom, O. This is confirmed by the teacher's response to Kgotso's answer that oxygen is diatomic (an R move, turn 183). The teacher thanked Kgotso (turn 184) and repeated his answer, thereby affirming him (Evaluation move, E) and marking his answer as correct and probably important. This E move by the teacher would close the chain so that the teacher's next utterance was likely to be an initiate, I move, opening up a new discourse chain.

This was indeed true of the teacher's statements in turn 184, "Thank you very much so oxygen is a diatomic molecule. Is there anyone else that will explain to us what we mean by the term molecules?" After evaluating and affirming Kgotso's answer the teacher initiated a new discussion on the definition of a molecule, linking this episode to an earlier one (turn 37) where he said that he would come back to the definitions later in the lesson. Meanwhile he

was also mediating for the learners an important link-making for knowledge construction (Scott, et al., 2011). The questions in turns 180 and 182 had been raised to check understanding of the concept of molecules (O_2 versus O) and in the rest of the episode the teacher questioned, probed and provided cues for learners to distinguish between a diatomic molecule and other (mono atomic?) molecules.

In the second half of this episode the teacher also performed Scott, Mortimer and Ametller's third form of link-making. The authors identified the third form as link-making for emotional engagement through which teachers strive to motivate, instil an interest and afford some enjoyment of the engagement with science content. In this case Mr Far picked up and addressed learners' reluctance to participate. From his remark in turn 191, "She is asking you Melo she is saying you will give us the answer", it seemed that the teacher had reason to believe that Lerato knew the answer but would rather Melo said it out. However, even Melo would not say give the answer. Meanwhile, another learner, Bongani, called out the answer without raising his hand or identifying himself. Unfortunately (for Bongani!) the teacher was able to identify him and called on him to be confident, "Someone is screaming it out. They are afraid. Why are you afraid? Bongani? Have confidence and say that it is two" at which Bongani called out "Two" (turns 195-197).

Similar interesting forms of engagement were observed in Mr Far's other lessons. The next set of excerpts taken from his lesson on momentum illustrate a similar pattern of communication between him and his learners. Again the lesson started with a session to "... just refresh quickly" (turn 12):

3	Teacher:	according to eh the definition of momentum it can be regarded as a measure of the product of the mass and the velocity. Now Kelvin if you think about mass and velocity think about mass in terms of the quantity can we regard mass as a vector quantity or is it a scalar quantity?
	Class:	vector ... scalar... scalar ... vector
5	Teacher:	now I will say that again think about it carefully
	Class:	<i>(talking among themselves)</i>
	Teacher:	think about mass where do we find mass because she has used the words mass and velocity
	Len:	scalar because
	Teacher:	why?
10	Kelvin:	because yah the mass is got size
	Ben:	yah its
	Martin:	mass is got size

- Teacher: so why am I asking this? Because our biggest problem that we experience and encounter is that most of us cannot distinguish between this and that (*scalar and vector*). So let's just refresh quickly. Len you said this is scalar why are you saying its scalar?
- 15 Sisa: because it has size only and no direction
- Teacher: thank you very much so we only have size which can be ...
- Busi: magnitude
- Teacher: magnitude. And here we have size or magnitude
- Busi: no direction
- Teacher: so this is what we are having we are having a scalar quantity which is mass and velocity a vector. Now remember what is momentum in real sense? We wanna make it simple in our heads coz we are labelling this thing. What can you describe momentum as? A simple word?
- 20 Len: collision
- Kelvin: colliding
- Teacher: thank you very much so we can regard momentum as a ...
- Class: collision
- Teacher: Collision. Before I come to where I want to go what is the symbol for momentum? This is work that we have done last year what is the symbol for momentum what is the unit for momentum?
- (Turns 3-24 from lesson on momentum)

The teaching purposes in this episode were mainly to introduce the topic of the day, starting with a review of prior knowledge of key concepts like scalar and vector quantities. The teacher's predominant interventions were elicitation and evaluation with mostly closed and some open questions. The teacher maintained control of the direction of the talk and adopted an IA communicative approach. The discourse type was largely IRE/F with the occasional IRPRPE closed chain. For example, in the first IRE triad in turns 3-5 the teacher opened the discussion with a closed question to Kelvin as to whether mass was a vector or scalar quantity (I), to which he got a mixed reaction from the class in general, with some learners shouting "vector" and others shouting "scalar" (R). The teacher's evaluative feedback (E) in turn 5, "I will say that again think about it carefully" was seemingly interpreted thus by the class who then engaged in private discussions among themselves to "think about it carefully" as the teacher had suggested. The teacher followed this with a clue about mass, which served as an initiate move for an IRPRRE discourse between Mr Far and five learners, Len, Kelvin, Ben, Martin and Sisa in turns 7-14. The chain stopped when the teacher made an evaluative statement in turn 15 thanking (and affirming) Sisa for her answer, thus indicating the end of the discussion. The evaluation was followed by a summary in turn 19 and a new initiate move for a discussion to find a simple word to describe momentum. This new discussion seemed to introduce an epistemological oversight on the part of the teacher or an outright misconception. The teacher accepted "collision" as a description of momentum without

qualifying the terms. While the two terms are related as in “impact” and “impetus” it is not scientifically correct to use them synonymously.

The next 15 minutes of the lesson were spent with learners simulating collisions with various objects and the teacher talking them through their observations. The following short excerpt from the practical activity illustrates again how Mr Far had the learners not only make their own observations but they had to write down and explain their own individual observations:

- 67 Teacher: Now this is what I want you to do. Take out anything you have in your pocket. Either you have two pens in your pocket take it out you have two coins you have two Pritt whatever you have take it out put it in front of you. This is the task you need to have those two objects that you have in front of you and make a collision make a collision then if you do that you have to look what type of collision can you have with your experiment whatever you have in front of you. So I will just walk around and see if you are with me. So put your objects two of them and then you collide those objects and look at the type of collision. *(Teacher walks around)*
- Nikitha: *(inaudible)*
- Teacher: Nikitha Nikitha is asking why do we need two?
- 70 Nikitha: *(inaudible)*
- Teacher: yes just throw it just let it collide Nikita
- Teacher: money money throw your money away and remember always what do we need to do? We need to *write down isn't it so?* what we are seeing or what we are observing then we work from there. Right? its a small experiment.
- (Lesson on momentum turns 67-72)*

Mr Far was quite creative about what he called “a small experiment”, asking learners to throw whatever it was they had on them and observe the type of collision. He walked around and instructed learners to write down what they saw (Turn 72). The nature of the practical activity in itself was conducive to learner participation as each learner had to conduct his/her own “small experiment” and observe. Also the fact that the teacher walked around as he talked the learners through the activity ensured that all participated. This was a highly interactive and dialogic lesson. Learners together with the teacher engaged in exploring learners’ ideas about collisions and together negotiated understandings of the terms as they talked about each of them in turn.

In the next two excerpts Mr Far’s teaching purpose shifted from exploring learners’ ideas and allowing them to explore their own ideas to developing the scientific story. His communicative approach changed from a fully interactive-dialogic one to an alternating between ID and IA communicative approaches:

- 77 Walter: Sir my observation Sir I had a two rand in one hand Sir
Teacher: yes different objects
Walter: so when I collide them the one rand went away which means the two rand is heavier than the one rand
- 80 Teacher: now describe to me exactly what you mean going away
Walter: the two rand pushes the one rand away Sir
Teacher: so someone else (inaudible)
Alan: equal masses I had two pens
Teacher: you had two pens of equal masses so we have one scenario different masses then we have the second scenario with same masses
- 85 Alan: ... (inaudible) different direction
Teacher: so you had (inaudible) this way and then it went different direction. Any other person? Yes P?
P: ... same as this
Teacher: how can it be same like this? How is it possible
P: (inaudible)
- 90 Teacher: ok
P: and they had the same mass ...(inaudible)
Teacher: right (in raised voice) he is saying he's doing this and I actually like this he says this might be his two pens throw them together they collide and they went opposite direction. Do you all see this?
Class: yes
Teacher: now describe this type of collision this type of collision (teacher hits his fists together and moves them in opposite directions) (inaudible)
- 95 Class: (inaudible)
Teacher: this type of collision
Altus: elastic
Teacher: now give me your definition of elastic
Altus: of elastic Sir?
(Lesson on momentum, turns 77-99)

In the episode above the learners were now reporting back on their observations of simulated collisions. The excerpt started with the teacher checking that the learners had finished writing their observations and then with Walter describing what he had done and seen when he made a one rand coin and a two rand coin collide. The teacher adopted a mix of IA and ID communicative approaches, eliciting learner ideas, questioning, probing and evaluating some but accepting others without evaluation. An IRFRPR open chain discourse ensued between him and Walter in turns 77-82. This open chain discourse resulted from an ID communicative approach commenced with an initiate move by the teacher (I) asking Walter to give a report, to which Walter responded in turn 77 (R) with a description of the coins that he had used, interrupted by the teacher in turn 78 with elaborative feedback (F) “Yes different objects”. In that statement the teacher affirmed Walter’s report with “yes” and then elaborated on it pointing out the fact that the objects were different. This would serve to mark the idea suggesting to Walter and the rest of the class that the difference was significant and would shift the talk from dialogic to authoritative creating the tension that Scott and Mortimer argue must exist if the teacher has to explore learners ideas while pursuing the scientific story. In

this case the teacher was indeed exploring learners' ideas about their own collision but also pursuing the teaching purpose of developing the scientific story on the basis of those ideas.

When Walter explained that his one rand coin “went away” because the two rand coin was heavier (response, R) the teacher probed (P) for an explanation of “going away” and then accepted the explanation (R) without evaluating it, moving on to solicit other learners reports (Turn 82). Alan's response in turn 83 confirmed that he had noted and taken up the teacher's point about the fact that Walter's coins were different. He started his report, “Equal masses I had two pens” and the teacher communicated his agreement by revoicing Alan's opening statement, elaborating on it, “we have one scenario different masses then we have the second scenario with same masses” (Turn 84). The teacher again took up and elaborated on Alan's next point that his pens went in different directions after the collision, again marking and foregrounding the idea. Finally, in response to a third learner, P who in giving his report gestured with his hands to illustrate movement of the objects, the teacher raised his voice and called the attention of the class to P's gestures.

In turn 92, the teacher made several interventions that finally linked his two teaching purposes, to elicit learner ideas and to develop the scientific story. First he affirmed P at the same time facilitating link-making for emotional engagement, “Right (*in raised voice*) he is saying he's doing this and I actually like this ...”, then he repeated P's gestures while paraphrasing his report, marking the idea as well as checking for consensus, “and then he he says this might be his two pens throw them together they collide and they went opposite direction. Do you all see this?” The teacher then took up P's idea (the gesture) and used it to get the class to think through and name the collision. Finally, Altus gave the correct scientific name for that type of collision as “elastic” (Turn 97). The teacher's next turn inevitably opens up a new episode to define an elastic collision. This kind of interaction continued throughout the lesson as the class identified the different types of collisions, the different energy changes and finally defined momentum itself. To end the lesson the teacher engaged the class in a non-interactive session taking an NIA communicative approach to pull together the different concepts covered and to get them to start thinking about the forces involved in the collisions.

As in Mrs Thoba's case, the excerpts show how Mr Far and his learners also alternated between the communication styles. Mr Far took a dialogic approach to explore learner

thinking and to involve them in practical activities and then switched to an authoritative style to develop the scientific story and explain new terms to the learners. His interventions tended to be evaluative resulting in mostly IRF triads and some closed IRPRP...E chains typical of authoritative communication. Mr Far's always made connections for the learners, engaging all three link-making strategies; link-making for knowledge building; link-making for continuity as well as link-making for emotional engagement. He engaged in meta-talk and had his learners writing in all his lessons and he used practical activities frequently whether in the form of teacher-demonstrations or learner simulations of collisions, for example. Mr Far also made the most small talk with his learners. It could be argued that he managed to create the kind of classroom environment described by Bishop and Denley (2007) where science learning was fun, and both teacher and learners dared to do things differently.

5.2.3 Characterisation of teacher-learner interaction in Mrs Nkosi's whole class lessons

Mrs Nkosi's lessons like Mrs Thoba's were generally interactive; she too involved her learners in classroom talk (see details in Appendix 5.03). Her key intervention was questioning and she often took her class through extended question and answer sessions. Mrs Nkosi combined different forms of questioning in her lessons, ranging from rhetorical questions (that did not necessarily require an answer) to closed questions (with one or a limited number of possible answers) to open and authentic questions that allowed learners to genuinely express their ideas and understandings. One way in which Mrs Nkosi's approach to interaction was different from the other teachers was that in all her lessons she and her learners always worked with written text. She either prepared a worksheet specifically for the lesson or had her learners refer to the textbook. Often she got the learners to take turns and read but there were times when she read to them. The discussion was always based on the selected text.

As in Mrs Thoba's case, Mrs Nkosi also maintained a predominantly authoritative style of communication but the proportion of dialogic episodes in her lessons was much higher than in Mrs Thoba's lessons. She too alternated between dialogic and authoritative discourse to a variable extent in each lesson. She adopted an Interactive/Authoritative as well as an Interactive/Dialogic communicative approach for the most part. In the conservation biology and respiratory diseases lessons for example her approach was more open to what learners

knew and believed about owls and about diseases of the respiratory system. In the lesson on gaseous exchange and the one on population dynamics on the other hand she maintained an authoritative stance channelling learner thinking towards the desired biological explanations while also opening up for learners to verbalise their individual understandings of the biological concepts under discussion.

There were two styles of communication in Mrs Nkosi's lessons that I did not pick up in the other two teacher's lessons. On one occasion in the gaseous exchange lesson she led her learners in a drill-like form of communication where they chanted after her repeating the term carbaminohaemoglobin over and over. The other communication style unique to Mrs Nkosi was what I called a look-alike or imitation Interactive/Authoritative communicative approach in which teacher-learner interaction was interactive in that the learners responded to teacher questions and it seems as if the teacher was channelling learner thinking in an authoritative style towards an acceptable scientific understanding or conclusion. However, when examined more closely it became apparent that the learners were not genuinely involved as the teacher did all the talking and then asked some rhetorical questions which did not require an answers but to which the learners chorused a word or phrase. I called this a look-alike or imitation Interactive/Authoritative pattern of interaction but it is to all intents and purposes a Non- Interactive/Authoritative style except that in this case the learner's voice is heard albeit in a chorus. These two communication styles resulted in many IRE/F patterns of interaction in Mrs Nkosi's lessons.

Other discourse patterns identified in Mrs Nkosi's lessons included both the open and closed IRPRP chains (Mortimer & Scott, 2003; Scott, et al., 2006) as well as the IRRR ...E chains (Brodie, 2007). These were shaped by a range of teacher interventions from the rhetorical questions that brought about the look-alike Interactive/Authoritative communication alluded to earlier, to the authentic questions that opened up the lessons for true dialogic interaction. In the discussion below I illustrate the pattern of interaction in Mrs Nkosi's lessons and show the nature of the interventions that determined her communicative approach and the resultant discourse patterns.

I consider first, some excerpts from the lesson on inhalation, exhalation and gaseous exchange. At the beginning of the lesson each learner received a copy of the worksheet that

the teacher had prepared for this lesson. The lesson started with a review of the previous lesson on blood circulation and then the teacher introduced the topic for the new lesson and emphasised what the learners had to know by the end of the lesson. She then led the class in a short brisk IRE session asking them questions that provided links between the present lesson and the previous day's lesson. This was followed by a longer session in which she brought one of the learners to the front and used her to demonstrate the mechanism of inhalation. The excerpt below begins midway through the open IRE episode and is followed by two from the demonstration episode. In these episodes the teacher was working to maintain a balance between two teaching purposes (Scott & Mortimer, 2005), developing the scientific story while constantly exploring and mediating learner understandings. To do this she would therefore need to move back and forth between Interactive/Dialogic and Interactive/Authoritative communicative approaches. However, as is evident from these excerpts, not all her communication was genuinely Interactive/Dialogic and Interactive/Authoritative:

- 40 Teacher: inferior vena cava yes that is going to be bringing in deoxygenated blood from the lower parts of the body. And from the upper parts...?
Class: (*chorus*) superior vena cava
Teacher: superior vena cava right so where will that blood be getting to? From the body to...?
Sindi: the heart
Teacher: the heart yes why is it supposed to get to the heart?
45 David: to get purified
Teacher : to the heart? It is purified somewhere else it goes from the body to the heart and it enters into the right what?
Class : (*talking loudly among themselves*)
Nombi: atrium
Teacher : right atrium so from the right atrium right what will happen it goes down when the muscles contract and a specific valve opens up which valve is that? So that it can
50 Class : (*talking loudly among themselves*)
Teacher : wait wait wait so that it can move from the right atrium into the right ventricle?
Mtha: tricuspid valve Maam
Teacher : tricuspid valve will have to open up right so then the blood will flow from the right atrium into the ...? right ventricle
Thembi: right ventricle
55 Teacher : then from there we said there is this specific artery now a specific artery which is going to transport this deoxygenated blood from the right ventricle to a specific part where something specific is going to happen what will that be?
Class : pulmonary artery
Teacher : good we are all clear about that the pulmonary artery will transport deoxygenated blood from the heart to ...?
Class : the lungs
Teacher : good why is this blood getting to the lungs
60 Class : to be purified

Teacher : so that it can be purified
(Turns 40-61 Lesson on Inhalation and gaseous exchange)

In this IRE sequence the teacher initiated the talk with a question to which a learner or group of learners responded and the teacher either repeated the learner's response or called out "Good" to confirm that the answer was acceptable. If the response was incorrect the teacher repeated the question and/or provided a clue. For example in turns 40-42 when David said that blood goes to the heart to be purified and the teacher responded "to the heart? It is purified somewhere else it goes from the body to the heart and it enters into the right what?" thus providing a clue to David that blood enters a heart chamber on the right and something important happens to it there. This gave the episode the feel of Interactive-Authoritative communication. However, this was a recitation interaction particularly because the learners were mostly simply reading the names off the worksheet. As Hardman and colleagues observed the resultant IRE sequences tended to be dominated by teacher explanation and learner recitation (Hardman, Abd-Kadira, & Smith, 2008). From the learners excited loud talk both to the teacher and among themselves it seems that the teacher's approach was achieving learner participation. What is in question though, is how effective that participation was in terms of meaningful engagement with the content. For example, David's answer, in turn 44, that blood was sent to the heart to be purified could be an indication of not just one misconception but several, for example, about circulation and the function of the heart or about the meaning of "purification" in biology which would have implications for understanding of the functions of other organs like the kidneys and/or the lungs. Although the teacher's evaluative response in turn 46, "to the heart?" may have suggested to David that his answer was wrong, the teacher did not immediately address the misconception and may have perpetuated herself when she referred to the processes of gaseous exchange in the alveoli as "purification" of the blood, in turn 61. I revisit this point in Chapter 6 when I consider Mrs Nkosi's dialogic pedagogic approaches.

The next excerpt helps to examine further the level of learner participation in this lesson. At this point in the lesson the teacher had brought a learner to the front of the classroom and was going to use her as a "model" to illustrate inhalation. She took on an Interactive/Authoritative communication approach:

- 71 Teacher: right she is going to be our model. You said we inhale oxygen from the atmosphere which means that oxygen will enter through?
Class: nose nose nose
Teacher: her two openings (*touching learner's nose*) what are these openings?
Class: nostrils nose nostrils
- 75 Teacher: the nostrils right? The two are separated by this part and we call this part the nasal septum right? The nasal septum (*writes it on the board*)
Teacher: right so (*holding learner's face*) oxygen then diffuses I am going to use the term and note those terms ok? The oxygen diffuses from the atmosphere through the two nasal cavities that you see so this is the part that we are talking about ok?
Class: Yes
Teacher: now you've got to note then you know when we talk of a cavity its something like a room ok? a room has the sides ok? (*points at walls*) it has windows the walls it has the ceiling as you can see as well as the floor ok?
Teacher: (*back to learner's face*) I can right say the same thing here the nasal cavity has the sides which are formed by the cheek bones and then this bone here can someone tell me what this bone is called? Do you know what this bone is? (*fingers around learner's nose*)
- 80 Dineo: which one?
Teacher: (*teacher moves her fingers from learner's nose up between eyes*)
Class: (*commotion*)
Teacher: ok this is the nasal bone ok? Forming the roof of your nasal cavity here
Class: (*loud talking among themselves*)
- 85 Teacher: and then this is the floor down here as you can see. You can just refer to the upper jaw ok? Then the cavity is here, (*touching each part in turn*) the sides the roof the floor. Now before even this air that we are inhaling reaches the lungs right certain things have to happen to the inhaled air right? For instance when it is cold obviously the air will be very cold
Class: yes
Teacher: and very irritating. Now that air is not supposed to reach your lungs in that state. So the air that she inhales (*indicating to learner to inhale*) Hhhm do so let's see (*learner inhales*) right so the air that she draws in if the temperature is low it is obviously very cold and very irritating so which means that this inhaled air must be warmed.
Class: warmed
Teacher: right? The inhaled air must be warmed. Now the question is what will warm this inhaled air?
- 90 Musa: the blood capillaries lining the nasal cavity
Teacher: wow good that's good. In other words when this inhaled air comes into contact with what with the blood capillaries lining your nasal cavity then it will be warmed. Why is it warmed? (*Turns 71-91 Lesson on Inhalation and gaseous exchange*)

At first glance this interaction looks dialogic but a closer look shows that only the teacher was really talking as she illustrated and explained the process of inhalation. Although she continued with the questioning from the previous episode this was an exposition. The questions were either rhetorical or closed questions with only one possible answer which

answer the teacher sometimes indicated by pointing at the model's face. This was therefore a typical IRE sequence with much teacher explanation. Although there was not much recitation there was perhaps some memorisation of terms. The teacher's communicative approach in this episode can be classified as Interactive/Authoritative since while she was focussing on developing the scientific story she also wanted to include the learners in the exposition. There were also instances where the learner's voice could be genuinely heard as in turn 80 when in response to the teacher's question Dineo asked a question of her own "Which one?" This could be an indication that Dineo (and probably other learners) was indeed paying attention and wanted to know which bone the teacher was asking about possibly with the intention of naming the bone. Again at the close of the episode in turn 90 Musa provided a well thought out answer to the teacher's question on what would warm the blood. The teacher's response could be taken to imply that she did not expect this answer from Musa; she probably considered this to be new information still to be made learned by the class. These incidents gave a dialogic texture to the interaction.

While Mrs Nkosi maintained this Interactive/Authoritative communication in most of the lesson, there were however, some genuinely dialogic episodes during the course of this lesson as seen in the next excerpt:

- 312 Teacher: *(indicates for learner to breathe in)* again yes what did you see here?
Teacher: *(points to a learner who is demonstrating to his friends)* yes
Hlatshwayo explain what you have just demonstrated?
315 Hlatshwayo: the the the lungs Maam
Teacher: not the lungs the chest cavity you can't see the lungs yes what happened?
Hlatshwayo: the chest cavity Maam
Teacher: what happens to it?
Hlatshwayo: iye (it) you know *(demonstrates by moving his hands in and out from his chest)*
320 Class: *(laughter)*
Teacher: it goes up and...? forward
Class: yes
Hlatshwayo: Yes
Teacher: good now if that happens what do you think happens to your ribs and intercostal muscles?
325 Sharon: they are raised
Teacher: they are also raised.
Teacher: Right can we go through this quickly? *(Teacher sends learner back to her seat and starts reading from handout)* The mechanism of inhalation er please note and highlight. Number one the diaphragm contracts and flattens it contracts and becomes a little bit flat and that will increase the volume of the thorax from top to bottom. Why must this volume increase?
Thabo: so that it may accommodate the oxygen

The teacher had just asked the class to watch the “model” breathe in and to then explain what they had seen. Some of the learners also breathed in and observed themselves and at this point a learner Hlatshwayo was demonstrating to his peers. The teacher then engaged with him in an IRPRP...E discourse which started with an elaborative intervention by the teacher correcting his statement that the lungs moved turns 315-317. The teacher then probed him further and when he failed to put into words what he had observed the teacher mediated by inserting clues (turns 318 and 321). Here the teacher suspended her authority for a while and allowed Hlatshwayo to think through and make sense of what he had observed. She then reverted to an authoritative approach by providing the word for what Hlatshwayo had demonstrated but failed to articulate in words (turn 321) to help him articulate the scientific understanding of his experience. This speaks to the tension between Interactive-Authoritative and Interactive-Dialogic communicative approaches alluded to by Mortimer and colleagues (Mortimer & Machado, 2000; Scott, et al., 2006) that arise as teachers attempt to balance the sometimes contradictory teaching purposes.

Another interesting point to note about this exchange was Hlatshwayo’s inability to articulate his observation in words. It was not clear if this was an English language problem or if it was due to a lack of the requisite biology vocabulary. Hlatshwayo was not a “quiet” kind of learner. I had often heard him and his friends engage in friendly banter in their local language in other lessons just as they had been doing just before the teacher picked on him to answer this particular question. However, I had never before seen him respond to the teacher’s question (which would most likely have been in English). Again this raises questions for future research about the role of language in the classrooms in these multi-lingual contexts.

Another interesting communication style that manifested in Mrs Nkosi lessons is what I called the look-alike Interactive-Authoritative communicative approach, which was in fact a veiled NonInteractive-Authoritative approach. I illustrate this from the inhalation and gaseous exchange lesson. At various intervals during the course of the lesson Mrs Nkosi would engage the class in reviewing episodes to summarise what had been covered in the lesson up to that point. It would be expected for the teacher to take a non-interactive stance for a reviewing session whose purpose is usually to summarise the key points of the lesson.

However, Mrs Nkosi's communication was not really Interactive/Authoritative although she still sought to include the learners in the talk as seen in the excerpt below:

- 128 Teacher: so one we said the inhaled air must be (*counting them off her fingers*) warmed
Class: warmed
130 Teacher: two we said the inhaled air must be moistened three we just said the cilia lining your nasal cavity must trap the dust particles and then those will be coughed out. But again that mucus has an important role to play as well. Right sometimes there are germs remember we said when we discussed the bacteria we said they are microscopic so we cant even see them but they are cosmopolitan they are all over so even in the air on the surface the desk surface here but we don't see them so as we inhale air obviously we may inhale them *angithi* (right?)?
Class: yes
Teacher: Substances that are in your mucus destroy the germs or they destroy the bacteria . And what is the term that we use when we talk of those substances that destroy the germs kill the bacteria? they are the anti toxins
Class: anti toxins
Teacher: the antiseptic good so we can proceed then. Remember I said you need to know the parts that are involved ok so part number one that we have looked at is the nose ok
135 Class: Yes
Teacher: so air is inhaled it gets into the nasal cavity then from there it will pass through (*walks to the board and writes*) one the nose then from there it goes to the pharynx a short tube (*walks back to the girl*) right remember we discussed digestion
Class: Yes
(*Lesson on inhalation and gaseous exchange, turns 128-137*)

From the first turn it is evident that the teaching purpose in this episode was to review what had been covered up to that point in the lesson as the teacher ticked off her fingers what had been said so far. The discourse took the form of IRE implying some form of teacher-learner interaction. However, the teacher neither explicitly evaluated nor elaborated on any of the learners' responses as she recited the main points covered in the lesson. The only questions she asked were rhetorical questions that did not necessarily require an answer and where an answer was required she would provide the answer herself as with *anti-toxins* in turn 132. As a result most of the learner responses were chorused "Yes"s or some indication of consensus.

Later in the same lesson Mrs Nkosi adopted an unusual communicative approach for this level of learners. Throughout the lesson she reminded the learners that one of the objectives of the lesson was to know the names of the anatomical parts and the processes involved in gaseous exchange. At this point she highlighted the three key things to remember and one of these was that some of the carbon dioxide would combine with haemoglobin to form

carbaminohaemoglobin, a “long term” which presumably would be difficult for learners to remember. She then engaged the class in a drill-like exercise where she had them do a chant of the word carbaminohaemoglobin:

- 385 Teacher: then it goes up up up until you exhale it. Now I want you to note this. This is very important people ok? Three things that you must note three things that will happen to carbon dioxide. Number one most carbon dioxide is this carbon dioxide which is going to be exhaled. And then some (*writing*)three things to note most CO-2 is exhaled and then some percent of CO-2 will combine again with haemoglobin
- Thabo: to form carbohaemoglobin
- Nomso: carbaminohaemoglobin
- Teacher: I want you to note that right when carbon dioxide combines with haemoglobin then we have this long term carbaminohaemoglobin (*chanting begins*)
- 390 Teacher: let's make sure that the other group is with us ok?
- Class: Yes
- Teacher: when carbon dioxide combines with haemoglobin that will become?
- T&Class: carbaminohaemoglobin (*chanting*)
- Teacher: Can you say that?
- 395 Class: carbaminohaemoglobin (*chanting*)
- Teacher: Can you say that?
- Class: carbaminohaemoglobin (*chanting*)
- Teacher: er can you say that on your own?
- Manto: carbaminohaemoglobin
- 400 Teacher: good girl. carbaminohaemoglobin (*chanting*). What is that?
- Class: carbaminohaemoglobin (*chanting*)
- Teacher: what is that?
- Class: carbaminohaemoglobin (*chanting*)
- Teacher: again
- 405 Class: carbaminohaemoglobin (*chanting*)
- Teacher: awuphinde futhi
- Class: carbaminohaemoglobin (*chanting*)

(Turns 385-407 Lesson on inhalation and gaseous exchange)

Prior to the drill just after she introduced the reaction of carbon dioxide with haemoglobin a dialogue took place in turns 386 and 387 between two learners, Thabo and Nomso. Thabo proffered an unsolicited contribution to complete the teacher's statement and said that CO₂ would combine with haemoglobin to form carbohaemoglobin (turn 386). To correct him Nomso broke into a chant of car-ba-mi-no-hae-mo-glo-bin (turn 387). It would appear that this was a familiar interaction for the learners although I only witnessed it this once. The teacher's remark in turn 390, seemed to confirm my observation when she said that she wanted to make sure that the two groups of learners were at the same level. She had started this lesson with some of the students in this class the previous day and had been interrupted by a call to a disciplinary hearing. It seemed that she had done the chant with the previous group who now broke into a whole class chant which was then joined by the rest of the class

from turn 391. For me this raised the question(s): Is there room for drill and recitation in high school Biology classrooms? Are there times and/or contexts in which rote learning might be preferable? I pick this point up again in Chapter 7.

5.3 Conclusion

I set out in this chapter to present my case-by-case data analysis addressing my first two research questions on how teachers use talk in their classrooms and what patterns of interaction result from the teacher's interventions.

I have shown that Mrs Thoba created a largely interactive discourse in her classroom. She traversed between an Interactive/Authoritative and an Interactive/Dialogic communicative approach in an effort to meet both the school science objectives of the lesson and the need to involve her learners in the interaction. The interaction in her lessons was in the form of the traditional IRF sequences as well as the IRPRP open and closed chains of interaction. Her questioning techniques both enabled and constrained interaction in her classrooms. In most of her lessons Mrs Thoba shut down the talk by asking closed questions or by not allowing sufficient wait time for learners to respond, sometimes providing the answers to her own questions. However, in some lessons Mrs Thoba did open up for meaningful interaction between herself and the learners and also among the learners by asking genuine questions. In such lessons she also consciously took up learner ideas and allowed them to determine the direction of the lesson, often foregrounding learner ideas for further interrogation by their peers. Her responses were a mix of elaborative and evaluative interventions.

In turn I illustrated how Mr Far attempted to work with learners' ideas while pursuing the scientific story and how in spite of attempts to take a dialogic communicative approach his interventions were largely evaluative creating the ID/IA tension that Scott and Mortimer alluded to as necessary for effective scientific engagement. The resultant discourse types in his lessons ranged from the traditional IRE/F triads to closed and open chains. In the IRPRP chains Mr Far's interventions took the form of both elaborative and evaluative feedback for the different teaching purposes. Like in Mrs Thoba's case, the discourse in Mr Far's lessons tended to take the form of IRPRPR ... E closed chains more than the IRPRPR open chains. The most significant features of Mr Far's pedagogical approach were 1) how he used various link-making moves, 2) how he often engaged in meta-talk both about what he was doing or

saying and what he was asking his learners to do or say, 3) how he always had learners write and 4) his frequent use of practical activities.

Mrs Nkosi's predominant communicative approach was Interactive/Authoritative with mostly the traditional IRE discourse pattern with much teacher explanation and recitation. There was a tendency to Interactive/Dialogic communication especially in the Conservation biology lesson where the interaction sometimes took the form of open IRPRP chains. She also often adopted a Non-interactive/Authoritative approach especially when summarising the discussion. Her approach at these times looked like an Interactive/Authoritative approach because it involved learners but close scrutiny revealed that the discourse was in fact non-interactive. The discourse in Mrs Nkosi's lessons was shaped by the nature of her questions which were mostly closed and/or rhetorical with a few instances of authentic questions. Although she took up learners' ideas, she did not always allow them to direct the lesson. Her responses were mostly evaluative with a few occasions where she worked elaboratively and probed learner thinking. Also, Mrs Nkosi was the only one of the three teachers who combined talking with reading in every lesson, an unusual strategy in the classrooms I observed, albeit a potentially powerful tool for developing multiple literacy skills in learners.

The data analysis in this chapter targeted interactive discourse to determine learner participation. In the next chapter, Chapter 6, I present my data analysis of the dialogic discourse to determine learner engagement. This is in answer to both my second and third research questions which are: "What patterns of interaction emerge as teachers and their learners engage in science talk?" and "What is the quality of the verbal interactions in the classroom when teachers use science talk?" To answer these questions I examined how elaborative or evaluative the teacher interventions during the Interactive-Dialogic and Interactive-Authoritative communication approaches were and how they shaped learner engagement with science content.

Chapter 6

Argumentation in whole class discussion: Joint construction of arguments for meaning-making, articulating understanding and for persuading

"Though there be scarce anything more groundless and unstable than popular opinions and persuasions, yet a wise teacher neglects them not, and may sometimes make much use of them as to draw thence arguments more operative than the most accurate syllogism logic could devise" (Robert Boyle 1661, p274 cited in de Berg, 1999).

6.0 Introduction

In Chapter 5 I dealt with teacher-learner talk and how it was used to foster participation in the lesson. I was addressing my first and second research questions which centred on how teachers shaped or guided talk in their classrooms and what patterns of interaction emerged as teachers and learners engaged in talk, respectively. In the present chapter I continue to address my second research question, focussing on argumentation as an emerging pattern of interaction during science talk. I also partially address my third research question: What is the quality of the interactions that emerge with science talk? My third question focused on the quality of the verbal interactions that emerged as teachers and learners engaged in science talk, that is, how argumentation facilitated substantive learner engagement. In this chapter I therefore report on both the nature and quality of argumentation; how meaning making was negotiated between the teacher and learners and among the learners by determining the nature of arguments constructed (research question 2) as well as the levels at which teachers and learners engaged in argumentation (research question 3) during class discussions.

My observations were premised on the understanding that when a teacher and learners engaged in discussion, sharing ideas and shaping each other's understandings, their talk facilitated co-construction of meanings and understandings. To determine the nature of this joint activity I examined the three moves of the IRF sequence (Luk, 2004) in relation to each other. I examined how the teacher initiated interaction (I), what questions she asked, how she elicited students' ideas and introduced them to the classroom discourse. This teacher move determines the student response (R). In turn I analysed the learner response to determine if it was simple recall or whether it was proffered as a claim with supporting evidence. The former would indicate a tendency towards recitation of knowledge without a show of

understanding while the latter could lead to critical or substantive engagement **with** the science knowledge under consideration (Nystrand & Gamoran, 1991). Finally the teacher's intervention or feedback (F) move was examined to determine if it was used to probe learner thinking. I wanted to understand how the teacher intervention opened up or shut down learner responses and how it facilitated learner use of evidence to support their own ideas and/or to evaluate and critique their peers' ideas. Understanding the relationship between the three moves could help determine how the teacher and learners jointly constructed arguments. Further, an understanding of the process of argument construction would enable me to determine how the teacher mediated and modelled argumentation for the learners, thus equipping them with this important science learning tool. Thus, I sought to understand how argumentation was used to achieve the goals of sense making, articulating and persuading about shared understandings of science content as discussed in Chapter 2 (Section 2.6).

In presenting the summary of data on argumentation in Chapter 4, I indicated the differences in the nature and forms of argumentation that played out in some of the lessons in each teacher's case. While there seemed to be a pattern of improvement in participants' argument construction skills in both Mrs Thoba and Mrs Nkosi's lessons, there was no obvious pattern in Mr Far's lessons, with very little argumentation if at all in his lessons. I showed how in two lessons, one each for Mrs Thoba and Mrs Nkosi, the high levels of argumentation were observed, with extended arguments and clear rebuttals. I present in this Chapter evidence of argument construction in each of these lessons. I also present some data from Mr Far's lessons to indicate the absence of argumentation in his lessons, in spite of the high levels of participation in his lessons.

The data presented here was collected in the form of video recordings of classroom observations in Mrs Thoba's lesson on energy changes during formation of chemical bonds, Mr Far's lessons on momentum and on properties of compounds as well as Mrs Nkosi's lesson on learners' indigenous knowledge of owls and biodiversity conservation. As noted in Chapter 4, these lessons provided the most substantial evidence of argumentation for each teacher. Transcripts of the lessons were analysed to identify and describe the arguments constructed by the teachers and their learners.

I characterised each teacher or learner move as a component of an argument according to Toulmin's argument pattern (TAP). The TAP model was explained in detail in Chapter 4 but I provide in the next section a brief synopsis of the model to remind the reader of its key features.

As discussed in Chapter 4, Toulmin's Argument Pattern (TAP) (Toulmin, 1958) was adapted by Erduran and her colleagues for analysing science classroom discourse (Erduran, et al., 2004). In terms of this model an argument comprises different components (Figure 6.01). First, there are claims (C), which are any form of position taking or conclusion – making an assertion, decision or prediction, a statement meant to answer a question or solve the problem, an expression of opinion or idea(s). Then there is data (D) which supports the claim and includes any evidence that supports the claim – observations, facts, events, or various authorities. Next are warrants (W) and backings (B) which provide justification for how the data supports the claim. Warrants provide the link between the claims and data while backings constitute the grounds on which the claim is being made, that is, any scientific information, theory or law that explains how the warrant links the data to the claim. Finally, rebuttals (R) are assertions about situations where a claim is not valid or when it may not hold true (see Erduran, et al., 2004; von Aufschnaiter, et al., 2008).

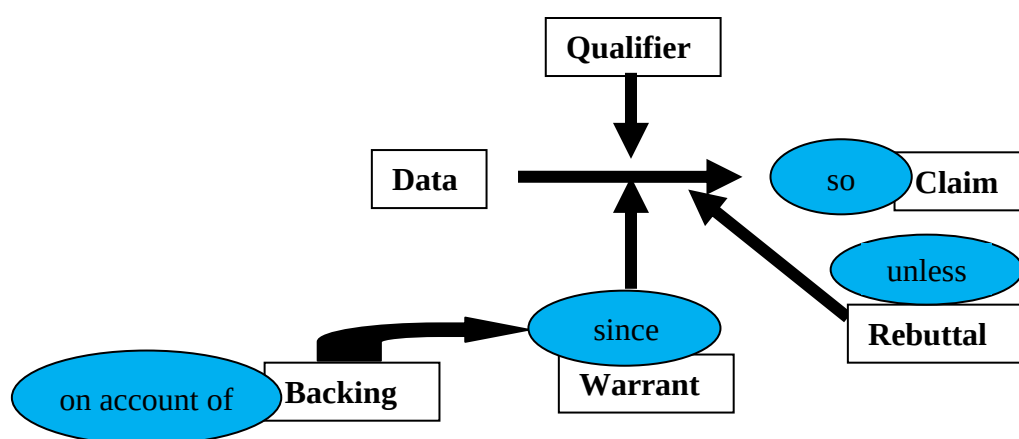


Figure 6.01 Toulmin's Pattern of Argument, TAP (adapted from Erduran, et al., 2004; and Toulmin, 1958, 1964)

Erduran and colleagues described arguments ranging from the simplest comprising only a series of claims or unjustified counter-claims which they termed Level 1 argument to complex Level 5 arguments comprising all of Toulmin's components in an extended form with more than one rebuttal. Level 1 arguments indicate that the students' argumentation

skills are still basic or in the formative stages. Students are not yet able to support their claims with evidence. Level 5 arguments are sophisticated forms of using evidence to support claims and are indicative of mastery of argumentation skills. In determining the complexity of arguments Erduran and her colleagues focused on the number of components of an argument that were represented in an argument and clustered arguments according to the number of components counted as explained below:

Furthermore, for our coding purposes, we concentrated on identifying arguments in terms of the quantity of TAP features in arguments, not qualitative differences across different permutations of TAP. That is to say, by collapsing different arguments into clusters, we are not differentiating between arguments that might have a different qualitative composition despite a quantitative equivalence in terms of TAP, i.e. “claim–data–warrant–rebuttal” and “claim–data–warrant–backing,” both instances of cluster 4, are grouped together since each has four features of TAP even though qualitatively there is a difference between the arguments in terms of the presence or absence of rebuttals and backings.
(Erduran, et al., 2004, p. 925)

Since my focus was not on categorising arguments into levels 1-5 but to describe the structure of the arguments and the pattern of their development as the lesson progressed I did not cluster the arguments in the way Erduran and her colleagues did. Instead I kept separate all arguments that differed by at least one component. In my case therefore, a “claim–data–warrant–rebuttal” (CDWR) argument was classified separately from a “claim–data–warrant–backing” (CDWB) argument. However, like Erduran et al I did initially place in the same category any arguments with similar representations of components but different frequencies of each. For example, CDWR and CDWRW arguments were grouped together as CDWR. However, in the discussion of the excerpts used to illustrate the different arguments I did separate such arguments so as to illustrate the complexity of co-constructed arguments.

Before I discuss argumentation in selected lessons by the three teachers I illustrate the role of the tasks in promoting learner argument construction.

6.1 The nature of the task and expectations for argumentation

Research has established that the nature of the task and the content context do influence not only the students’ ability to construct arguments but also their level of argumentation. In earlier studies in Europe and the UK, researchers observed that students found it difficult to

formulate and support arguments on content-specific tasks that were not closely related to their prior knowledge (von Aufschnaiter et al., 2008). They were better able to construct and support arguments on tasks that allowed for them to draw from their everyday experiences, particularly on their moral judgment and on their value systems (Osborne et al., 2004). A study of argumentation in South African classrooms showed that the way students drew on scientific information also varied depending on whether they argued on a scientific or socio-scientific issue (Braund et al., 2007). The authors demonstrated that students were better able to draw on scientific information to support their decisions on whether they considered Euglena to be an animal or a plant than they did in arguing for or against organ trafficking. For the organ trafficking task student found it difficult to identify the science to use as evidence for their arguments and they drew instead on moral values. The activities discussed in Mrs Thoba (bond energy changes) and Mr Far's (illustrating momentum) classrooms were based on mainstream science concepts while the task in Mrs Nkosi's lesson was socio-scientifically based. I examine first the tasks used by Mrs Thoba and Mr Far.

6.1.1 Bond energy and momentum tasks

This was an introductory lesson for the topic "Energy changes during formation of chemical bonds". The objective was to introduce the topic and then cover the potential energy changes that take place during formation of the covalent bond. The teacher adopted a mixed approach strategy. She intermittently introduced new concepts and explained them and then engaged her learners in a question and answer session to get them to think through the new information they had received and predict how the chemical processes might proceed. In the excerpts discussed in this chapter for example, the teacher had introduced the idea that two atoms that are about to take part in bond formation are initially far apart and at that point they possess maximum potential energy and that as they draw closer to each other their potential energy changes. She then asked, "What do you think will happen as they come closer?" The intention was to get learners to think about changes in potential energy between the two atoms. However, Tahari's answer that, "... if they decrease they are now going to be negatively charged" revealed that she was thinking in terms of a different chemical process, that of ion formation instead of the idea bond formation that the teacher was pursuing. The interaction then unfolded as arguments between the teacher and several learners about their different understandings of the scientific information under consideration.

Two points are worth noting about the nature of this task and its implications for expectations about argumentation. First, the task was not intentionally designed for purposes of argumentation. The teacher had not intended to engage her learners in an argumentation session in this lesson as she was still introducing what she considered to be a difficult topic. The subsequent argumentation simply emerged within an otherwise traditional whole class science discussion. It was mainly an outcome of teacher decisions on appropriate interventions to draw on in order to help resolve the misunderstanding of the intended focus of the lesson in terms of content. Thus, in terms of the literature that I had reviewed for argumentation there were no expectations of the arguments that the learners later constructed. However, in terms of the content, if this task been deliberately intended for argumentation one might expect learners to be able to draw from their prior knowledge of the different energy types or their knowledge of ion formation. Subsequently they did pull in their prior (mis)understandings of the two processes, revealing to the teacher a knowledge gap that had to be addressed before the lesson objectives could be met.

6.1.2 *The indigenous knowledge and biodiversity conservation task*

The discussion in Mrs Nkosi's lesson was based on a task that was deliberately designed to stimulate debate. The task had two characteristics which are significant for argumentation research. First, it was based on a socio-scientific issue, the conservation of biodiversity that includes a culturally controversial species of bird. Generally owls are not viewed favourably by many South African cultural groups (see Kemp 1995; Msimanga 2000). They tend to be associated with bad luck, witchcraft and death. Secondly, the task design was a concept cartoon. Literature reports positive results where concept cartoons have been used to stimulate learner talk (see for example Keogh & Naylor 2007; Keogh, Naylor, de Boo & Feasey 2002; Webb, Williams & Meiring, 2008). This task could therefore be expected to stimulate much debate and probably very elaborate learner arguments because of its socio-scientific nature and its presentation as a concept cartoon. However, it was not likely that the learners' arguments would be well supported with scientific evidence, a situation observed elsewhere.

The owl IK task had three complementary objectives to the task. First, the teacher wanted to address issue of biodiversity conservation, a topic that was part of the Life Sciences curriculum at Grade 12 at the time. Secondly, she was aware of the indigenous knowledge

and cultural beliefs and traditions about owls and intended to use these to incorporate IK into the science lesson. This too was a curriculum requirement for science teaching and learning in a South African classroom. Thirdly, since Mrs Nkosi shared a cultural background with the learners, she was aware of their cultural experiences and possible prejudices against the owl. She therefore, sought to surface these beliefs and place them in the context of the scientific topic of biodiversity conservation. Thus, by its very nature this task was bound to create debate in this cultural context.

As noted earlier, research both in South Africa and abroad has shown that although such socio-cultural issues have the potential to stimulate learner argumentation, it is not always possible to get learners to identify the science of the task that may be masked by learner belief systems and their everyday experiences (Braund et al., 2007; Osborne et al., 2004; Webb et al., 2008). I approached the data analysis of the lessons reported in this chapter with the expectations of argumentation discussed in this section.

6.2 Results and discussion

In this section I first provide a summary of my observations on argumentation in each teacher's lesson and then using excerpts from the lessons I illustrate these observations and close each teacher's section with a discussion of the factors that seemed to facilitate or constrain argument construction in the lesson.

6.2.1 Summary of observations on argumentation in Mrs Thoba's lesson on bond energy

6.2.1.1 Although argumentation in this lesson was spontaneous and not planned for

- a. The teacher was attuned to learner talk and was able to identify erroneous learner thinking and the need to open up the social space for learner engagement with each other's thinking.
- b. The teacher was willing to pause and divert from the focus of the present lesson so as to afford learners an opportunity to think together. She seemed to have an intuitive connection with her class.

6.2.1.2 The teacher facilitated and mediated argument construction by

- a. Making time for the learners to engage with each other.
- b. Developing the dialogue that afforded learners deep engagement with content.

- c. Opening up for negotiated understandings. Although some teacher interventions tended to funnel learner thinking towards the correct answer, for the most part she responded elaboratively to learners' contributions.
- d. Probing learner thinking while encouraging them to evaluate and critique their own and their peers' ideas. However, she often provided answers to her own questions, thus quelling learner involvement.
- e. Genuinely taking up learners' ideas. Although there was variation in the extent to which the teacher exercised genuine uptake of learners' ideas, she did take learners' ideas and understandings seriously.

6.2.1.3 *The teacher made the rules of engagement explicit* and made an effort to adhere to them herself. Both Bernstein's instructional (relational) rules and criterial rules (expected level of performance) were often made visible during the course of the lesson (Bernstein, 1990). This way the teacher was also modelling for her learners the skill of argument construction. As a result, learners:

- a. Began to make attempts to justify their arguments with evidence and warrants thus, providing grounds for their claims.
- b. Became critical of their own as well as others' thinking as they evaluated each other's ideas.
- c. Constructed shared understandings of the content under discussion together with their teacher.

Because the main focus of the discussion was to understand an existing body of science knowledge and to resolve learner understandings of agreed upon scientific concepts, there was a tendency towards Berland and Reiser's (2008) articulating and meaning-making arguments with fewer persuading arguments.

6.2.2 *Summary of observations on argumentation in Mr Far's lessons on momentum and on properties of compounds*

6.2.2.1 As in Mrs Thoba's case, where it happened, argumentation in Mr Far's lessons was spontaneous and not planned for:

- a. The teacher responded to learner's ideas, identified erroneous learner thinking
- b. The teacher attempted to open up for engagement with learner thinking during the course of the classroom discussion.

6.2.2.2 The teacher attempted to facilitate argument construction by:

- a. Making time to engage with individual learners during the course of the lesson.
- b. Initiating dialogue that could potentially afford learners engagement with content. However, the teacher tended to funnel learner thinking towards the correct answer, often providing obvious clues and/or answers to his own questions.
- c. Attempting to open up for negotiated understandings. The teacher responded elaboratively to learners' contributions and probing learner thinking. However, the probing was often short lived and ended as in b) with a cue or answer from the teacher.
- d. Taking up learners' ideas. As in Mrs Thoba's case, there was variation in the extent to which the teacher took up learners' ideas, often overlooking some that had potential to be interrogated by their peers, which could result in argumentation.

6.2.2.3 The teacher made the rules of engagement explicit. Both Bernstein's instructional (relational) and criterial rules (expected level of performance) were made visible during the course of the lesson (Bernstein, 1990). However, the teacher did not always model for the learners the skill of argument construction. As a result:

- a. Learners did not provide evidence to justify their arguments.
- b. Learners were often not critical of their own or their peers' ideas.

6.2.3 *Summary of observations on argumentation in Mrs Nkosi's lesson on indigenous knowledge of owls and conservation*

6.2.3.1 This lesson topic seemed to lend itself well to development of learner arguments and argumentation developed spontaneously

- a. The teacher encouraged learner arguments by asking direct questions eliciting learners' knowledge of owls and the beliefs held by their communities.
- b. She spent a considerable proportion of her time managing the discussion to maintain focus and ensure orderly interaction.

6.2.3.2 Teaching did not facilitate for argument construction and did not consciously mediate argument construction. The teacher often overlooked learner thinking that had the potential to develop into rich arguments. However, there was evidence that the teacher:

- a. Made time for the learners to engage with each other

- b. Consciously elicited learners' knowledge and thinking and opened up for negotiated understandings.
- c. Responded both evaluatively and elaboratively to learners' contributions. That is, she alternated between interventions that funnelled learner thinking and those that elicited and probed learners' ideas, alternatively. On the one hand she probed learner thinking and encouraged them to evaluate and critique their own and their peers' knowledge and understandings while on the other, she engaged in extended exposition sessions which tended to shut down learner talk.
- d. Genuinely took up learner's ideas. Again there was variation in the extent to which she exercised genuine uptake of learners' ideas.
- e. Vacillated between facilitating for shared meaning making and upholding the subtle ethical demands of managing a discussion on cultural issues, some of which were apparently of a sensitive nature.

6.2.3.3 Mrs Nkosi also often made the rules of engagement explicit and while for the most part she helped her learners adhere to them she herself often did not adhere to them. I will illustrate how this created contradictions that constrained development of some potentially rich arguments in her lesson. As a result:

- a. Learners did make attempts to justify their arguments with evidence and provide grounds for their claims.
- b. Learners were critical especially of others' ideas and much less of their own.
- c. On occasion, learners together with the teacher co-constructed arguments and provided rebuttals for their peers' arguments.

Since the main focus of the lesson was to elicit learners' indigenous knowledge of owls and conservation and not to change their minds, arguments were largely the form of Berland and Reiser's articulating and persuading arguments. There was no evidence of meaning-making arguments.

I discuss first, argumentation in Mrs Thoba's classroom.

6.3 Argumentation during Mrs Thoba's lesson

This was an introductory lesson for the topic of energy changes that occur during the formation of chemical bonds. The objective was to introduce the topic and then cover the potential energy changes that take place during formation of the covalent bond. The teacher

started the lesson with a question and answer introductory session in which she took the class through a review of the different types of chemical bonds. She probed learner understanding of the nature of the bonds and how they are formed. She then proceeded to question them on their knowledge of the different types of energy and examples of situations where they would expect those forms of energy to occur. After this she told the class that the day's lesson was on changes in potential energy that take place when two hydrogen atoms bond covalently.

From analysis of this lesson discussion I made three key observations. First, arguments were initially co-constructed by the teacher and learners in a teacher-led dialogic discourse and only later were the arguments among learners and their peers. Next, there were two levels of complexity of the arguments constructed; the presence or absence of rebuttals at one level and at another, change in the composition, length and elaboration of the arguments in terms of combinations of Toulmin's components as the discussion progressed. Finally, how argumentation was used in an unusual way, as a tool for meaning-making beyond mere explanation and exposition as usually happens in any good classroom discussion. Lemke (1990) observed that classroom discussions which allowed for true dialogue enabled children to talk to each other and explain their understandings of science concepts. In other studies Mercer and colleagues observed that the use of language in collaborative tasks improved children's reasoning (Mercer, et al., 1999). In this case, however, Mrs Thoba facilitated not only for her learners to talk to each other about their thinking but also to question and evaluate each other's arguments, their supporting evidence as well as the grounds on which they were made. The result was shared meaning-making through argumentation as described later.

In the next section I illustrate my observations in terms of the structure of arguments constructed, the process through which they were co-constructed and how they were constructed as part of a sense-making argumentation process. The full analysis of this lesson is given in Appendix 6.01 showing how the argument components were characterised.

6.3.1 Structure of arguments constructed during Mrs Thoba's lesson

All six components of an argument were represented in this discussion. The learners made many claims, initially not supporting them, but through the teacher's intervention they later provided not only the evidence to support their claims but also rebuttals for their peers

arguments. In the end, the participants (both the teacher and the learners) provided grounds for most of their claims, making 18 claims and 42 attempts to support them. Support for claims was in the form of 17 warrants, 20 pieces of data, 4 backings, 1 qualifier (Table 6.01). There were also five rebuttals, which according to Erduran et al. are evidence of high level arguments (Erduran, et al., 2004).

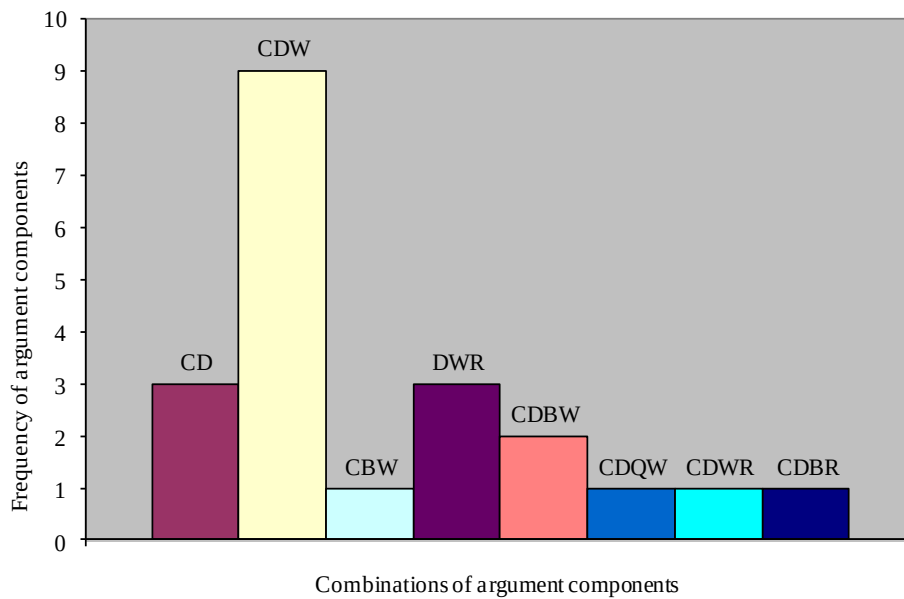
Table 6.01. Summary of argument components identified in Mrs Thoba's lesson discussion

Argument component	Frequency
Claim, C	18
Data/evidence, D	20
Warrant, W	17
Backing, B	4
Qualifier, Q	1
Rebuttal, R	5

For learners who were not tutored in argumentation, the ability to provide evidence and grounds for their claims as well as advance rebuttals for each other's arguments is unusual. In a study of a similar group of learners in the Western Cape in South Africa, Lubben and his colleagues reported low levels of the kind of evaluative engagement necessary for the provision of rebuttals for their peers arguments (Lubben, Sadeck, Scholtz, & Braund, 2010).

In Table 6.01 I only provided summaries of frequency counts of the components of the arguments. To indicate the structure and elaboration of the arguments, I present a graphical representation of the various combinations of argument components (Figure 6.02). These combinations can be used as an indicator of both the quality and diversity of the types of arguments constructed in this discussion.

The arguments varied from simple pairs of components to more sophisticated combinations of three or four of Toulmin's components. According to Erduran (2004) any combination of a claim with one other component constitutes an argument, albeit of a lower level. Thus the CD arguments in Figure 6.02 would be the simplest in this discussion while the last two, CDQW, CDWR and CDBR would be the most sophisticated because they included at least one rebuttal. However, as mentioned earlier, analysing using Erduran's method tended to mask other complexities in the argumentation process, like how elaborate the arguments were in terms of frequency of components in the extended co-constructed arguments. From the graph one gets the impression that the longest arguments were those with four components each.



Key: Combinations of argument components:

CD	Claim and Data
CDW	Claim-Data-Warrant
CBW	Claim-Backing-Warrant
DWR	Data-Warrant-Rebuttal
CDBW	Claim-Data-Backing-Warrant
CDQW	Claim-Data-Qualifier-Warrant
CDWR	Claim-Data-Warrant-Rebuttal
CDBR	Claim-Data-Backing-Rebuttal

Fig 6.02. Combinations of argument components identified in Mrs Thoba's lesson

The graph only shows combinations according to occurrence of types of components and does not give the full composition of the extended arguments that were constructed in this discussion. For example, of the three DWR arguments only one was a true DWR, the other two were in the form WDWR and RDWDWW, that is, a warrant followed by data and then another warrant and a rebuttal in the former argument and in the latter, a rebuttal followed by data, a warrant, some more data and two warrants in immediate succession. Similarly the CDWR argument was actually in the form RDWCW. However, since I was interested in the co-construction of arguments, I wanted to highlight this elaborateness of arguments and therefore, in the following discussion of the process of argument construction I revert to the extended forms of the arguments.

From the discussion above it appears that there were two levels of argument complexity in this discussion. First, as in Erduran's analyses, there were different levels of argument complexity as determined by the presence or absence of rebuttals as well as the elaboration of the argument as seen in my data where extended arguments were in the form of repeated series of Toulmin's components. Secondly, I also identified a trend in complexity of argument structure, progression from simple to complex arguments as the class discussion progressed. The discussion opened with simple two or three component arguments of a largely articulating nature and built up to more elaborate sophisticated four to six component arguments as the teacher and students engaged in a series of sense-making and/or persuasive arguments (Berland & Reiser, 2008). The discussion then slowed down again to three component arguments as the class moved towards a consensus and the argumentation died down as illustrated in the excerpts below.

6.3.2 Teacher-learner co-construction of arguments

The first two arguments took place early in the lesson as the teacher reviewed learner prior knowledge of the different types of energy. The first was constructed within what can be classified as IRF sequence by the teacher and the first learner, Mdu. The teacher initiated (I) the interaction with a question on why a metal atom becomes positively charged when it bonds. Mdu responded (R) by making a claim and providing the evidence (data). The teacher's intervention was in the form of feedback (F) proffered in two separate turns, thus articulating a Claim-Data-Warrant argument in the two turns:

9	Teacher:	Atoms that bond they share the electrons... What about the ionic bonding? What about ionic bonding?
10	Mdu:	One one atom will bond (<i>inaudible</i>) its ion and another one (<i>inaudible</i>) one atom will give its electrons to another one the other one will accept the electrons and The other one will give its electrons
	Teacher:	Ok and it takes place between what type of elements?
	Mdu:	metals and no-metals
	Teacher:	Between metals and non-metals. Metals in this regard will give off their Electrons to ...? non-metals
	Class:	non-metals
15	Teacher:	Metals will give off their electrons to non-metals. Why does the atom become positively charged?
	Mdu:	Since the atom er since the atom is neutral, Maam it has the same Number of protons and what you call electrons (Data) so obviously if the electrons (<i>inaudible</i>) so the number of atoms the number of protons will be more than the number of electrons (Claim)
	Teacher:	Positively charged protons in the nucleus will exceed the number of electrons around the nucleus (Data) hence the atom will be positively charged (Claim)

Class: charged
Teacher: Because now the protons the number of the protons is no longer the same as the number of electrons **(Warrant)**

20 Class: electrons
Teacher: Ok let us talk about non-metals they give off no they accept the electrons and they become negatively charged

Class: negatively charged
Teacher: negatively charged. Why?
Mdu: Because it has accepted the electron from the nucleus it has .. **(Warrant)**

25 Teacher: Because now the number of electrons...exceeds the number of protons in the nucleus **(Data)**. Ok today we are going to look at the energy changes during these two types of bonding. What do you understand by the term energy?

Class: *(softly)* ability to do work
Muzi: *(louder)* the ability to do work
Teacher: Ability to ...do work
Class: do work

(Turns 9-29 in Transcript of Bond Energy lesson)

Mdu drew on the evidence of atomic charge to make the claim that when a neutral atom gives up an electron the number of protons then exceeds the number of neutrons and the atom becomes charged. In this episode Mdu drew from an implied scientific rule that atoms are neutral - (turn 16) *“since the atom is neutral...”* - because they have equal numbers of protons and electrons , therefore an ion is formed when this balance is interrupted as they *“... give off their electrons ...”* according to the teacher’s statement (turns 13 and 15). Because this was the answer that the teacher was looking for, she affirmed the learner in the next turn (turn 17) by elaborating on his answer, extending the argument with another data-claim-warrant sequence. Note how the learner’s claim in turn 16 became data for the teacher’s claim which is articulated from the teacher’s original question (turn 17). This seems to be the case with extended arguments and is one of the challenges of using TAP as an analytic tool (see for example Erduran, et al., 2004; Sampson & Clark, 2008a)

In this episode the learner articulated his understanding by way of an argument and the teacher extended it into a meaning-making argument for the rest of the class, providing what she deemed to be a necessary scientific connection but which was missing from Mdu’s contribution. This is evidence of teacher uptake of learner ideas (Brodie, 2007; Nystrand & Gamoran, 1991). By taking up and elaborating on the learner’s idea the message communicated to him was that his answer was appropriate and acceptable and that it was valued. For the rest of the class the message could be that Mdu’s answer comprised important scientific information that was worth learning. This early in the lesson, the learners were already providing evidence for their statements. The teacher asked questions that not only

elicited learners' knowledge or ideas about energy but she also asked probing questions inviting learners to explain their understandings.

When one of the learners mentioned potential energy the teacher took up the learner's response and used it to move the lesson forward and introduce the concept of the changes in potential energy as two atoms take part in covalent bond formation. She then put up two diagrams on the board (Figure 6.03).

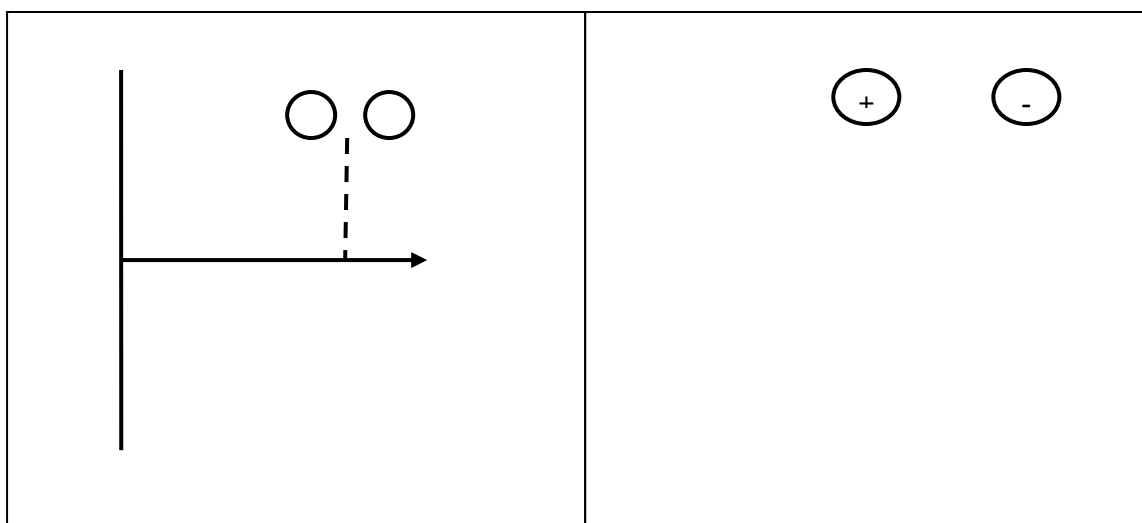


Figure 6.03 Mrs Thoba's diagram on the board, used to illustrate changes in potential energy during covalent bonding of two hydrogen atoms.

The first diagram (on the left) consisted of the x and y axes and two circles (for two atoms) as the beginning of a graphical illustration of the changes in potential energy. The other diagram (on the right) comprised two circles with a positive and negative sign, respectively, to illustrate changes in relative position of the atoms as they engage in bond formation. The teacher then led a whole class discussion based on these two diagrams. From this point onwards the lesson alternated between extended telling/exposition sessions by the teacher, and question and answer sessions about the concepts being considered at that point in the lesson. The teacher explained that by virtue of their positions from each other the two atoms possessed potential energy and that in order to form a bond they had to get closer to each other and so that potential energy would then decrease. This exposition episode was broken by another question and answer session during which a misconception arose as one of the

learners' responded to the teacher's question about what they thought might happen as the two atoms moved closer to each other. Most of the argumentation took place during the part of the lesson dedicated to addressing that error.

6.3.3 From articulating arguments to sense-making and persuading arguments

In the next five episodes the teacher engaged the learners in an unusual type of argument construction that incorporated both a sense-making and a persuasive function. When the teacher asked what the learners thought would happen when two atoms drew closer together as their potential energy decreased one learner, Tahari answered that "*the atoms are now going to be negatively charged*". The teacher then engaged the class in a series of question and answer episodes aimed at addressing this error. The excerpt below marks the beginning of that discussion with the teacher foregrounding Tahari's error for public consideration by the class:

- 114 Teacher: If they move closer to one another this means that the distance between them decreases. What do you think is going to happen?
- 115 Tahari: er if they decrease they are now going to be negatively charged
(Claim)
- Teacher: Why?
- Tahari: Maam because er now they are attracting each other **(Warrant)**
Maam. *Angithi manje sezahlangana sezifunukuhlangana* (now they are just about to come together **(Data)**)
- Teacher: What do you think? What do you think of that statement?
(Turns 114-118 Transcript of Bond Energy lesson)

Since Tahari, had not provided any support for her claim that, "... *they are now going to be negatively charged*", the teacher intervened elaboratively, foregrounding the claim by repeating it in turn 115. She then probed with a "Why?" question (turn 116) to which the learner then provided both the evidence, *they are about to come together* and a warrant, *since they are attracting each other*, that links the evidence to the claim (turn 117). The learner did not see the need to support her claim but the teacher wanting to get to her thinking asked her to say why she thought the atoms would be negatively charged. In response the learner provided justification for her thinking, that *as the atoms attract each other they come close to each other and as they are about to come together they become negatively charged*. At this point it was clear that Tahari held a misconception about how atoms acquire a charge and in the more traditional instructional practices common to the classrooms I observed, the teacher would either ask another learner for the right answer or provide it herself so as to save time

and get back to the main focus of this lesson. Mrs Thoba herself often responded this way to learners' erroneous answers. However, in this instance she kept the error in the social space of the classroom discussion and invited other learners to interrogate Tahari's thinking. This way she might get Tahari to realise the error in her response through the help of her peers and if this was a shared misconception her questioning might expose this from the rest of the learners talk. The teacher therefore, facilitated for and mediated shared meaning-making for the class.

As the conversation continued the teacher again rephrased Tahari's response and asked another thinking question. This created for learners an opportunity to make sense of the statement and to evaluate its validity in light of the evidence that had been advanced so far. Hence she opened up the dialogue for continued sense-making and articulation of the emerging learner understandings. In sense-making argumentation the aim would be to get learners to open up to their peers' ideas and modify their own understandings (Berland & Reiser, 2008). In the excerpt below another learner, Vuma joined the conversation with an argument to articulate his own understanding of the issue.

- 121 Teacher: She says that if they come closer the hydrogen is going to become negative because of the attraction force. What do you think about that?
 Vuma: Er Maam I much agree **(Claim – repeated, rephrased)**
 Teacher: You agree?
 Vuma: Yes Maam coz Maam when they bond covalently they are bonding to achieve the nearest noble gas **(Data)**
 125 Class: Yes
 Vuma: ok fine then soon as they reach the noble the nearest noble gas both of them what they share and then soon as they are sharing er both of these er they become negatively charged
(Turns 121-126 Transcript of Bond Energy lesson)

Although Vuma agreed with the claim made earlier by Tahari, he did so on different grounds than Tahari. While Tahari warranted her claim on the nature of forces operating between the atoms as the distance between them decreases, Vuma premised his argument on evidence about covalent bonds (turn 124). This new argument apparently did not bring the class discussion any closer to solving the problem but it did reveal more learner erroneous thinking, providing the teacher with resources to work with in mediating learner understanding. The teacher then responded to Vuma with a question that suggests that she had identified the learners' misunderstanding – the circumstances under which an atom becomes negatively charged. She therefore, asked the question, "When does an atom become

negatively charged?” The next excerpt is a conversation following this question. The arguments in this excerpt are of particular interest to me because of the rebuttals that the learners provided. It is also significant in that it illustrates teacher questioning that maintains the cognitive demand of the task by not simplifying the question for learners. Research findings in mathematics classrooms in South Africa indicate that as the teacher senses that her learners are struggling to get to the correct answer there is a tendency to then ask simpler questions thus reducing the cognitive demand of the task at hand (Brodie 2007). Mrs Thoba, in this case, asked the question differently but without reducing its difficulty and so maintained the cognitive demand of the task. In terms of development of the argument, the learners were at this point beginning to respond more directly to each other’s ideas. In the next episode for example, all the rebuttals were made by learners and not the teacher.

- 151 Teacher: When does an atom become negatively charged?
Teacher: Let me give you a chance
Thinta: Maaam I disagree with the statement coz Maam I think when the two atoms (inaudible) the chemical potential energy will increase
(Rebuttal, appeal to evidence about potential energy)
Teacher: Why do you disagree with the statement?
155 Thinta: Its because Maam when the the two atoms interact its impossible for them to be negatively charged. **(Warrant for evidence in rebuttal)**
Tahari: Maam didn’t you say...?
Teacher: Why?
Thinta: *Azikathintani* Maam (They are not yet touching).
Class: Yes yes yes
160 Tahari: Maam didn’t you say when they er when they get closer to each other when they attract each other the potential energy it will decrease
(Rebuttal of L11’s rebuttal appeal to evidence about potential energy)
Thinta: Its like this... (*holding pen and set square in each hand and moving them towards each other*)
Tahari: It will decrease...
Thinta: *Azikathintani* (They are not yet touching)
Tahari: Maam you said you said the potential energy will decrease and therefore those atoms are going to be negatively charged **Claim-Data-Warrant**
(Turns 151-164 Transcript of Bond Energy lesson)

Two learners, Tahari (again) and Thinta were in conversation with the teacher here and in this episode the teacher seemed to be seeking a rebuttal. Her opening statement was a direct question about the validity of the statement being discussed, the claim that the atoms would become negatively charged. In response learners, Tahari and Thinta engaged in what appears to be a dialogue with each other in turns 155-164. However, a closer look at their utterances in this interaction reveals the fact that they were in fact pursuing independent arguments. In turn 153, Thinta rebutted the claim under discussion by reverting to answering the initial question that had brought about this claim, stating that if the two atoms came closer to each other the potential energy would increase. The teacher however, maintained the idea under

discussion by insisting that he (Thinta) provide the grounds on which he disagreed with the claim on the table (turn 154), to which Thinta then said that it was impossible for the atoms to be negatively charged (turn 155). At this point Tahari interjected with a statement meant to bring in evidence from what the teacher had said earlier, but the teacher overlooked (ignored) Tahari and persisted with the questioning of Thinta to elicit evidence for his previous statement (turns 156-157). In the next turn (turn 158) Thinta provided the evidence, that the atoms were not yet touching, and a few other learners agreed with him. In spite of Tahari's interjection in the next three turns (160-162), Thinta continued to reaffirm his position by repeating the evidence two more times, first as an illustration with a pen and set square and then as a statement between Tahari's utterances.

Tahari on the other hand, upheld her position that the atoms would be negatively charged and in turn 164 she appealed to evidence from the teacher's earlier telling episode and the graph on the board which the teacher had been using to illustrate how as the two atoms drew closer to each other their potential energy decreased. For Tahari this was the evidence for the atoms becoming negatively charged.

The teacher's opening statement in this episode had been a question calling for a rebuttal and it does seem to have yielded the teacher's desired outcome since both learners, Tahari and Thinta did provide not only the rebuttals but ultimately also the grounds on which the rebuttals were made. However, instead of bringing the class closer to resolving the problem, this interaction only revealed how much the teacher and her learners were still at variance in their understandings of the concepts under discussion. The last teacher-learner argument considered here brought this conversation to a close as the teacher pointedly asked whether the atoms would be negatively charged, a question probably deliberately aimed at closing the discussion. She restated the statement under discussion and then asked this closed or leading question, which elicited the desired correct answer and brought the discussion to a close.

- 166 Teacher: Ok the statement is if the potential energy decreases then the hydrogen atoms are going to be negatively charged. Are they going to be negatively charged?
Class: No no yes no yes no
Teacher: When does a negative ion form?
Vuma: It's whereby Maam it gains er electrons
170 Teacher: Do we have any gaining of electrons here?
Class: No
Teacher: So how can a negative ion form?
Sabelo: Yes

(Turns 166-173 Transcript of Bond Energy lesson)

Although I have included this excerpt here it is not a real argument like those considered so far from this class discussion. This is an example of funnelling: of the teacher reducing the cognitive demand of the task and narrowing the question to a much simpler version of the original question (Brodie 2007). Typical of a funnelling situation the teacher's question in turn 166 is followed by a chorus answer from the class, a mix of "No" and "Yes" which clearly indicates that there is still no consensus. This casts doubt over whether the long discourse had actually yielded the results the teacher was hoping for, to resolve the misunderstanding about the atoms acquiring a negative charge as they get closer to each other. The teacher's next question (*turn 168*) elicited the correct answer from Vuma and subsequently the rest of the class (turns 169-171). This justified the teacher's decision to close this session and move on with the lesson. However, as the teacher prepared to get back to the diagram on the board, a learner, Bonga raised his hand to make an unsolicited contribution:

- Bonga: I don't think of any er er negative charge forming (**Claim**) coz we are dealing with covalent bonding here (**Warrant**) (inaudible) they share their electrons with each other (**Data**) so I think negatively charged electrons only form when you are dealing with ionic bonding (**Rebuttal**)
- Class: Yes
- (Turns 184-185 Transcript of Bond Energy lesson)

What is interesting about this last argument in this discussion is that this was the first time Bonga participated in the discussion with an unsolicited contribution in the form of a well articulated and fully justified argument. It would appear that this might be articulation of an internal argument that had been going on inside Bonga's head while listening to and thinking through his peers' responses to the teacher's interventions. From the timing and the manner in which it was externalised I speculate that it might serve all the three purposes of argumentation. Bonga might be articulating a sense-making argument for clarification (to himself) or for validation by the teacher and/or the rest of the class. This could also be a persuasive argument to convince those of his peers who still did not understand the concept. Bonga's argument is also interesting in that it had four of Toulmin's components; a claim, data, warrant and a rebuttal making it a sophisticated explanation of his understanding of the difference between covalent and ionic bonding. By so doing he provided the solution to the problem and helped bring the argumentation session to an end.

The foregoing analysis of argument construction in Mrs Thoba's lesson illustrates all three of Berland and Reiser's forms of argumentation, that is, argumentation to articulate understandings, for meaning-making as well as for persuading. In the next section I illustrate attempts at argument construction by the teacher and learners in two of Mr Far's lessons, on momentum and on properties of compounds. However, attempts often aborted before arguments were fully constructed and I show how teacher intervention may have been responsible for the incomplete argumentation.

6.4 Argumentation during Mr Far's lessons on momentum and on properties of compounds

The first two excerpts are taken from the lesson on momentum. The teacher had planned to start the lesson by asking learners to simulate collisions and to then build up from their observations to the concept of momentum. However, as he introduced the lesson a learner, Kelvin, asked whether momentum was a vector or scalar quantity. In response the teacher asked for a definition of momentum to which another learner gave the standard definition of momentum as the product of mass and velocity. The teacher then engaged Kelvin and the rest of the class in a discussion to determine from the definition whether momentum was a scalar or vector quantity and why:

3	Teacher:	according to eh the definition momentum can be regarded as a measure of the product of the mass and the velocity. Now Kelvin if you think about mass and velocity think about mass in terms of the quantity can we regard mass as a vector quantity or is it a scalar quantity?
	Ls:	vector ... scalar... scalar ... vector
5	Teacher:	now I will say that again think about it carefully
	Ls:	(talking together)
	Teacher:	think about mass how do we regard mass because she has used the words mass and velocity
	Len:	scalar
	Teacher:	why? (Teacher calling for justification)
10	Len :	because yah the mass is got size (Evidence, D)
	Langa:	yah its
	Melo:	mass is got size
	Teacher:	so why am I asking this? Because our biggest problem that we experience and encounter is that most of us cannot distinguish between this and that (<i>underlining vector and scalar</i>). So let's just refresh quickly. Len you said this is scalar and why are you saying this is scalar?
	Sindi:	because it has size (Evidence, D, repeated)
15	Teacher:	thank you very much so we only have size which can be ...
	Kelvin:	magnitude
	Teacher:	magnitude. And here we have size or magnitude
	Sipho:	no direction (Warrant, W)
- (Turns 3-18 from momentum lesson)*

In the opening turn the teacher reiterated the definition of momentum and then to provide Kelvin a cue to think through the question he asked him to “think about mass in terms of the quantity can we regard mass as a vector quantity...?” At that point the class chorused variable answers and in turns 5 and 7, the teacher kept the question in the social space, challenging the learners to “think about it carefully”. When Len finally answered and said that mass was a scalar quantity (turn 8) the teacher did not just accept his answer and move on. Instead, he asked that Len justify his answer a that Len justify his answer “Why?”, thus creating an opportunity not only for Len to justify his answer, but also for possible rebuttals from the rest of the class seeing as they had earlier chorused conflicting answers (turns 4 and 6). In response, Len provided justification for his answer drawing from the scientific evidence that mass has size. In the next two turns his peers, Langa and Melo expressed their agreement with Len. In the next turn (turn 13), the teacher engaged in meta-talk about the reason for the probing that he was subjecting the learners; to determine if they could distinguish between scalar and vector quantities. In so doing the teacher was also providing pedagogic link-making for both knowledge-building and for continuity, helping learners recall information from past lessons in the current or earlier grades as well as relate it to the current lesson on momentum. The question at the close of turn 13 could be viewed as repetitive of the previous episode’s conversation. However, what the teacher did with the answer in turn 15 indicates a shift in teaching purpose as he cued the learners to introduce a more “scientific” term for size (magnitude). The episode closed with an unsolicited contribution from Sipho in turn 18, providing the warrant for the argument that mass is a scalar quantity; that it only has magnitude and no direction.

The next excerpt, taken from a discussion later in the same lesson, was the only other argument identified in this lesson and it is a lower level claim-data argument:

55	Teacher:	right so can we regard momentum as this or that? (<i>pointing at scalar and vector</i>) And I will ask Shakira. She was not paying attention that’s why I asked her
	Shakira:	Sorry Sir
	Teacher:	Sorry Sir (<i>imitating Shakira</i>) Nikita?
	Nikita:	its a vector (Claim, C)
	Shakira:	its a vector
60	Teacher:	why is momentum a vector? So momentum is a vector vector quantity vector quantity (teacher writing). Why regard momentum as a vector quantity? (Call for justification of C)
	Austin:	because of direction
	Nadia :	size

Teacher: it consists of both ... ?
 Nadia: size and direction.
 65 Teacher: size and ... direction **(Warrant)**
 Austin: direction
(Turns 55-66 from lesson on momentum)

This episode opened as the teacher once again asked whether momentum is a vector or scalar quantity. When Nikita and Shakira (turns 58 and 59) gave unsupported answers the teacher used a “Why?” question to extract justification of Nikita and Shakira’s claims (turn 60). However, both were not able to support their claims and the justification was subsequently provided by and two other learners, Austin (turn 61) and Nadia (turn 62). The teacher then provided evaluative feedback affirming both Austin and Nadia and thus confirming the justification (turn 65).

The next three excerpts taken from the lesson on properties of compounds do not contain clear evidence of argument construction but I use them to illustrate the potential for argumentation in this lesson:

43 Teacher: I will need two volunteers two people to assist me with the experiment but before we come to the experiment remember I’m saying we are performing the experiment with regard to magnesium and air. So write down your hypothesis. What do you think is going to happen if those two chemicals react? If those two chemicals react what do you expect to see? So that will be your hypothesis
 Class: *(students writing - 17 sec)*
 45 Teacher: So please write down what do you think is going to happen? What you expect to see? And please think about how fast it will happen if possible or how slow it will be if possible. Musa are you done? Because I need a volunteer, Musa.
 Learners: *(writing their hypotheses, while teacher and two volunteers . prepare for the experiment)*
 Teacher: Right are you done Sobuka? Right so magnesium. While we are waiting for Musa to clean this for us does anyone recall anything about magnesium? Remember we’ve done the Periodic Table. Yes Tebogo?
 Tebogo: *(inaudible)*
 Teacher: Right so according to Tebogo he says the property or one of the properties of magnesium is? It is?
 50 Walter: flammable
 Teacher: it is flammable that is what he says. So if you have good eyesight this is a very small bottle but we will send it around. Please look at the symbol that’s on this bottle look at it and send it around and see if it is confirmation for what he’s saying. She’s looking for the sign and the symbol. For this experiment we need to do a safety prevention. Look at how if we say magnesium is flammable it will burn then we must take precaution isn’t it so? Precautionary measures. So we must think about where are we going to perform this experiment? How far from clothes or books this experiment must be performed. That’s why I am using it as a demonstration. If I use it on the table close to you it might burn

Class: you or it might burn ...?
 Teacher: the table
 Teacher: the table. So I assume you already have your hypothesis accordingly. So we are just waiting on Musa then we start.
(Lesson on properties of compounds, turns 43-53)

The conversation in this excerpt had the potential for argumentation with a different set of teacher interventions. In turns 43 and 45 the teacher instructed the learners to write down their hypotheses, providing guiding questions for thinking through the process such as, "... what do you think is going to happen? What you expect to see?" Follow up like "Why do you think that will happen? Why do you expect to see that?" would suggest to learners to critique their own ideas about the experiment that they were about to observe. If learners had the opportunity to discuss each other's hypotheses then they could also be guided to pick up and exercise evaluative skills which are necessary for argumentation.

Likewise, the telling episode in turn 51 could be turned into a whole class discussion of the precautionary measures, thus creating an opportunity to elicit learner ideas and foreground them for critique by their peers. Alternatively, the teacher could model such skills by presenting selected learner hypotheses for whole class discussion and critique under his guidance. In the excerpt below Mr Far started to model these skills as he played the devil's advocate in a critique for Sobuka's suggestion that the reaction between magnesium and oxygen would yield a mixture:

125 Teacher: We are going to mix. According to Sobuka he is going to mix and he is gonna explain to us how he is gonna mix these two chemicals that he is having. He is having an element magnesium which is a solid by the way which is a metal by the way and the gas that we cannot see around us which is oxygen. How he is going to mix them because after the mixture we are supposed to separate them again **(teacher uses his hands to illustrate separating)**. That's according to definition of a mixture. We supposed to physically separate them again. Then it becomes a mixture. But this will it be a mixture? So think about this term that we have on the board. A compound according to Simphiwe what was the definition of a compound again?
 Simphiwe: a substance formed of two ...
 Teacher: say again
 Simphiwe: a substance formed of two or more elements chemically united in fixed proportions
 Teacher: chemically?
 130 Sobuka: United
 Teacher: united in a fixed ratio. That is what he is saying. So that is what we are trying to do as well. So please let's start. Observe. Sobuka so please take note ne you are saying you want to perform a mixture and he is saying a compound. Ignite
(Lesson on properties of compounds, turns 125-131)

In turn 125, Mr Far engaged in what could potentially be an argument based on participants' predictions on the nature of the product of the reaction the class was about to witness. Learners could discuss from two opposing camps; those learners who agreed with Sobuka that the product would be a mixture and those who said that it would be a compound. Each group of learners would be required to provide justification for their position or to critique the other group's claims using some of the evidence already made available in turn 125 by the teacher and in turns 126-130 between the teacher and Simphiwe.

A similar situation arose later in the same lesson as the teacher guided learners in constructing the chemical equation for the reaction they had just observed:

- 174 Teacher: Magnesium oxide
 175 Class: *(murmuring softly as they write their equations in their books)*
 Teacher: Right so can someone give me the symbol for Magnesium
 Class: Mg Mg
 Teacher: Mg.
 Thabisile: plus O-2
 180 Teacher: what are you saying Thabisile? Say that
 Thabisile: silent
 Teacher: hah? Why are we writing it as O-2 and not as O? Remember I said when I started that I will come back to the definition a specific term
 Raesibe: oxygen is diatomic
 Teacher: Thank you very much so oxygen is a diatomic molecule. Is there anyone else that will explain to us what we mean by the term diatomic molecules? Kabelo?
 185 Kabelo: *(silent)*
 Teacher: *(To Kabelo)* Shake your head *(to Lerato)* Lerato what does the word diatomic stand for?
 Lerato: *(muttering)*
 Teacher: She is asking you Melo she is saying you will give us the answer
 Melo: *(muttering)*
 190 Teacher: What does di- mean?
 Melo: *(murmuring)*
 Teacher: someone is screaming it out. They are afraid. Why are you afraid? Bongani? Have confidence and say that it is two
 Teacher: So diatomic means
 Bongani: two
(Lesson on properties of compounds, turns 174-194)

The teacher reiterated a learner's answer that the name of the product was magnesium oxide and to initiate a whole class discussion to construct the chemical equation he asked for the symbol for magnesium (turn 176). The class chorused, "Mg" (turn 177), which the teacher revoiced in turn 178, thus providing evaluative feedback that confirmed the answer as accurate. When Thabisile volunteered the rest of the formula for magnesium oxide the teacher took up her contribution and foregrounded it for further interrogation first by

Thabisile herself and then by the rest of the class. In turn 182 the teacher made two interesting interventions. First, he probed for reasons why Thabisile was suggesting that the formula would be O-2 and not just O. This intervention had the potential to bias the argument and open up the interaction for argumentation as the teacher elicited learner ideas, probing them to provide supporting evidence for either claim. Secondly, the teacher performed two of Mortimer and Scott's pedagogical link-making moves in the same turn.

While in the question, "Why are we writing it as O-2 and not as O?" he did pedagogical link-making for knowledge construction, in the statement, "Remember I said when I started that I will come back to the definition a specific term" he performed pedagogical link-making for continuity. He was helping learners make sense of both the chemistry behind the combustion of magnesium and the skill of constructing chemical equations. To do this he linked this episode of the class discussion to an earlier one in the introduction where the learners defined a molecule. In turns 183-194 the teacher probed learner understanding of the concept of di-atomic molecules and finally Raesibe (turn 183) and Bongani (turn 194) provided the acceptable answers. The information on di-atomic molecules could be useful as grounds to support learner claims for either O-2 or O in the argumentation process.

The excerpts from Mr Far's two lessons illustrate some evidence of argumentation and/or attempts at argument construction. It seems that Mr Far's frequent use of evaluative feedback and closed questioning did not open up the social space sufficiently to allow learners to support their own and/or critique each other's ideas.

I now turn to Mrs Nkosi's lesson on owl indigenous knowledge, in which all three forms of argumentation were evident, albeit with only a few incidents of argumentation for meaning-making.

6.5 Argumentation during Mrs Nkosi's lesson on indigenous knowledge of owls

In the lesson presented here, Mrs Nkosi's used one of the ideas from the teaching materials that the teachers had put together during the teachers workshops described in Chapter 3 as part of the school based support programme of the ICC project. The lesson addressed a very controversial topic for the South African multi-cultural context in which it was delivered. The focus of the lesson was to explore learners' indigenous knowledge of owls as well as their beliefs and attitudes that might impact their understanding of biodiversity conservation.

For many black people in Africa, owls are associated with evil and witchcraft. Some believe that the owl is used by witches to carry bad spells or to cause sickness and death. It is a sign of bad luck to see an owl or hear it call and it is taboo to touch it or its carcass (see for example, Msimanga, 2000). The owl is thus, not a welcome topic for discussion. However, part of the biology content that must be learned at this level relates to energy transfer in food chains and in food webs. The owl occupies the position of predator in the food chain, preying mostly on rodents. In areas where rats and mice populations are high it might be advisable for residents to understand the biology of the owl so as to at least be able to tolerate owls. The three tasks under discussion in this lesson were premised on this conflict between cultural views of the owl and its potential in bio-control of pests as well as conservation of biodiversity.

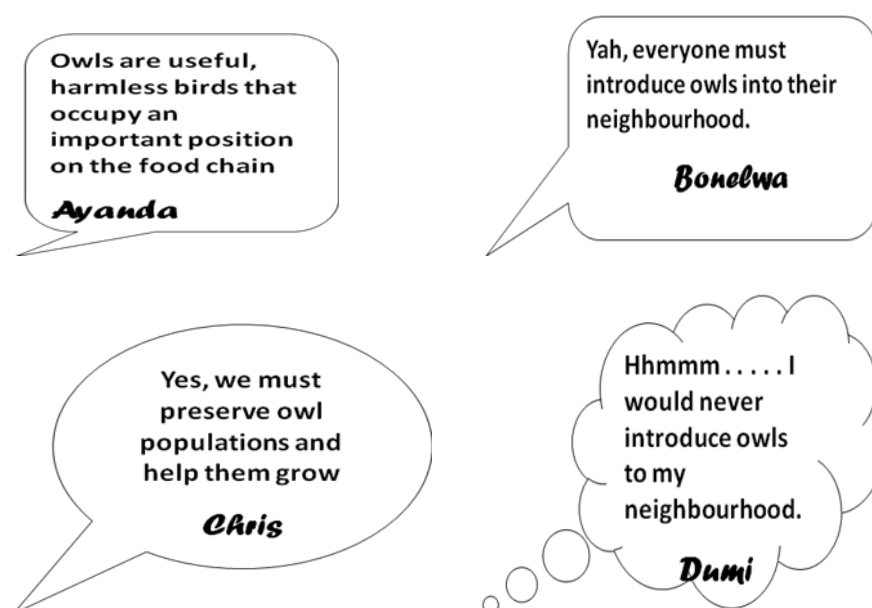
After handing out the worksheets with the different tasks to groups of learners, the teacher adeptly started the lesson with a general discussion of animals and their role in the life of the learners. She then steered the discussion towards the activity for the day and called on learners to read the tasks on the worksheets. She then engaged the class in a discussion of the tasks which would ultimately lead to a discussion of the learners' own beliefs about owls and their conservation.

The three tasks discussed were as follows:

Task 1: Role play of a notice from the local administrative council

<i>New notice from the council offices</i> “IN THE INTEREST OF ENSURING ANIMAL DIVERSITY AND SPECIES CONSERVATION, GOVERNMENT NOW REQUIRES ALL RESIDENTS TO KEEP AT LEAST ONE OWL IN THEIR BACKYARD” Discuss the new notice Remember that everyone’s idea is important, so • Everyone must participate • Everyone must say what they think • You must listen to what others have to say • You must always give reasons for what you say

Tasks 2 and 3: Concept cartoons on learner IK on owls and biodiversity conservation



Question for task 2: Who do you agree with? Why do you agree with them?

Question for task 3: Who do you disagree with? Why do you disagree with them?

From the data analysis I made four key observations. First, after the initial, culturally “benign” introduction the teacher struggled to get the learners to articulate their ideas about the apparently culturally sensitive status of the owl. The teacher had to coax the ideas out of the learners as is evident in the first two arguments illustrated later in this chapter. Secondly, when learners were still making claims about the culturally sensitive knowledge of owls they did not immediately provide the grounds for their claims, the teacher had to probe them for their reasoning. However, later in the discussion when they moved on to less sensitive issues learners provided both the claims and their grounds sometimes within the same utterance. Thirdly, learners did not challenge the first claim made about the owl and witchcraft, most actually expressed agreement. However, they readily challenged each other’s subsequent arguments often providing rebuttals for the evidence used to support the claims. The fact that learners made as many as ten rebuttals in this discussion is quite significant as will be discussed later. Finally, learner arguments in Mrs Nkosi’s lesson were largely used to articulate learner beliefs and understandings as well as to persuade their peers of their convictions about owls. The teacher however, often inserted or highlighted the science base of some of the claims in an attempt to steer the discussion towards meaning-making arguments. It would appear that because of the emotional nature of the engagement learners

often did not pay attention to the teacher's interventions targeting this sense-making goal of argumentation and only engaged in persuasive arguments.

In presenting the results of this analysis I first give a frequency count of the components of an argument identified in this lesson (Table 6.02) as well as an indication of the diversity in form and quality of arguments articulated. I then illustrate the arguments using excerpts from the lesson transcript which is given in full in Appendix 6.02.

6.5.1 Structure of arguments constructed during the discussion on owl IK and conservation

All the six components of Toulmin's argument were represented in this discussion. The teacher and learners together made a total of 12 claims with 29 attempts to provide the grounds on which the claims were made, including 12 pieces of data, 7 warrants, 5 backings, 4 qualifiers. A total of 10 rebuttals were offered (see Table 6.02). According to Erduran and colleagues' classification of arguments the high incidence of rebuttals are an indication of a high level of argumentation in this lesson.

Table 6.02. Summary of argument components identified in the discussion in Mrs Nkosi's lesson.

Argument component	Frequency
Claim, C	12
Data/evidence, D	12
Warrant, W	7
Backing, B	5
Qualifier, Q	4
Rebuttal, R	10

As in the case of Mrs Thoba's class these learners were not tutored in argumentation and their ability to provide so many rebuttals is therefore, worth noting. The high incidence of rebuttals has not been reported in South African classroom discussions of socio-scientific/socio-cultural issues by untutored learners. In fact other studies have shown that untutored learners struggled to provide rebuttals in arguments (Lubben, et al., 2010) and also that in discussions

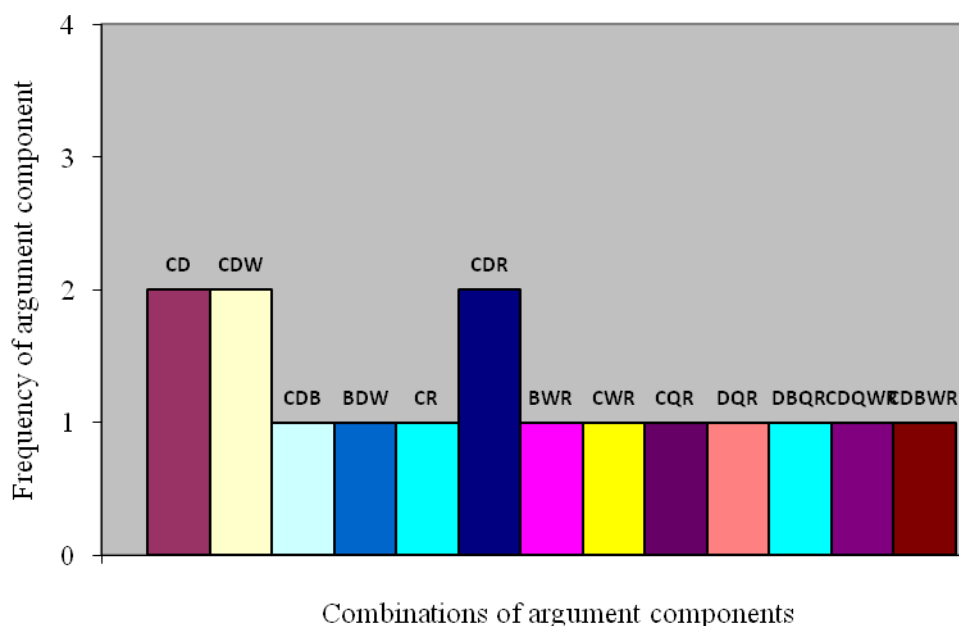


Fig 6.04 Combinations of argument components identified in Mrs Nkosi's lesson discussion

based on socio-scientific issues learners provided noticeably fewer rebuttals for each other's arguments than in discussions of scientific issues (Braund, et al., 2007). Figure 6.04 illustrates the structure, diversity and quality of arguments in this lesson.

The range of combinations of argument components in this lesson was quite diverse as depicted in Figure 6.04. Arguments ranged from simple pairs of components such as CD and CR to more sophisticated combinations of four or five components which also included rebuttals. In terms of argument complexity there were again two levels: complexity in terms of inclusion of rebuttals as well complexity as seen in how elaborate the extended arguments were in terms of the number of components included. In this particular lesson there were ten arguments with rebuttals as opposed to four without.

As noted earlier, the high incidence of rebuttals in this lesson is quite interesting in the light of evidence from other studies. A study by Braund and colleagues in the Western Cape Province of South Africa found that learners made many fewer rebuttals during discussions of socio-scientific issues (see later discussion of evidence from Braund, et al., 2007). Although the authors attributed this difference partly to task design they also felt that it might be due to the fact that the evidence for socio-scientific issues which was largely drawn from

students' diverse personal and cultural, moral or religious beliefs was not shared among the students from different cultural backgrounds. In a similar study in the UK however, Osborne and colleagues (Osborne, et al., 2004) observed significantly more argumentative discourse when students discussed socio-scientific issues than when they talked about scientific issues. They also attributed the difference to the nature of the evidence that students used to support their claims arguing that student knowledge of the evidence was a requirement for successful engagement in argumentation and scientific reasoning. They concluded that it might be harder and more demanding for both teachers and students to initiate arguments in scientific contexts. Evidence from the discussion in Mrs Nkosi's lesson seems to mirror that in the UK study. This could be for similar reasons as in the UK study, that learners had a good knowledge of the evidence required to make the kinds of arguments they were making. However, as in the case of the Western Cape study the nature of the argumentation could be attributed to the nature and design of the task. Mrs Nkosi's task had the potential to generate high levels of argumentation inside and outside of a science classroom context because of its dual socio-cultural and socio-scientific nature. Unlike in both the UK and Western Cape studies where evidence was in the form of the learners' social norms and values as well as their scientific knowledge of the topic, participants in Mrs Nkosi's lesson could draw on the social norms and values, their cultural beliefs and practices as well as their scientific knowledge of the biology of the owl, of ecosystems, food chains and food webs in general. This makes Mrs Nkosi's task a potentially interesting one to use to generate both learner participation and development of argumentation skills. However, as will be seen later from discussions of the excerpts, this kind of task makes high demands on the teacher to mediate and scaffold engagement with the scientific aspects of the lesson. From the apparent contradictions in evidence from different studies of argumentation on socio-scientific issues, it would seem that there is need for further research into argumentation on socio-scientific issues in South African multi-cultural classrooms. I now proceed to illustrate and discuss development of the various arguments in this lesson.

There was much enthusiasm as the teacher led the class through an introductory question and answer episode in which learners identified different types of animals and how they were useful to humans. Learners seemed excited as they responded to the teacher's call to read out the scenarios depicted in the worksheets. However, the enthusiasm died down almost immediately when the teacher changed the focus of the lesson to the learners' own cultural

knowledge of the owl. As the teacher asked direct questions to elicit learners' knowledge there was a general buzz as learners spoke among themselves but none would speak up for the whole class to hear. The teacher repeated her question several times without getting a response. In first the excerpt below the teacher repeated a statement by one of the character in the concept cartoon and then asked Lindokuhle to explain his earlier reaction to the contents of the worksheet:

- 163 Teacher: he says (*referring to the character in the concept cartoon*) "Hhmm no way I would never introduce owls to my neighbourhood" (*and then to the class*) Now let's hear why wouldn't you introduce owls into your neighbourhood? You should be having reasons why you are against it. You should be having reasons why. Lindokuhle why wouldn't you want to have an owl? Think about the perceptions. Remember people there are different perceptions about certain animals *angithi*? Some people would say er I don't want to have a cat in my home and give a reason. I overheard Lindokuhle say "No no" to an owl (**Claim- agrees with cartoon character**). Now he must tell us why.
- Lindokuhle: owl?
- 165 Teacher: yes what is it that you know? maybe it something that you read in a book in a newspaper. Or you saw in the television? Or if its something that is er that you learnt from your parents or your grandparents or in your community. Remember different communities have different beliefs. So let's hear about that. *Iskhova ah isikhova hhm (teacher imitating the boys)*
- Lindokuhle: *ah Maam isikhova ah* (no Maam an owl no) (**Claim repeated**)
- Class: (*girls laughing*)
- Lindokuhle: *isikhova?* (an owl?)
- Teacher: you said "No no no" now tell us why
- 170 Lindokuhle: *isikhova?* (an owl?)
- Teacher: no just be free. Oh someone wants to help him
- Nanelo: er Maam because many people believe that owl are used to witch other people (**Data**)
- Class: yes yes
- Teacher: there you are
- 175 Class: yes yes
- (Turns 163-175 Lesson on owl indigenous knowledge and conservation)

I refer to what happened in this episode as "learner cultural difficulty" to articulate the argument. Lindokuhle's immediate reaction to the teacher's question on whether he would be willing to introduce owls into his neighbourhood was "No, no, no". However, when the teacher probed for his reasons he could not articulate them. Instead, in turn 164, he asked what seemed to be a question "Owl?" and then went on to declare "No Maam an owl no" (turn 166). Judging from these and his subsequent utterances it seems that Lindokuhle was overwhelmed by the idea that anyone could even consider introducing owls into their neighbourhood. It also seems that Lindokuhle had an opinion or cultural understanding of owls in his mind but something constrained him to externalise his stand point. Ultimately, in turn 172, Nanelo offered a reason for Lindokuhle's position, that owls are believed by many

to be related to witchcraft. Nanelo's veiled warrant could be that since many people believe this it would be unacceptable for anyone (who is not a witch) to introduce owls since they might provide a resource for witches. In subsequent turns (173 and 175) the class almost unanimously agreed with Nanelo. This seems to have hindered argumentation. Since the whole class agreed with her, Nanelo had no reason to engage in an argument to persuade her peers of her claim. This may be significant for argumentation tasks based on issues with strong cultural implications on two accounts. First, there seemed to be an established shared "understanding" of owls based on a common belief system, hence no need for argument. Secondly, it would take a very bold learner to challenge this common understanding since such a learner might be viewed as taking sides with witches. If it is culturally unacceptable to deny that owls are used by witches then by so doing the learner would be suspected of being somehow associated with or supportive of witchcraft. If the foregoing is true, it is not surprising that there were no rebuttals for this argument. This episode was broken very briefly when one learner advanced an alternative claim and another raised a rebuttal querying the nature of the evidence used to support and justify the argument about witchcraft:

- 179 Teacher: ok someone says it feeds on the mice as well (**Rebuttal**) so that's a positive effect (**Warrant for rebuttal**) but most of you are saying no no no do we believe in what people are whispering about? Because I can hear people are saying things but they don't want to come forward now come forward talk about these things
- 180 Class: (*whispering*)
Teacher: is it related to what I overheard people saying? bewitching?
Class: No
Teacher: ok he says no (**Rebuttal**) because he hasn't seen it (**Warrant for the Rebuttal**) but have you heard anything to that effect?
Class: yes
- 185 Teacher: that some people use it to bewitch other people? I remember as a young girl I used to hear those negative things about owls (**Data**). Let's hear man some of you are from KZN (**Backing**)
Class: (*talking noisily at the same time*)
(*Turns 179-186 Lesson on owl indigenous knowledge and conservation*)

The recording did not capture the learner's contribution at the onset of this episode but I picked it up from the teacher as she repeated it for the rest of the class. The learner pulled in evidence from his knowledge of the biology of the owl as a predator to support an assumed claim that he would be willing to introduce owls into his neighbourhood because they feed on mice since (as an implied warrant) the mice are not desirable. It would have been interesting to hear other learners' reactions to this rebuttal of the previous argument. However, the teacher picked up on dissenting voices in the background and intervened so as to steer the

discussion back to the initial claim. To do this she biased the argument with the claim that “but most of you are saying no no no” and playing the devil’s advocate “... do we believe in what people are whispering about?” thus challenging learners’ beliefs about the owl. As mentioned in the introduction to this section, this is an example of the challenge that teachers are faced with when handling tasks like this. The teacher could have (and perhaps should have) taken up this learner’s idea of owls as predators which was in line with what one of the other cartoon characters argued that owls occupy an important position in the food web. This would serve to develop the scientific story (Mortimer & Scott, 2003) of biodiversity conservation. However, she made the decision to pursue the witch craft argument with interesting results as seen in this next excerpt:

- 193 Teacher: remember we are sharing information here. It’s a sharing of ideas.
Yes Nelisiwe?
- Nelisiwe: about an owl?
- 195 Teacher: Hhm
- Nelisiwe: *Eh tjo Maam* (oh no Maam)
- Class: *(laughing)*
- Nelisiwe: *Tjo Maam li-violent igama lelo* (Oh no Maam the word is violent)
- Teacher: say it in vernacular
- 200 Nelisiwe: No Maam it is a sign of death **(Claim)**
- Class: yes yes
- Teacher: Hoo that’s another issue. You see now?
- Thabo: no Maam **(Rebuttal?)**
- Teacher: don’t say no because you never said anything. Some people believe that it is a sign it symbolises death
- 205 Class: yes yes
- Thabo: how?
- Class: *(talking noisily at the same time)* yes yes
- Teacher: you see now? And some of you people are actually saying yes
- Thabo: how?
- 210 Class: *(talking noisily at the same time)* yes yes
- Teacher: no wait now does it mean that if an owl passes over my home
- Class: yes yes
- Teacher: it means death
- Class: yes yes no no no *(mostly girls shouting yes and boys saying no)*
- 215 Teacher: Whoa people *(to learner shouting “No”)* you said you didn’t know anything about it so don’t say no and some people are talking about what they know it’s what they have heard and some people believe that if it passes over my home then I must anticipate death **(Warrant)**.
- Class: yes yes no no
- (Turns 193-216 Lesson on owl indigenous knowledge and conservation)*

The teacher’s first utterance was a reminder to the class of the goals of the discussion. She often did this, articulating the teaching and learning agenda and keeping it explicit. At this point the teacher picked on Nelisiwe whose hand was not raised to speak but who had been talking to her peers about something. Nelisiwe’s response in turn 194, is interesting for two reasons. In the first place she articulated her response in question form as if seeking

clarification of the teacher's question when in fact she was expressing a reluctance to talk about owls. This is evident in her next two turns (196 and 198) where she exclaimed "*Eh tjo Maam li-violent igama lelo* (oh no Maam the word is violent)" referring to the word "death" which in some African cultures is taboo to even mention. Her response also seemed to change the tone of the conversation moving it from the seemingly more culturally accepted and "undisputed" association of owls with witch craft to a more debatable belief about owls and death. While most of the class shouted agreement Thabo raised a counter claim (which could have developed into a rebuttal), "No Maam" phrased in the next two turns as the question "How?" (Turns 20, 206 and 209). Clearly in Thabo's culture (or in his personal conviction) the owl does not depict death thus he called on Nelisiwe to provide evidence for her assertion. Once again an instructional dilemma arises. While it is desirable for learners to challenge their peers ideas and raise rebuttals, they themselves should be willing to make their own claims (share their ideas as the teacher kept reminding the class) which Thabo had declined to do earlier, according to the teacher's remarks at this point (turn 204). This is a similar kind of tension to that cited by Scott and colleagues between the authoritative nature of science as a subject and the dialogic requirements for meaning-making (Scott, et al., 2006). The teacher's role is partly to manage and mediate this tension and in this case Mrs Nkosi could have challenged Thabo to provide a rebuttal by articulating his own belief about this particular topic. Mrs Nkosi did do this in turn 208, for the group that supported Nelisiwe's position by biasing the argument while playing the devil's advocate (Braund, et al., 2007; Simon, Erduran, & Osborne, 2006) and articulating the evidence (turn 204). However, all they did was agree or disagree until in turn 215 she provided a warrant (again playing devil's advocate) which some learners agreed with. This led to some (weak) rebuttals in the next two episodes:

- 217 Nanelo: we don't know about that **(Qualifier)** but everyone believe on that **(Warrant)**
Teacher: people believe it?
Class: (boys) not everyone not everyone **(Rebuttal)**
220 Teacher: ah ah ah whoa. uNelisiwe has something to say. Yes?
Nelisiwe: ok Maam I was correcting Nanelo not everyone but most of us
Class: (boys) yah yah
Teacher: ok most of the people
Class: (boys) no no no
225 Nanelo: Maam people pretend **(Claim)** (inaudible) but *sonke nje siyazi ukuthi iskhova siyathakatha* (but we all know **(Data)** that an owl is used for witchcraft **(earlier claim repeated)**
Teacher & Class: (general laughter)
Teacher: Alright alright people. Remember we are sharing ideas.
(Turns 217-227 Lesson on owl indigenous knowledge and conservation)

In response to the teacher's last utterance from the previous episode that "... some people believe that if it passes over my home then I must anticipate death" Nanelo responded in turn 217 with a statement that was difficult for me to resolve in terms of Toulmin's argument pattern (TAP). It seemed to me that the statement "We don't know about that but everyone believe on that" could either be a combination of a warrant and a qualifier or it could be an independent claim. On the one hand, her argument could be that she and the others do hold this belief (claim) even if they do not have evidence. On the other hand, she could be arguing that there is no need for evidence that owls signal death (claim) because it is a culturally accepted belief (data) since everyone believes it (warrant). This concurs with observations in literature about the difficulty of resolving differences especially between claims, warrants and data in extended and/or co-constructed arguments (see for example Erduran, et al., 2004; Sampson & Clark, 2008a; von Aufschnaiter, et al., 2008). Note how even after she was challenged by her peers who claimed that not everyone believed as she did, Nanelo maintained her stance (turn 225 drawing on the evidence of shared cultural knowledge about owls and arguing that the rest of the class were pretending not to share the same belief. Her only source of evidence was the fact that "everyone knows".

A similar situation arose again later in the lesson when Sandile raised another strongly held cultural belief about owls and traditional medicine:

- 263 Sandile: ah *mina* Maam what I know about owls Maam *into* (something) that they use it for *ukuthi bayisebenzisa* to (they use it to) other people the traditional healers they catch it they kill it then they make *umuthi* Maam **(Claim)**
- Mulalo: yaah
- 265 Teacher: there you are
- Class: *(talking noisily at the same time)*
- Teacher: you see now? Some people believe whoa *(calling for silence)* people the problem with you is that you have some information but you don't want to share it with us and if someone comes up with something then you want to *(gesturing about interruptions)*
- Class: yes
- Teacher: he is saying that's another point remember there are different views here. Now he says people right use it especially traditional healers let me just be specific as he said. He says traditional healers kill this animal for what purpose to form some mix it maybe with some herbs I don't know but it is used for healing purposes **(Warrant)**. Yes?
- 270 Nanelo: *mara mina into engiyaziyo ngale eshiwo wuSandile ukuthi lowo muthi lowo osuwenziwe ngalesoskhova* (but what I know about what Sandile is saying is that the *muthi* made from the owl)
- Teacher: Uhuh?
- Nanelo: *akusiwona umuthi okuphilisa* (is not for healing) **(Rebuttal)**
- Teacher: ok?

- Nanelo: *wumuthi we* (it's for)
 275 Lufuno: *(shouting) wokubulala* (for killing) **(Warrant)**
 Nanelo: *wumuthi wukuthakatha* (it's only for witchcraft)
 Class: *(talking loudly)*
 Nanelo: *vele wokubulala someone* (it's just for killing someone)
 Class: *(talking at the same time)* **(in agreement with rebuttal)**
 280 Teacher: Ok ok shh
 Class: *(talking to each other about how some healers are also witches)*
 Teacher: Quiet er did you hear what she said?
 Class: yes yes
 Teacher: now on the contrary to what Sandile said she says those people
 use the *muthi* to bewitch others **(Rebuttal rephrased)**
 285 Class: yes
 Teacher: and she is supported by someone who says that is true they never
 use that for healing purposes **(Backing)**
 Lufuno: yes
 Teacher: but they use it to destroy the lives of other people
 Class: yes yes
 (Turns 263-289 Lesson on owl indigenous knowledge and conservation)

This is an example of co-construction of an argument by the teacher and learners together. The claim was made by Sandile in turn 263, supported by Mulalo in turn 264, warranted by the teacher in turn 269 and then Nanelo joined in with a rebuttal in turn 272, which she and Lufuno warranted in turns 275, 276 and 278. In her intervention in turn 284, the teacher took up both Nanelo's and Sandile's ideas and contrasted them highlighting for the class the link between the claim and rebuttal. She then pulled in a backing (for the rebuttal) which another learner had made in the background (turn 286). At the same time that she was mediating this argumentation process Mrs Nkosi seemed to be conscious also of the need to emphasise the rules of engagement, as she did at the beginning of this episode in turn 267, "the problem with you is that you have some information but you don't want to share it with us and if someone comes up with something then you want to (interrupt)". Mrs Nkosi's style here as in other parts of this lesson and in her other lessons seemed to be an attempt to find a balance between managing the discussion process, mediating learner engagement according to the norms of argumentation and keeping them focussed on the goals of the lesson. She made the rules of engagement explicit as it were, so that she and her learners maintained a common understanding of both the social and scientific goals of the lesson. This is important for negotiation of understandings and for co-construction of arguments (Driver, et al., 2000; Erduran, et al., 2006).

In subsequent arguments learners seemed to be on cue about the teacher's attempts to develop an understanding of the norms of argumentation and the rules of engagement in this kind of

discussion. The next three excerpts illustrate arguments in which learners actually consciously pointed out the importance of evidence and either provided it or demanded:

- 234 Teacher: Bandile what was your issue?
 235 Bandile: Maam scientists Maam believe on evidence **(Rebuttal)**
 236 Mpendulo: yes
 237 Bandile: where I live Maam there are owls **(Data or Claim?)** I'm seeing them **(Data)** almost every day **(Qualifier)** but there is no death **(Backing, Warrant or Claim?)**.
 238 Teacher: oh so you are looking at it from a scientific point of view?
 239 Class: *(boys)* yes yes
 240 Teacher: and as a student who is doing Physical science you want evidence?
 241 Class: yes
 242 Teacher: so which means you need to do *(suggesting experiment)* but you cant do that you don't know how they put their things together and get their effect
 243 Class: *(talking noisily at the same time)*
(Turns 234-242 Lesson on owl indigenous knowledge and conservation)

In presenting a rebuttal for the preceding claims (turn 235) Bandile made an explicit distinction between the nature of argumentation so far in the lesson and what he considered to be a scientific argument. By so doing he shifted the conversation away from the socio-cultural goal to the scientific one, arguing for the importance of evidence in a scientific argument. In turn 237, he then referred to his own observations within his neighbourhood (as evidence) that there were owls in his neighbourhood and that since there was no death (warrant) in spite of the presence of owls then the claim (that owls are a sign of death) did not hold true under those circumstances. This is as Braund et al. (2007: 95) observed that “warrants made to support claims based belief systems ... are hard to evidence and therefore, to back, ... in the sense that a scientist might use evidence”. This is confirmed in the dilemma that arose as the teacher in turn 241, in elaborating on Bandile’s statement started suggesting that he might conduct an experiment to gather the evidence and then realised that an experiment would be inappropriate in this context. In an experiment Bandile would duplicate the healers’ procedures (according to the scientific method) and would expect similar results to the healers’. However, according to the teacher this would be difficult since he did not know “how they put their things together”. There is however, another implied challenge in the suggestion to conduct an experiment to obtain the requisite scientific evidence. For Bandile’s experiment to be successful death would have to occur and that would present a moral dilemma.

In the next episode, shown in Chapter 5 to be an open dialogue, Nkululeko volunteered an argument based on the biology of the owl:

- 246 Nkululeko: *er Maam kahle kahle into nje okumele abantu bayazi ukuthi iskhova nje asidalelwanga ukuhamba emini sihamba ebusuku yikho nje abantu bethi iskhova siyathakatha* (er Maam what people should know is that an owl was not made to be active during daytime it comes out at night **(Data)** that is why people say an owl is a witch **(Warrant)**)
- Class: yes yes
- Teacher: oh ok
- Nkululeko: *asikwazi kahle ukuhamba emini* (it does not move around during the day) **(Warrant)**
- 250 Teacher: it is nocturnal not diurnal
- Class: yes
- Teacher: in other words what he is saying is people are justified **(Claim)**
- Class: yes
- Teacher: to believe that it is used for a negative purpose because it is not seen during the day **(Data)**
- 255 Class: yes yes
- Teacher: and anything that is associated with darkness than light is usually **(Qualifier)** er right believed **(Backing)** to have an implication of what of being used to bewitch other people **(Warrant)**
- Ls: yes
- Teacher: that's what he is saying
- (Turns 246-258 Lesson on owl indigenous knowledge and conservation)

The teacher took up Nkululeko's contribution and used it to shift the focus of the discussion from beliefs about the owl, which had been the focus so far, to the biology of the owl. In turn 250, she followed up on Nkululeko's assertion (in turn 246) that the owl does not move during the day by inserting the scientific terms *nocturnal* and *diurnal*. She then elaborated on Nkululeko's argument that in light of the evidence available then people were justified to believe the way they did about owls (turns 252, 256 and 258). This way the teacher's intervention had the potential to mediate engagement with the biology as well as emphasise the skills of argumentation.

Earlier in the lesson (Turns 179-186) Mrs Nkosi had overlooked/ignored a learner's contribution based on the owl's biology, the fact that it fed on mice, but in the episode above and in the next two she took up the learners' ideas and used them to develop the scientific story of the lesson:

- 333 Nkululeko: *okunye Maam ukuthi iskhova sibalulekile* for human beings. *Iskhova okokuqala sidlamagundwane lezezismoshela thina impahla* (owls are very important for human beings **(Claim)** first, an owl eats rats **(Data)** that destroy our property **(Warrant)**)
- Teacher: so that's a positive

- 335 Nkululeko: *esinye sidli inyoka lezi ezisibulalayo* (some eat snakes **(Data)** which kill us **(Warrant)**
 Teacher: two that's a positive again
 Nkululeko: *so yikhoke ngithi sibalulekile iskhova* (that is why I say an owl is important)
 Teacher: so it is very important in the food chain **(Claim extended)**. There will be less snakes there will be less mice in our environment
(Turns 333-338 Lesson on owl indigenous knowledge and conservation)

Nkululeko's argument in this excerpt further shifted the discussion to the importance of owls based on their biology (turns 333, 335 and 337). He however, did not use the appropriate scientific terms and this would keep the discussion within the realms of everyday knowledge. The teacher took up his idea in turn 338, and used it to point out both the positive role that owls play in the environment and the scientific explanation for this role, "so it is important in the food chain ...". While this often came through as a strength in her pedagogical style, Mrs Nkosi could have deepened learner engagement with the science content of this lesson by pursuing further this line of argument. She might probe learner understanding of the biology of the owl itself and that of the energy transfer in the food chain/food web. Also she might avoid providing the scientific terms herself and challenge her learners to do so. The last excerpt further illustrates this point.

- 339 Sifiso: *ngicelukubuza Maam iskhova sihamba ebusuku ne? So amagundwane siwadla nini?*(Maam I want to know since the owl is active at night when does it eat the rats?)
 340 Class: *ebsuku* (at night) (noisy laughter and talking)**(Claim)**
 Nkululeko: *whoa Sifiso ngizokhonuku kphendula lapho kubakhona lokho ku yinyoni okundiza nje kulokhu kume ndawonye kuyabe kubhekile kanje siyondiza sifike phansi silibambe sihambe* (oh Sifiso I can answer you there is this one that hovers like this and then comes down takes the rat and flies off) **(Data; Warrant)**
 Sipho: *hayi eyinyinyoni leyo* (no no that's a different bird) **(Rebuttal of evidence)**
 Class: *(noisy disagreement with Nkululeko)*
 Sifiso: *awusho i-Fish Eagle wena?* (Dont you mean the Fish Eagle?) **(Claim)**
 345 Teacher: right ok. Yah that's a different type of bird
 Class: *(still talking loudly)*
(Turns 339-346 Lesson on owl indigenous knowledge and conservation)

On the one hand, Sifiso's question in turn 339, on how owls feed on rats at night had the potential to open up the discussion for learners to draw on evidence from their knowledge of biological concepts like the nocturnal attributes of owls and perhaps begin to make links between the cultural belief systems discussed so far and the actual biology of the bird. Nkululeko's response (turn 341), on the other hand, might take the discussion further to contrast owls with other birds like the Fish Eagle that he seemed to be referring to. This could

provide the link to the food chain/ food web, ecosystems and biodiversity conservation, which did not happen in this lesson.

The excerpt above illustrates how most arguments in Mrs Thoba's lesson were made to articulate understanding (or opinions) and to persuade others of one's cultural convictions. Learner claims were mostly supported with evidence from their cultural experiences, with only a few cases where they drew from their scientific knowledge. Evidence was used more to make explicit learners' positions/convictions about culturally sensitive issues without much concern as to whether the others were prepared to change their minds and believe the same or not. There was thus, no evidence of learners changing their minds from their cultural persuasions.

6.6 Teacher actions that seem to facilitate or constrain learner argument construction

Within the Vygotskian perspective the notion of social mediation is critical for knowledge construction and according to Mercer (1995), social mediation in the zone of proximal development encompasses talk. While acknowledging that individual learners do differ in innate capacity, Mercer argues that learner achievement is influenced by or is a measure of the communication between teacher and learner. Thus, "talk in and around learning activities can constrain or extend intellectual potential of the individual learner" (p72). Secondly, Mercer posits that for teaching to be effective it should include both instruction and scaffolding which he maintains are different teaching activities. Scaffolding on the one hand, is about providing support and guidance which is withdrawn or intensified depending on how development of learner competence is perceived to be progressing. Instruction on the other hand, is about telling or instructing and telling has an important place in social mediation in order for the teacher to make available to the learners the resources necessary for meaningful engagement in the process of knowledge construction. Teacher mediation should therefore, include both instruction and scaffolding. This way, knowledge construction becomes a joint teacher-student activity.

The incidence of argumentation in Mrs Thoba's lesson was spontaneous. That is, the teacher had not deliberately planned her lesson so as to provide for any argumentation which might arise during the normal course of instruction. She then responded by consciously creating a dialogic space in which she facilitated and mediated joint negotiation of understanding and

guided learner argument construction. Both the success and limitations in developing high level arguments emanated from her style of scaffolding learner engagement. She persistently probed learner thinking and their reasons for agreeing or disagreeing with their peers' ideas, asking some thinking questions and often foregrounding learners' ideas for further interrogation by their peers. While on the one hand, she facilitated for argument construction by supplying some of the scientific information they required she, on the other hand, sometimes tended to provide the answers to some of her own questions. This could be prompted by a consciousness of the time limits within which to cover the lesson but it would curb the extent to which arguments developed.

Similarly, Mr Far often shut down talk by provided answers to his own questions or by channelling learner thinking with closed, guiding questions or clues. Although there was evidence of learner attempts at argument construction, his frequent use of evaluative feedback and closed questioning tended to curb learner critical engagement and they did not support their own and/or critique each other's ideas.

By its very nature Mrs Nkosi's lesson lends itself very well to argumentation and the task design had potential to stimulate learner arguments. However, by its nature also it did not provide for negotiation of understandings or for learners to modify their ideas. The focus of their talk was to win others over and their served a more persuasive than sense-making purpose. There was very little chance that learners would change their minds about their beliefs as would happen in meaning making argumentation where the outcome would be conceptual change (Berland & Reiser, 2008; Hewson, Beeth, & Thorley, 1998). Argumentation on socio-cultural issues has been shown to result in very little or no change in learners' ideas (Braund, et al., 2007; von Aufschnaiter, et al., 2008) and this partly attributable to the diversity of cultural world views that inevitably exist in such a context and which are deeply held (Ogunniyi, 2007a).

6.6.1 Teacher questioning techniques

The types of questions that a teacher asks determine the level of engagement in the lesson (Traver, 1998) and open-ended questioning allows for multiple perspectives (Aguiar, et al., 2010; Berland & McNeill, 2010). All three teachers asked probing questions and Mrs Thoba and Mrs Nkosi, in particular pressed the students for warrants and/or rebuttals. They often

asked some open and thinking questions such as “Why?” “Do you agree?” “What do you think about that?” or “Why do you disagree with the statement?” Such questions helped to foreground learners’ ideas. Although for the most part Mrs Thoba was funneling the learners’ thinking towards a correct answer, by probing she surfaced some common misunderstandings and facilitated negotiated meaning making. While Mr Far did ask some open ended questions, he quickly shifted to closed questions, channelling student thinking towards the answer. Mrs Nkosi’s questioning varied from closed to open-ended questions hence both facilitating some elaborate arguments and also shutting others down.

6.6.2 *Working with learner contributions*

Mrs Thoba was open to learner ideas and responded both elaboratively and evaluatively to their contributions. She often took up learners’ ideas (Nystrand & Gamoran, 1991) foregrounding them and probing learner thinking but also tended to funnel the discussion. In scaffolding the task at hand she simplified the task making it more accessible to learners but maintaining its cognitive demand. She did not reduce its cognitive demand for instance, by over simplifying her questioning (Brodie, 2007). She provided additional scientific information and explanations where she deemed them necessary and only seemed to reduce the cognitive demand of the task as a way to bring the discussion to an end. However, she also often provided answers to her own questions thus truncating the process of learner engagement.

Mrs Thoba seemed to have an intuitive connection with her class often anticipating learner talk. She created a space for negotiating understandings, encouraging learners to evaluate and critique their own and others’ thinking. She thus, consciously developed a dialogue that afforded substantive learner engagement with content (Nystrand & Gamoran, 1991). Meaning making was a shared experience, with both teacher and learners initiating, supporting and/or justifying arguments.

For the most part, Mr Far responded to learner contributions in similar ways to Mrs Thoba (and to Mrs Nkosi – see below). However, he was mostly concerned about moving the lesson forward hence statements like “I am not going to waste my time I will tell you that”. Also, the fact that he too (like Mrs Thoba) often provided answers to his own questions attests to this need to redeem time and move the lesson forward. His responses were different

from Mrs Thoba's in that where she maintained the cognitive demand of the task Mr Far sometimes reduced it by asking simpler, guiding questions or providing obvious cues. However, in spite of this tendency to shut down dialogic engagement in his lessons Mr Far engaged with his learners in ways that suggest potential for argumentation as shown from two of his lessons. He did begin to open up the social space to facilitate learner talk and substantive engagement. The fact that of the three teachers in my study, Mr Far was the only one teaching in his area of training and expertise may suggest that further research is implicated into the ways in which specialist and non-specialist teachers adapt new strategies for their contexts.

While Mrs Nkosi did take learners' ideas and understandings seriously, there was variation in the extent to which she did so ranging from genuine uptake and use of learners' ideas to shape the course of the discussion to overlooking some ideas if they did not seem to address the current focus of the discussion. She therefore, responded both evaluatively and elaboratively to learners' contributions. She too was open for negotiated understandings, encouraging learners to evaluate and critique each others ideas. This was however, constrained by the nature of the topic under discussion which in spite of favouring persuading arguments did not allow for learner change of ideas.

6.6.3 Shared understanding of the goals of the discussion

There is consensus in argumentation research that there are gains in student performance whether measured as acquisition of argumentation skills or science content when students engage collaboratively. One of the constraints in engaging collaboratively is student concern with what Jimenez-Aleixandre and her colleagues referred to as "doing the lesson" and not "doing the science" (Jimenez-Aleixandre, et al., 2000). They argued that sometimes teachers and students are more concerned about the technical and/or the logistics (the motions) of the lesson rather than engaging with the science content. This could also be due to a disjuncture in teacher and/or learner understandings of the task and the goals of the lesson.

There is also evidence in literature that student benefits from argumentation are influenced by their understanding of the goals of the argumentation process itself (Berland & Reiser, 2008) as well as an understanding of the intended outcome of argumentation (Sampson & Clark, 2008b; 2011). According to Berland and Reiser there are three instructional goals of

argumentation; to articulate understandings, to persuade others of these understandings and to make sense of the phenomenon under study. They refer to the latter two as persuasive and sense making argumentation, respectively. In persuasive argumentation students make many claims and counterclaims, do not pay attention to the ideas of others, and are not open to changing their own ideas as they are intent on changing their peers' minds instead. Such argumentation if not properly guided by a skilled teacher may lead to disputational interaction as seen in some episodes in Mrs Nkosi's lesson. In sense making argumentation on the other hand, students seek to make sense of the task and/or the science content. In this case the students are open to each others' ideas and do modify their ideas or understandings. Some of the student interaction patterns in Mrs Thoba's lesson match sense making argumentation. Thus it is important for teachers and students to be clear of the goals of the discussions in order to achieve specific desired outcomes, as happened in Mrs Thoba's case.

In Mrs Thoba's lessons, there was evidence towards the end of the debate that learners had begun to gain an understanding of the direction of the teacher's questioning and the intended goal of the debate. Initially the debate was between the teacher and learners Tahari and Vuma and then Thinta and Sabelo joined the discussion later and soon after that Bonga also joined in. This could be because they had by now processed the information in their own personal internal sense-making arguments and become sufficiently confident to articulate their arguments to their peers. This speaks to the Vygotskian notion of learning as internalisation of the interaction on the inter-psychological to sense-making on the intra-psychological space inside the individual learner's head (Vygotsky, 1978). According to Berland and Reiser (2008) student benefit from argumentation is influenced by their understanding of the goals of the argumentation process. Also, students can benefit from an understanding of the intended outcome of argumentation (Sampson & Clark, 2008b; 2011). The gradual entrainment of learners in the argumentation process in Mrs Thoba's lesson is indicative of student eventual understanding of the intended outcomes of the discussion; to support their own claims and expect others to do the same for theirs.

6.6.4 Making the rules of engagement explicit – facilitating understanding of the task

It is important that students understand what is required of them so that during the process of negotiation of meanings they can judge their own level of understanding or misunderstanding of both the task itself and the science content (Scholtz, et al., 2008). This may require them to

call upon their prior knowledge of content and/or draw from other resources available to them. Guk and Kellogg (2007) argue that a collective zpd is established during such whole class discussions. The ZPD is considered as the area where individual optimum learning occurs and it is where scaffolding takes place. Thus shared understandings of the task, the goals of the lesson as well as the norms and disciplinary rules of engagement would enhance scaffolding in the ZPD.

All three teachers endeavoured to make the norms of argumentation as well as the rules of classroom interaction explicit for the learners, creating a space for shared understanding of expectations. Argumentation is enhanced and effective learning is more likely when both teacher and learners are aware of the norms of engagement (Driver, et al., 2000; Zohar & Nemet, 2002). Throughout the course of their lessons both teachers made the rules explicit. In Mrs Thoba's case she also made a concerted effort to adhere to the rules, thus modelling for learners the skills of argument construction. While Mr Far and Mrs Nkosi also made the rules explicit they were not always able to adhere to them. For example, Mr Far sometimes interrupted potential critical learner engagement in order to redeem time and move the lesson ahead. Similarly, although Mrs Nkosi often reminded her learners that the goal of the lesson was to share ideas she sometimes had to overrule and shift the focus to the scientific story which for the most part was contradictory to the shared ideas that emanated from learners' cultural backgrounds.

The need for teachers to make the rules of doing the lesson and of engaging with the subject matter explicit has been the subject of much discussion particularly in research seeking to understand the socio-cultural contexts within which science teaching and learning happens. For example, there are arguments that for teacher pedagogical practices to be effective in facilitating learning especially for learners from low socio-economic background it is important for teacher mediation and scaffolding methods to make these rules explicit for the learner (Berland & McNeill, 2010; Bernstein, 1999). Substantive engagement takes place when teachers establish ground rules (Nystrand & Gamoran, 1991) making learners conversant with expectations, roles and rules for engagement in discussion (Braund, et al., 2007). Clearly, this is an area for further research in South African classrooms.

6.7 Chapter summary

In this chapter my aim was to illustrate the quality of the verbal interactions in the classroom as teachers and learners engage in science talk according to my third research question. I have shown how the teachers worked with their learners' talk to stimulate negotiation of meaning in the classroom. Using Toulmin's argument pattern (TAP) I analysed the three moves of the IRF sequence in teacher and learners' talk to determine how teachers initiated argument construction, how learner's responses articulated their understandings, reflected the process of sense making and how they persuaded each other of their thinking and understandings.

In presenting the results of my data analysis I have shown how argumentation was used in various ways in teacher led whole class discussions. In Mrs Thoba's lesson it was used mainly as a tool for shared meaning-making. This is an unusual use for argumentation skills for science learning. Research in South Africa has so far examined the use of argumentation for persuasive purposes as was demonstrated in Mrs Nkosi's lesson which was based on a culturally rich topic on learner indigenous knowledge of owls and biodiversity conservation. In this case argumentation was used mostly for persuading than for sense-making. In both cases I have illustrated that with adequate mediation learners can and do argue and provide rebuttals for their peers' arguments. In Mr Far's case I illustrated some evidence of attempts at argument construction in two of his lessons and how Mr Far's largely evaluative interventions and closed questions either did not open up for learner arguments or closed down potential learner argumentation.

I have demonstrated that the two teachers in my study, Mrs Thoba and Mrs Nkosi, who successfully facilitated and mediated argument construction for the learners did so by way of their questioning techniques and the manner of scaffolding of the interaction. They asked mostly open ended thinking questions, there was a high level of uptake of learners' ideas and using them to guide the course of the discussion. To varying degrees the teachers were open to negotiation of shared understandings and they made the implicit rules of engagement explicit.

My findings also suggest that there may be a case for investigating argumentation as a strategy in whole class teaching in South Africa's multi-cultural science classrooms. It seems that while teachers do take up and adapt innovative teaching strategies such as argumentation

little is known about the dynamics of verbal interactions and learner engagement in their local contexts.

In Chapter 7 I highlight some evidence of emergence of dialogic pedagogies in the classrooms I worked in. The chapter addresses all of my three research questions providing an overview of the use of science talk in these multi-cultural multi-lingual classrooms.

Chapter 7

Emerging dialogic discourses: Pedagogical response to contextual factors

“It is easy and more comfortable to revert to comfortable methods. You need someone to nudge you to new strategies from time to time.” (Mrs Nkosi, 2009, pers comm. Imfundo High School Soweto, South Africa)

7.0 Introduction

In Chapter 5 I presented the results of data analysis that addressed my first and second research questions. In Chapter 6 I continued to address my second question and also addressed the third question. Thus, in Chapter 5 I illustrated how teachers guided science talk in their classrooms by adopting one or more of the four communicative approaches through a variety of teacher interventions. I also illustrated the patterns of interaction that emerged and placed special focus on learner participation. In Chapter 6 I discussed the quality of verbal interactions in these classrooms, by examining different types of arguments generated during the teacher-led whole class discussions. My focus was on the nature and quality of learner engagement during classroom interactions.

In the present chapter I take the discussion on my third question, “What is the nature of the interactions that emerge with science talk?” further, and seek to understand how meaning making is negotiated between the teacher and learners and among learners. To do this I revisit some of the patterns of interaction summarised in Chapter 4, to further elucidate the quality of interaction in the three teachers’ classrooms. Through a cross-case analysis of the data I try to link the teacher communicative approaches and the resultant discourse patterns discussed in Chapters 5 and 6 with some contextual factors. This way I hope to gain a fuller understanding of how my data addresses all three research questions. As in case-by-case analysis, cross-case analysis is both descriptive and explanatory – it seeks to answer not just the *what* and *how* questions but also the *why* question. Further, cross-case analysis seeks to understand more deeply the “... processes and outcomes across ... cases, to understand how they are qualified by local conditions, and thus to develop more sophisticated descriptions and more powerful explanations” (Miles and Huberman 1994:172). This chapter considers a wider number of lessons than Chapters 5 and 6. I examined all eleven lessons in each case and determined emerging patterns for each teacher. However, the qualitative data used to

illustrate the trends is taken from those lessons where the patterns were most clearly represented.

I adopted Miles and Huberman's variable-oriented interpretation of the data. Variable-oriented interpretation establishes and explains relationships between selected variables, in this case, teacher communicative approaches and resultant discourse patterns. I also drew from Froggatt's (2001) method of drawing conclusions. According to Froggatt, methods of data transformation in cross case analysis involve drawing conclusions by noting patterns (relationships) and themes (explanations for the patterns); noting relations between variables; making contrasts and/or comparisons as well as noting extreme cases. Working inductively, I identified emerging patterns between two variables - teachers' communicative approaches and the resultant discourse patterns - and the contexts in which they interacted. From these patterns I determined themes or possible contextual explanations for the relationships between variables. For instance, I wanted to determine whether some forms of engagement unique to the cases and their contexts could be identified, whether and what patterns of dialogic engagement emerged, whether and how traditional pedagogical practices persisted (or did not).

Clearly, there is a tension between the need to preserve the uniqueness of each case (the particular) while achieving comparison of cases (the universal) and it is for this reason that Silverman (2000) argues that cross-case analysis is not simple. It is as Miles & Huberman put it, an attempt at "reconciling an individual case's uniqueness with the need for more general understanding of generic processes that occur across cases" (1994, p. 172). From the patterns emerging from two factors and the contexts of interaction I hoped to determine "*how come*" particular outcomes emerged within and across the cases (Miles & Huberman, 1994, p. 143).

Four themes (categories of engagement in science talk) emerged from my analysis and the discussion in the rest of this chapter is based on these four themes:

1. Prevalence of traditional forms of engagement, such as:
 - a. traditional IRE triads,
 - b. drill, recitation and memorisation.
2. Emerging interactive and dialogic forms of engagement, for example:

- a. the tension between Interactive-Dialogic, NonInteractive-Dialogic and Interactive-Authoritative teacher communicative approaches.
 - b. incidences of active learner involvement or participation and/or
 - c. occurrence of argumentation (mainly co-constructed arguments).
- 3. Engagement within hybrid spaces or “unconventional” forms of engagement:
 - a. combinations of scientific, formal, academic engagement with informal, context-based forms of engagement
 - b. learner cultural differences: affordances and constraints to engagement
 - c. teacher attempts to make language visible and/or invisible.
 - d. engagement in the mother tongue or learners’ languages
- 4. Linking science talk with other forms of engagement. For example:
 - a) talking, reading and writing
 - b) talking through practical activities and demonstrations
 - c) talking in small groups
 - d) talking outside the classroom.

7.1 Summaries of the four themes or categories of engagement in science talk

7.1.1 *Prevalence of traditional forms of engagement*

In all three teachers’ classrooms traditional forms of engagement were prevalent. By traditional forms of engagement I mean classroom interactions where a) there is little learner participation, b) there is dominance of the teacher’s voice, c) emphasis is on factual recall and d) learners are not afforded opportunities to question or explore ideas (see for example Lyle, 2008; Mercer, Dawes, & Staarman, 2009). This form of engagement was prevalent mostly in Mrs Thoba and Mrs Nkosi’s lessons in the form of teacher-centred IRE discourse in which teacher feedback was largely evaluative. The teacher tended to funnel learner thinking, often ignoring some good ideas and/or learner thinking. Also, all three teachers often provided answers to their own questions. Both Mrs Nkosi and Mrs Thoba engaged in extended episodes of telling or exposition dominated by teacher talk. It is worth noting however, that some of the extended exposition sessions were part of introduction lessons in which new concepts or ideas were being explored. Also both Mrs Thoba and Mrs Nkosi engaged learners in recitation sessions. Some “exceptional cases” (Miles & Huberman, 1994, p. 172) included forms of traditional engagement such as a deliberate drill session in Mrs Nkosi’s lesson on respiration and gaseous exchange. Later in this chapter (Section 7.3.1) I show how these

traditional forms of engagement unfolded in each teacher's classrooms, highlighting the key similarities and differences as well as possible contextual factors that influenced the interactions.

7.1.2 Emerging interactive and dialogic forms of engagement

As seen in Chapter 5, in interactive discourse the teacher involves the learners in the lesson, that is, the learner's voice is heard even if the participation and engagement may not be at desired levels for effective learning. In dialogic discourse the teacher explores different points of view through teacher feedback that is more elaborative than evaluative as the teacher follows up on learners' ideas, seeking clarification and asking them to explain their thinking. Dialogic discourse also involves making the objectives, criteria and rules of engagement explicit to the learners. In Chapters 5 and 6 I also illustrated how such interactive and dialogic discourse results from three teacher communicative approaches; Interactive-Dialogic (ID), Interactive-Authoritative (IA) and NonInteractive-Dialogic (NID) communicative approaches resulting from specific teacher interventions.

In ID the teacher and learners are in conversation. They explore ideas, generate new meanings, pose genuine questions, offer, listen to and work on different points of view. The conversations aim to achieve specific teaching purposes: to engage learners mentally in initial development of scientific story, making meanings available in the social plane of the classroom, providing opportunities to talk and think individually, in small groups or together as a class. In IA the discourse is less conversational as the teacher takes greater control of the focus and direction of the talk. The teacher continues to involve learners but focuses strictly on the scientific view. Thus, IA and ID allow for development of negotiated understandings as the teacher selects, takes up and foregrounds learners' ideas for further interrogation. The teacher can model appropriate engagement, questioning in specific ways and guiding use of evidence to support claims. Also such interaction has the potential to create a conducive learning environment for construction of meaningful arguments and shared meanings by affording learner opportunities to evaluate and challenge each other's ideas.

All three teachers in my study adopted both forms of communication in different ways for different purposes. They all engaged in largely Interactive-Authoritative ways with some

incidents of Interactive-Dialogic episodes, some of which resulted in emergence of argumentation, especially in Mrs Thoba and Mrs Nkosi's classrooms.

In NonInteractive-Dialogic communication the teacher considers various points of view or different perspectives for the specific teaching purposes of making meanings available in the social plane of the classroom. The teacher revisits learner ideas, shaping ideas, reviewing and summarising. In the three teachers' lessons there were only a few incidents of NonInteractive-Dialogic communication. Teachers seldom reviewed or returned to learners' ideas but they did summarise sections or whole lessons and in particular Mr Far and Mrs Nkosi sometimes made explicit where learners' ideas fit into the curriculum.

All three communication types result from teacher interventions guided by specific rules/norms of engagement relevant to the discussion in progress (see for example, Driver, et al., 2000; Engle & Conant, 2002; Sawyer, 2006). It is therefore, the teacher's role to make these norms of engagement explicit or at least to facilitate for the norms to be negotiated between the teacher and learners or among learners themselves in order for effective learner engagement to take place. However, in the case of my three teachers the teacher interventions that facilitated this negotiation were not always explicit. Teachers often engaged in meta-talk. By meta-talk I am referring to teacher talk about what s/he was talking about or how s/he or the class was talking. Meta-talk allowed for implicit reference to the norms and objectives of the discussion or of the lesson as a whole. Occasionally, there was evidence of explicit teacher modelling or teacher-learner negotiation of the norms of engagement. I will illustrate these from Mrs Thoba's lesson on bond energy and from Mr Far's lesson on momentum (see Section 7.3.2).

7.1.3 Engagement within hybrid spaces or “unconventional” forms of engagement

The notion of hybrid spaces is borrowed from Berland and Hammer (2011), who describe them as social spaces where participants engage in combinations of scientific and everyday context-based interactions. I have included here what I see as “unconventional” forms of engagement. By “unconventional” I mean interactions that do not conform to what are considered as mainstream or formal academic forms of engagement. I include here various forms of informal and/or context-dependent forms of engagement. In this category I considered the complexities of discussions in multicultural, multilingual classrooms

(Brookfield & Preskill 1999; Karmen et al, 1997). I looked at the nature and role of the cultural experience and world views that both teachers and learners bring to the classroom, both in terms of their individual views about science talk and in terms of cultural and scientific content knowledge. A good example of this was observed in the lesson on owl indigenous knowledge in Mrs Nkosi's classroom, where both teacher and learners enriched the discussion with their cultural and biological knowledge of owls and their habitats (see Section 7.3.3 below). Teacher and learner cultural capital includes language. Although I did not focus on issues of the language of teaching and learning (LOLT), its influence and implications for classroom interaction and science talk were obvious in all three teachers' lessons. I did, however, consider a few examples of learner engagement in their languages and issues of the language of science itself. Examples of the former came mostly from Mrs Nkosi's lessons with a few from Mrs Thoba, while the latter is illustrated mostly from Mr Far's lessons and to a limited extent Mrs Thoba's. Mr Far and to some extent Mrs Thoba engaged in ways described by Setati et al. (2008) as making language both visible and invisible. Mrs Nkosi on the other hand, did not engage consciously with language issues during her lessons.

7.1.4 Linking science talk with other forms of engagement

Although there is not as much evidence for this theme as there is for the other three, it is difficult to ignore the trends that emerged from the data within the various contexts of the lessons I observed. This is particularly so because of the potential for development of meaningful science talk in the three teachers' classrooms if such links between talk and other forms of engagement could be strengthened. For example, literature records one of the weak points for South African learners as revealed by frequent international testing as the inability to read at expected levels (see for example, Fleisch, 2008; Taylor & Vinjevoold, 1999). Observations in Mrs Nkosi lessons on how she invariably got her learners to read may have implications for continued efforts to develop learner literacy levels. Such research would be of interest for two reasons. First, it would be expected that primary school teachers would make an effort to develop learner reading skills during the course of their other teaching. That Mrs Nkosi did this consistently at high school level is significant and worthy of further exploration. Secondly, it might be expected of language teachers to take the time to plan for learner reading skills, but that Mrs Nkosi did this in a Life Sciences classroom is noteworthy.

Literature also laments the scarcity of and teacher difficulty in conducting practical work (e.g. Hattingh, et al., 2007; Lubben, et al., 2010; Stoffels, 2005b) and small group discussion (see Brodie, et al., 2002b; Taylor, et al., 2003) in South African classrooms, largely due to inadequate teacher preparation for such engagement (e.g. Chisholm, 2004; Scholtz, et al., 2004). Further, while the national department of education encourages integration of information and computer technology (ICT) into the teaching and learning of science, implementation of such policies is still a challenge in South Africa mainly because of teacher lack of adequate skills and knowledge of ICT as well as lack of requisite tools (e.g. Department of Education, 2003c; Vinjevold, 2009). I observed attempts by two of the three teachers to use practical activities to stimulate science talk in their lessons. Both Mrs Thoba and particularly, Mr Far engaged their learners in hands-on activities and got them to discuss their observations. In Mrs Thoba's case I only observed this in two of the eleven lessons while five of Mr Far's lessons included some form of practical activity. In the organic chemistry lessons learners discussed in small groups of four, while in the mining lesson they conducted a research project in groups of four and reported back in a whole class discussion with the teacher and their peers. In the momentum lesson individual learners simulated collisions and discussed their observations with the rest of the class.

An emerging area of interest both for school level science and for research in science education is learning of science in informal settings and in informal ways (see for example, Ash, et al., 2007; Kralina, 2010; Lelliott, 2010). The importance of informal (mostly outside class) learning has been debated and its role in providing additional sites of learning has been established. For example, research on students learning about electricity and magnetism in informal settings shows that students draw from personal experiences to aid learning of science concepts (Anderson, Lucas, Ginns, & Dierking, 2000). Other scholars found that some science topics were better understood if taught in informal settings which tended to help with the transition from everyday to scientific ways of reasoning (Ash, 2004; Hofstein, et al., 1997). While most studies of informal ways of talking about science describe interactions outside of the classroom I did observe some forms of informal engagement in the classrooms I worked in. For instance, in most of the lessons by all teachers involved in the Project (not just the three that I focussed on for my PhD study) teacher-learner interaction was characterised by traditional authoritative forms of engagement. These forms of engagement may be related to the fact that science is viewed as an abstract, formal subject (see for

example, Rannikmäe & Teppo 2010). Both Mrs Thoba and Mr Far often deviated from the traditional authoritative forms of engagement typical of science classroom discourse in this context and opened up for informal, light hearted ways of talking. Most of the informal interactions took place during the more dialogic communication episodes when the teaching purpose was to elicit learner ideas. In Mrs Nkosi's lessons the informal talk took a different form. She often drew on learner contributions to communicate various life skills and to give moral lessons to students.

For the reasons discussed above, I could not ignore any evidence of teacher attempts to link, for example talking with reading and writing, talking with practical activities and demonstrations, talking in small group activities or the use of computer technology with science talk even if this was not the focus of my study. Also, any evidence of learner science talk outside the classroom is indicative of the potential for engagement in less formal, relatively more relaxed settings. This is an important area for future research to understand the dynamics of these links and their potential for enriching the learning experience and for the development of holistic scientific literacy in learners. Such research also has the potential to increase or enrich the teachers' repertoire of pedagogical strategies or tools.

7.2 Discussion of the four categories of engagement as observed in the three teachers' classrooms

I now proceed to illustrate each of the four themes with excerpts from six lessons that provided the most compelling evidence. I also pull in evidence from other lessons where necessary to support my arguments:

1. Mrs Thoba's lessons on Reactions of acids (Lessons 1 and 2) with some evidence from the Bond energy and Waves lessons.
2. Mr Far's lessons on Momentum and Properties of compounds with some evidence from the lesson on Mining processes.
3. Mrs Nkosi's lessons on Population dynamics and Gaseous exchange with some evidence from the lesson on Owl IK and conservation.

7.2.1 Prevalence of traditional forms of engagement in the three teachers' lessons

In all three teachers' classrooms traditional forms of engagement were prevalent. The most common were the IRE/F triads in the form of question and answer sessions. Teachers asked questions that called mostly for learners to call to memory science terms, definitions,

formulas, equations or disjointed bits of scientific information or. There were also episodes of drill and recitation aimed at helping learners commit pieces of information to memory. I look at the traditional IRE/F triads first.

7.2.1.1 Traditional IRE/F triads

I start with excerpts from Mrs Thoba's lessons on Reactions of acids and I contrast Lesson 1 with Lesson 2. As explained in Chapter 5, in Lesson 1 Mrs Thoba used a mix of pedagogical strategies starting with a brief teacher-led whole class introduction session followed by small group discussions and a teacher-led whole class feedback session. Lesson 2 with the other Grade 11 class was a teacher-led whole class discussion throughout. Although Lesson 1 was taught first I start with excerpts from Lesson 2 so as to make the comparison clear:

1	Teacher:	What happens when an acid reacts with a metal?
	Andiswa :	<i>Kuphuma amabubbles</i> (bubbles are produced) (inaudible)
	Teacher:	<i>Kuphuma ama</i> bubbles (bubbles are produced). Ama bubbles is an indication <i>ukuthi</i> (that) there is a gas coming out. <i>Ne</i> (right)?
	Class :	Yes
5	Teacher:	Ok but what I want is when an acid reacts with a metal a salt is going to form. A salt is always a product of an acid <i>ne</i> ?
	Class:	Yes
	Teacher:	a salt is going to form. You are going to have a salt plus those bubbles that he was talking about.
	Class:	Yes
	Teacher:	Ok let us have an example. Let us take Hydrochloric acid. Hydrochloric acid reacts with a metal let us take sodium. (<i>Writes HCL + Na on the board</i>) What is the name of the salt that will be produced?
10	Class:	(<i>mumbling</i>)
	Teacher:	Hydrochloric acid it reacts with sodium. Sodium ...?
	Tefo:	(<i>Inaudible</i>)
	Teacher:	how do we write sodium hydroxide? Sodium hydroxide (<i>writes NaOH</i>). But look at your reactants. There is no oxygen <i>liyabona</i> (<i>do you see?</i>)? So it cannot be sodium hydroxide.
	Class:	(<i>commotion</i>)
15	Sipho:	hydrochloric sodium
	Malusi:	sodium hydrochloric
	Teacher:	remember there are two products that are going to be formed? A salt and a gas he was talking about. So what is the name of the salt?
	Lebo:	sodium hydroxide
	Teacher:	That sodium hydroxide (<i>laughs</i>)
20	Sipho:	sodium hydrochloride
	Kedibone:	(<i>inaudible</i>)
	Teacher:	Come again Kidebone
	Kedibone:	sodium chloride
	Teacher:	its sodium chloride. What happens is this hydrogen of an acid is going to be replaced by sodium and then we have sodium chloride. But you still there is a gas that will come out. The name of the gas is hydrogen H-2. It's a diatomic molecule. Is it

- 25 Class: balanced? Let us look at the equation. Is it balanced? (*the equation on the board is $HCl + Na \rightarrow NaCl + H_2$*)
 Teacher: No
 let us balance it. How many hydrogens do we have this side? We have 2 so we need 2 there. It also affects the chlorine atoms so we need 2 there we also need 2 there. So the number of atoms this side is exactly the same as the number on the other side. Ok any questions?

(*Reactions of acids Lesson 1- Introduction. Turns 1-21*)

In this IRE/F discourse, the teacher took an Interactive-Authoritative communicative approach and her interventions were largely evaluative. This is evident from the teacher's response to Andiswa's answer in turns 1-5 that a reaction of an acid and a metal produces gas bubbles. Although the teacher seemed to be asking a genuine question in turn 1 her statement in turn 5 that Andiswa's answer is "ok but what I want is ..." implied that there was an expected answer to the question. In a normal IRE triad she would then continue asking the question to other learners, each time initiating and responding evaluatively to their answers until they gave the expected answer. In this case however, she seemed to want to move forward more quickly and so she provided the answer herself in turn 5 (that a salt will form). A typical IRE interaction followed when in turn 9 she asked for the name of the salt that would be formed and as learners engaged in what seemed to be guess work she ignored incorrect answers by Siphon and Malusi in turns 15 and 16. In turn 18 however, when Lebo repeated the wrong answer that Tefo had given earlier the teacher responded evaluatively, revoicing the answer and following it with a laugh. This signalled to Lebo and the class that hers and Tefo's answer was unacceptable. She again ignored Siphon's contribution in turn 20. Kedibone then gave the correct answer in turns 21 and 23 as is evident from the teacher's acknowledgement and affirmation in turn 24. Finally, in turn 26 in what appears to be an invitation to the class to balance the equation together with her the teacher then proceeded to provide the answer herself, voicing out her method of balancing the equation. No opportunity was provided for learners to engage with the task. This was a common form of interaction in Mrs Thoba's lessons as is seen in the excerpts below from the neutralisation reaction first in Lesson 2 whole class discussion and then in Lesson 1 introduction and feedback sessions:

- 176 Teacher: ok let us look at the last one the reaction of an acid plus a base.
 What happens when you react an acid with a base?
 Teacher: Ok fine let us take a base that we use in the laboratory. Can you
 give me an example of a base that we use in the laboratory?
 Siyibona kanjani i-base ukuthi this is a base? (How do we know
 a base?) We recognise an acid with this *H ukuthi ma iqala nje*
 ngo H we know that this is an acid. How do we recognise a base?
 Fish: a base Maam is a substance that can provide a proton.

- 180 Teacher: do you understand what you said?
 T&Ls: (*laugh together*)
 Teacher: my question was Fish we recognise an acid with this H *ekuqaleni ne* (at the beginning right)?
 Fish: yes
 Teacher: how do we recognise a base?
 Fish: it starts with oxygen
 185 Class: (*commotion*)
 Teacher: noooh
 Mandisi: Is it always solid?
 Teacher: not necessarily. Ok we recognise it *ekugcineni la* (at the end here) its having O-H. Sodium hydroxide potassium hydroxide (*writing out and underlining the O-H in each case*) this O-H here it tells us that it's a base. Ok let us have an acid hydrochloric acid and let us have potassium hydroxide. We are going to get a salt what is the name of the salt?
 Class: potassium
 190 Teacher: potassium?
 Class: potassium chloride hydroxide
 Teacher: you have potassium hydroxide (*as a reactant*) you cannot have potassium hydroxide again because they are going to react.
 Class: chloride chloride
 Teacher: potassium chloride ... and?
 195 Class: water
 Teacher: water. *Siyabona?* (do we see?) Potassium chloride and H-2-O. Is it balanced?
 Class: yes
 Teacher: yes its balanced. What has happened here is acid it's having its own properties you are going to find them out now. A base is having its own properties so when they react they neutralise each other. Acid its no longer having its own properties a base is no longer having its own properties. They are now neutral. We call this type of a reaction Neu-tra-li-sa-tion.
 Class: neutralisation
 200 Teacher: So do you see that in neutralisation always a salt and water are formed? Any question? Any question?

(Lines 176-200; Lesson 2 Reactions of acids. Whole class discussion)

This is another example of an IRE/F discourse pattern from the whole class discussion of reactions of acids in Lesson2. The teacher seemed to be taking an Interactive-Authoritative communicative approach but this was in fact not genuinely interactive discourse. The learners appeared to be involved but their participation was limited to chorus answers and unquestioning agreement with the teacher's statements. The teacher responded evaluatively as seen in turns 179 and 186 in response to Fish's definition of a base. In turn 178 Fish defined a base as "a substance that can provide a proton" to which the teacher responded in turn 179 "do you understand what you said?" and pressed him for the correct answer asking him "how do we recognise a base?". When Fish responded "it starts with oxygen" the teacher responded evaluatively "noooh" in turn 186. When another learner, Mandisi tried to obtain more information from the teacher asking, "Is it always solid?" presumably to get a clue towards the correct answer, the teacher again responding evaluatively in turn 188, "not

necessarily” proceeded to provide the answer herself “Ok we recognise it *ekugcineni la* (at the end here) its having O-H”. In turns 190-192 when learners resorted to guessing at the name of the salt the teacher continued to evaluate their responses as inaccurate until in turn 193 they shouted the right answer which she affirmed (evaluative intervention) by completing the answer herself. In the last five turns in this episode the teacher passed up an opportunity to let her learners engage with each other and with the concepts discussed so far. The episode closed with a call for consensus with the teacher asking the learners “So do you see that in neutralization always a salt and water are formed?” and then soliciting learner questions. Often after an interaction like this the lack of learner questions is taken to be an indication that they understand the content taught to them. It signals to the teacher that she has successfully enabled learner access to science content. One wonders whether this was true of the learners in this lesson at this point. This form of engagement is in complete contrast to the more dialogic one that she had on the same topic with her other Grade 11 class (see Section 7.3.2.1). The difference between the teacher’s strategies in these two lessons could be explained in terms of Stoffels’ (2005a) observations on factors influencing teacher curricular decision-making within a curriculum change situation. As in the case of Stoffels’ teachers Mrs Thoba had indicated just prior to teaching the second lesson that unlike in the first lesson, taught the previous day she was not going to place learners in small groups “to save time”. She felt that if she took the class through a whole class discussion she could maintain a pace that would allow her to cover more content than she had done the previous day. As reported by Stoffels and others, this seems to be a major deciding factor for South African teachers’ decisions about making the pedagogical shifts required for implementing the reform curriculum. In my study, Mrs Thoba was not alone in the struggle not to “waste time” and thus move ahead quickly to cover the content prescribed for the year. Mr Far often had to make similar decisions as seen in the excerpts below:

151	Teacher:	I am not gonna waste my time. I am gonna say it is a product. The right hand side is called the product the left side we call what?
	Sam:	ingredients
	Teacher:	we call it the reactants. Now if you look at our products. This colour is black to me. Is there anyone in this class who can tell me what this is?

(Turns 151-155: Lesson on properties of compounds)

Mr Far had allowed time for learners to think through the question but when they could not come up with the correct answer he had to save time and move on with the lesson.

I now turn to traditional forms of engagement in Mr Far's lessons. The excerpt below is from the lesson on properties of compounds which involved a demonstration conducted by learners themselves and it illustrates instances in which Mr Far engaged in IRE discourse with the learners:

- 18 Teacher: We are just doing baseline evaluation with regard to definition of an element. Simphiwe said an element is ...?
 Maya: a substance that cannot be broken down
 20 Teacher: a substance that cannot be broken down into smaller
 Class: pieces
 Teacher: particles or pieces. A compound? Tebogo?
 Tebogo: a substance that ah is made up of two or more elements
 Teacher: A substance that is made up of two or more elements. Anyone have an idea what is a gas? Because this was the only key term that came out of you. Because I don't know maybe you can help me.
 25 Teacher: Right while you are still thinking about a gas. I am looking at hydrogen and I am looking at oxygen. Can we classify hydrogen or oxygen as a mixture? So I am asking what is a mixture? (Writing on the board)
 Sebuka: adding ... adding
 Teacher: Sebuka?
 Sebuka: adding different things
 Teacher: adding different chemical substances together.
 30 Class: Yes
 Teacher: that is a mixture. So how does a mixture differ from a compound? if there is a difference? Siviwe?
 Siviwe: A compound exists in fixed proportions while a mixture is different
 Teacher: please listen to that a compound it is a fixed and the word he uses is pro...?
 Lesedi: portion
 35 Teacher: portion. And a mixture? It doesn't have a specific ratio isn't it so? Now why am I doing this again? because I'm gonna come back to a molecule but our aim for and our objective for today is to look at how Magnesium will react with air. What type of chemical do we find in air?
 L?: oxygen

(Lesson on properties of compounds. Turns 18-36)

In this IRE discourse Mr Far appeared to be taking an Interactive-Dialogic approach but in actual fact he was engaging in Interactive-Authoritative communication. In turns 19, 26 and 34 he offered only evaluative feedback to Maya, Tebogo and Sebuka, acknowledging their contributions and moving on until Siviwe offered what seemed to be the expected answer. The interaction pattern then changed from a simple IRE in an Interactive-Authoritative communicative style to a NonInteractive-Dialogic communicative pattern as the teacher took up and used Siviwe's answer to move the lesson forward. Mr Far used meta-talk quite often in all his lessons. In this case he mentioned "why I am doing this again" (turn 35) to make explicit the objectives of the interaction as well as the criteria for learner achievement. In this case he went on to articulate the objective immediately after the meta-talk stating "our objective for today is to look at how magnesium will react with air". Within the same turn Mr

Far also made some important pedagogical link-making moves for continuity between what he had just done and what was to follow “because I’m gonna come back to a molecule”.

Similarly Mrs Nkosi engaged in IRE discourse quite often. Mrs Nkosi’s practice was characterised largely by extended episodes of exposition/telling and evaluative feedback with much funnelling of learner thinking. There were also episodes of look-alike Interactive-Authoritative communication as well a deliberate drill session. However, she did use some open-ended thinking questions and her tasks were designed to stimulate science talk and/or argumentation (as in the case of the lesson on owl indigenous knowledge and conservation). In the first excerpt below she took her learners through what I refer to as a look-alike Interactive-Authoritative communication episode.

- 242: Teacher:right it’s not only one alveolus but I am only showing one for purposes of us being able to discuss this gaseous exchange ok? So your oxygen goes down this way until it reaches your alveolus. So you have a situation like this to simplify the whole thing (*draws diagram of an alveolus*). So this oxygen coming in here into what? Into your alveolus right?
- Class: Yes
- Teacher:next to the alveolus is the blood ..?
- 245 Class: capillary
- Teacher:capillary so obviously then in your blood capillary there is blood flowing there are white ..?
- Class: blood cells
- Teacher:blood cells there are red ..?
- Class: blood cells
- 250 Teacher:blood cells Yes?
- Class: food
- Teacher:there is food that you’ve eaten once it has been finally digested. Remember we mentioned that it has to diffuse out.
- Thabo: (*inaudible question*)
- Teacher:Diffusion? I have mentioned that. What is diffusion?
- 255 Class: (*commotion*)
- Teacher:(*goes to the board to write*) right can someone tell us what diffusion is?
- Sihle: it’s the movement
- Teacher:you mean as I am moving? (*Teacher makes some body movements*)
- Sipho: it’s the loss of blood
- 260 Nancy: it is the movement of molecules from higher concentration to lower concentration until they reach equilibrium...
- Thabo: slow down
- Teacher:someone has just said something. Its the loss of blood?
- Class: (*commotion*)
- Teacher:ok we will come back to that one. Diffusion remember diffusion simply refers to the spreading of the particles right?
- 265 Thabo’s freinds: (*noisy commotion*)
- Teacher:so when you talk about diffusion the movement of particles from a higher concentration to a lower concentration until a state of equilibrium is reached until the particles are evenly ..?
- Class: distributed

- Teacher: distributed right you said deoxygenate blood collected from all parts of
your body goes to the heart from the heart to the lungs
- Class : lungs
- 270 Teacher: what is this deoxygenated blood? Yes? What is deoxygenated blood?
Esther: *(inaudible)*
Teacher: no *(to another learner sitting next to her)* what is deoxygenated blood?
Mercy: *(inaudible)*
Teacher: Pardon?
- 275 Thoko: *(inaudible)*
Teacher: *(to all 4 girls)* yes you must focus. Deoxygenated blood is the blood that is
heavily laden with carbon dioxide. In other words it's the blood that has a
lot of carbon dioxide
Class: carbon dioxide
(Gaseous exchange; turns 242-277)

A cursory look at this episode of IRE discourse gives one the impression of an interactive classroom with learners responding to the teacher's initiate (I) moves. However, a closer look soon reveals the fact that the learners were not really participating meaningfully. In half of all the learner turns in this episode all they did was complete the teacher's sentence with a word or two and in most cases the teacher started saying the word and the learners joined her and completed it with her. In essence the learners were not participating and it is doubtful that they were conscious of the substance of the interaction as they parroted their responses to the teacher's initiate moves. From turn 252 onwards there seemed to be some teacher-learner direct interaction as the learners struggled to define diffusion. However, when Nancy (turn 260) finally gave the correct answer Mrs Nkosi first overlooked her response and commented on Sipho's response about the loss of blood. She did not however, engage with this error but simply stated that they would "come back to that one" (turn 264) which she did not do in this lesson. The teacher then moved on to talk about deoxygenated blood (turn 266) and never made link between the concepts, that is, the alveolus, oxygen, blood cells, diffusion and deoxygenated blood.

While such forms of interaction were quite common in Mrs Nkosi's lessons it would not be true to say that they were the norm. This teacher had the most diverse selection of teaching strategies which however, were not always co-ordinated. For example, although she always referred to the objectives of the lesson and the main concepts for learners to focus on Mrs Nkosi often lapsed into the type of interaction described in this excerpt and as a result she seemed to lose the flow of the lesson. Thus, she could in some episodes guide and shape science talk so as to afford her learners clear opportunities for joint meaning-making and to make the connections between concepts and in other episodes in the same lesson she would not achieve appropriate pedagogical link-making moves. Two excerpts taken from the same

lesson as the one I have just discussed are used in Section 7.3.2.1 to illustrate the diversity of Mrs Nkosi's strategies.

7.2.1.2 Drill, recitation and memorisation

As explained in Chapter 5, I observed an unusual form of interaction for a high school classroom in one of Mrs Nkosi's lessons. Towards the end of the lesson on gaseous exchange Mrs Nkosi engaged her learners in an obvious drill session:

- 385 Teacher: then it goes up up up until you exhale it. Now I want you to note this. This is very important people ok? Three things that you must note three things that will happen to carbon dioxide. Number one most carbon dioxide is this carbon dioxide which is going to be exhaled. And then some (*writing*) three things to note most CO_2 is exhaled and then some percent of CO_2 will combine again with haemoglobin
- Thabo: to form carbohaemoglobin
- Nomso: carbaminohaemoglobin
- Teacher: and the group that I did not have I want you to note that when carbon dioxide combines with haemoglobin then we end up with this long term
- Class: carbaminohaemoglobin (*chanting*)
- 390 Teacher: let's make sure that the other group is at the same level with us ok?
- Class: Yes
- Teacher: when carbon dioxide combines with haemoglobin that will become?
- T&Ls: carbaminohaemoglobin (*chanting*)
- Teacher: Can you say that?
- 395 Class: carbaminohaemoglobin (*chanting*)
- Teacher: Can you say that?
- Class: carbaminohaemoglobin (*chanting*)
- Teacher: er can you say that on your own?
- Manto: carbaminohaemoglobin
- 400 Teacher: good girl. carbaminohaemoglobin (*chanting*). What is that?
- Class: carbaminohaemoglobin (*chanting*)
- Teacher: what is that?
- Class: carbaminohaemoglobin (*chanting*)
- Teacher: again
- 405 Class: carbaminohaemoglobin (*chanting*)
- Teacher: *awuphinde futhi* (say it again)
- Class: carbaminohaemoglobin (*chanting*)
- Teacher: ok thank you. Now people I want you to listen to this again.
- Class: (*talking loudly*)
- 410 Teacher: Ok thank you
- Teacher: and then the remaining percentage is the one that will react with water to form carbonic acid. Carbon dioxide number one most carbon dioxide will be expelled. Reason being once there is excess carbon dioxide that hampers with the functioning of the cells. That is why breathing is a continuous process. You continue taking out what? Carbon dioxide so as to ensure that it is kept at the correct level. Secondly it will combine with haemoglobin to form carbanimo...
- Thabo: carbo...(*inaudible*)
- Teacher: not *carbo carba* and lastly carbon dioxide remaining will combine with water to form carbonic acid. Now the final issue to note carbonic acid will react with potassium to form potassium
- (Turns 385-413; Gaseous exchange lesson)

One would expect drill to take place more in primary school classrooms and the fact that Mrs Nkosi used this strategy in a high school classroom makes it interesting. In turn 388 Mrs Nkosi said that the product was “a long word” and it seemed that she felt that her learners would not be able to remember this long word yet it was apparently important for them to remember. In the next few paragraphs I illustrate how Mrs Nkosi engaged in other traditional strategies like the long telling or exposition:

- 237 Teacher: I am seeing another concept here. A xerophyte what is that? Xerophytes what is that?
 Sisa: plants that grow in a desert
 Teacher: ok plants that grow in a very dry area or in a desert
 240 Class: desert
 Teacher: yah so these are the plants that are differently made from the trees that we have here in our premises? How do they differ from such? How would you know that the area is a semi desert? How would you know? When you look at area some plants that you see there will indicate to you that this is a semi desert. For instance I have been in the rural areas right? and one place that we visited the trees there are short the trees there have very small leaves. Now why must the leaves be that small? What do you think is the reason for that? The leaves remember are the organs through which transpiration takes place right so the smaller the leaves the better for the plants why? Because it reduces transpiration so such plants then number one they will have very small leaves. Now I am talking about the size. Number two the leaves will be few. That is the number now not the size. They will have very few leaves. Now that will also help in minimizing transpiration. Remember what transpiration is? The lost of water from the plant in the form of?
 Class & T: water vapour through the stomata of leaves
 (Turns 237-242; *Gaseous exchange lesson*)

This excerpt from the lesson on population dynamics was one of several long teacher talk sessions. The lecture included some good questions and attempts to link the biological concepts to real life situations but Mrs Nkosi did not offer her learners a chance to answer these questions or to engage with the examples and analogies. The next excerpt is from the lesson on owl indigenous knowledge and conservation:

- 355 Teacher: And different animals contribute in the food chain *angithi* (right?) so that some animals do not starve or they become extinct as we say so there are positive as well as negative issues surrounding that but at the end of the day if you look at that other copy here it says the Council let's go back to that one now “In the interest of ensuring animal diversity and species conservation ..” so that is the issue here there must be different types of animals there must be conservation of different animals. We mustn't end up talking about dinosaurs that we never saw *angithi* (right)?
 Class : yes
 Teacher: so that is why there must be conservation so that from one generation to the next generation those animals must be available. When people conduct experiments they must use animals that they can see they must talk about animals that they can see. That is why then conservation is important. Different types of animals are there for different purposes. And we use

- these animals for our own benefit *angithi*? We benefit from different animals. We get food we get dairy products as you were saying from the cows the skin is used for different purposes, so there is economic value. That is why poaching is not allowed. What is poaching? Yes?
- Sabelo: hunting and killing of animals
- Teacher: You hunt and kill what these elephants for what purpose?
- 360 Thuso: jewellery
- Teacher: *ja* (yes) for jewellery purposes. So they hunt them to kill them to get those horns and there is a lot of money that they are making. That is why there are laws there are laws and we need to abide by these laws. So here is the issue here “In the interest of ensuring animal diversity different types of animal must be available ...” You are a science group. One day you will pass your Matric I suppose which is this year and you will go to university maybe some of you will be specialising in Botany some of you will be specialising in what? In Zoology. That is when you will learn more about different types of animals. That is when you will be doing your research to find out more about these things. But yes of course some of you came up with ideas that some traditional healers use these for healing purposes some say the owls are used for bewitching other people. Whatever the belief is but at the end of it all we all find the positive as well as the negative. But economically they are needed. As Life Science students you need to know about them *angithi*?
- Class : yes
- Teacher: because you will be doing the researches you will be specialising maybe you will be the doctor in this field you will be telling us more about them. But the issue is conservation. There must be different types of animals. That is why the government has what? It has policies the laws to ensure that there is no extinction. If you go back to this “In the interest of ensuring conservation and species diversity Government...” and whatever the government says it has to be done *angithi* so the “... government no requires all residents to keep some owls in their backyard ..” yes we heard that some people say yes I can keep it but some say no I won't keep that. So you have all participated actively and I could pick that some of you are getting heated *nguZulu* that resurfaces inside of you and you want to tell us that this is true this is the reality but some of us are actually saying well we hear that but it's not what we believe. You may believe it's not what other people believe.
- (Turns 355-363; Lesson on indigenous knowledge of owls and conservation)

In this nine-turn episode, five were by the teacher and they were quite lengthy and sometime uncoordinated as the teacher seemed to be rambling and jumping from point to point without making any real connections for the learners. For instance, the four of the teacher's utterances above seem to be an attempt to make connections between the different concepts considered in the preceding discussion but it is not clear what the links she is making are. For example, in turns 355, 361 and 363 she made the point about the importance of diversity for stability of ecosystems and for sustainable utilisation. While these are relevant it is not clear how she expects her learners to make connections between them.

Mrs Nkosi's telling sessions tended to constrain learner engagement. The excerpt below illustrates this:

- 200 Teacher: yes bacteria tell us and give us how it becomes an issue of commensalism?
 Senzo: Maam (*inaudible*) make sour milk (*inaudible*)
 Teacher: ok if bacteria make sour milk for us we benefit but now where are these bacteria located? Yes I know they are beneficial bacteria like you are saying like the tanning of leather right? making of vinegar but now where is the association there? Because remember when you are talking of mutualism there is an association there is a relationship. These live together. Right? There must be two organisms living together and both benefitting? Remember in parasitism I gave you an example I am a human being right? But I provide what? the shelter for the tape worm inside of me. Now in mutualism you have to come up with a similar situation where you are saying here are two organisms they live together but they benefit each other. ok?
- Bahle: I am thinking of er the animals
 Teacher: aha?
- 205 Bahle: the goats the cows
 Teacher: right? Herbivorous animals Hhm
 Bahle: they eat grass and the grass is made up of er they are covered with cellulose.
 Teacher: Yes
 Bahle: When they eat grass the cellulose are not digested inside the animal
- 210 Teacher: Yes
 Bahle: so therefore the bacterias come in where they digest the cellulose
 Teacher: excellent example. Now how does it happen? Remember the bacteria will do what? They will break down the cellulose right? so then it means the very herbivorous animal the goat for instance will not starve because it breaks down cellulose and make it available to herbivorous animal and the herbivorous animal provides does what? It provides shelter. That's a very good illustration. Ok ok so how many have we counted as factors that decrease a population?
 (*Population dynamics lesson. Turns 200-213*)

Senzo's answer in turn 201 to the teacher's question about commensalism introduced an example that had the potential to create rich learner-learner interaction on their individual experiences and views of formation of sour milk and how this was or was not mutualism. This could have developed into an argumentation session to determine if Senzo's example illustrated mutualism. Clearly, if Senzo had knowledge or experience about bacteria and sour milk his peers would too. However, the teacher's follow up, an extended telling session, shut off any potential engagement with this knowledge whether it was scientific or indigenous knowledge. When Bahle in turn 203 mentioned mutualism in ruminants again an opportunity was created for learner engagement and the teacher with good questioning could have fostered the engagement. Bahle, however, proceeded to elaborate on his idea in spite of lack of teacher scaffolding. In turn 203 the teacher again seemingly "hijacked" Bahle's idea and lapsed into a long telling session.

The excerpts above illustrate how Mrs Nkosi sometimes lapsed into traditional forms of engagement, characterised by long sessions of teacher talk, drill and memorisation. The drill

session seemed to be her way of scaffolding understanding and recall of a difficult biological term, carbamino-oxyhaemoglobin. Research elsewhere reports the use of drill and recitation in monologic discourse in the classroom (see Hardman, et al., 2008) and in South Africa, classroom discourse is reportedly dominated by teacher talk and recitation as well as learner silences (Taylor et al., 2003; Verspoor, 2006). Thus, on the one hand, the occurrence of such obvious drill episodes as seen in Mrs Nkosi's lesson would therefore be a cause for concern. On the other hand, however, the fact that these episodes were so few and far apart is a positive one, that the discourse was more dialogic than monologic. Research is implicated on the persistence of traditional methods, particularly the use of drill in high school classrooms.

7.2.2 Emerging interactive and dialogic forms of engagement

All three teachers, Mrs Thoba, Mrs Nkosi and Mr Far adopted a variety of pedagogical approaches and practices that either afforded or constrained learner effective engagement and link making. In this section I illustrate and discuss teacher-learner engagement that indicates how dialogical pedagogical practices played out (or did not) in their lessons.

7.2.2.1 The tension between Interactive-Dialogic, NonInteractive-Dialogic and Interactive-Authoritative communicative approaches

Openness to different viewpoints means that the teacher does not restrict engagement to the scientific view. The teacher engages learners in conversation-like discourse and not recitation. Teacher interventions include elicitation of learner ideas and open-ended questioning. It involves ability to effectively open up the interactional space for learners' different views. There was variation in the extent to which the three teachers achieved this, especially in terms of use of elicitation moves and the types of questions they asked. For instance, Mrs Thoba and Mr Far often asked authentic thinking questions while Mrs Nkosi's questions tended towards low level closed questions and sometimes rhetorical questions. Uptake of learner ideas means that the teacher takes learners' ideas and understandings seriously and does not ignore learner contributions, thus allowing learner ideas to influence the direction of the lesson (Scott & Mortimer, 2005). There was variation in the extent to which teachers exercised genuine uptake of learners' ideas. While all three did take up learners' ideas Mrs Nkosi often did not allow learners' ideas to influence the direction of the lesson. She tended to exert her authority as the transmitter and either ignored or down played learner ideas in a bid to maintain the direction of the lesson as determined by her as the

teacher or by the text under consideration. Mrs Thoba and Mr Far however, genuinely took up learners ideas and used them to direct the lesson. For example in the Bond energy lesson discussed in Chapter 5 Mrs Thoba dedicated time for her class to interrogate their peer's erroneous idea and to try and reach consensus. She diverted from the normal course of the lesson and allowed the class the opportunity to engage with a concept that had been covered in previous grades. This enabled her learners to draw upon their prior knowledge so as to be able to co-construct new understandings and make sense of the new concepts being presented. Scott and Hammer (2011) refer to this as pedagogical link-making for continuity, linking the content under consideration to that covered in previous lessons.

The next set of excerpts from Mrs Thoba's lessons on acid reactions, provide a contrast between the traditional IRE/F pattern of interaction in Lesson 2 as discussed in Section 7.3.1.1 and a more dialogic one in Lesson 1 in which learners are given an opportunity to engage with the concepts and hence a better chance to gain access to the science content under consideration. I consider the excerpts in two sets. The first set comprises the first part of the introduction relating to reactions of acids with metals and the part of the feedback that relates to the learners answers to this task. The second set of transcripts also comprises part of the introduction relating to the neutralization reaction and the feedback relating to learners solutions for the neutralization reaction.

The first two excerpts are part of the introduction of reactions of acids with metals and the third is from the report back session being a teacher-led whole class discussion of the learners' answers obtained during small group discussions:

- 3 Teacher: Ok let us continue reactions of acids ok when acids react with other substances one of the products that is formed is salt. *Siyezwana ne?* (We understand each other right?) when acids react with other substances one of the products that is formed is salt. Ok, let us look now at the reaction of acids and metals. (*Writing on the board*) when an acid reacts with a metal you have an acid you have a metal they react one of the products that will be formed is a salt and you'll find this yourselves. Ok, let us look at the second one the reaction of acid and a metal oxide. Can you give me an example of a metal oxide? Let me start here can you give me an example of a metal? What are metals? Where do we find them in the periodic table?
- Class: Group 1 group 2....
- Teacher: Group 1, group 2 group 3. Those are the metals. Can you give me an example of a metal oxide? Any metal oxide? What is a metal oxide?
- (*Reactions of acids Introduction; Turns 3-5*)

This was a very brief interaction and unlike in the previous class, Mrs Thoba started the discussion by explicitly stating the concept that was to be the main focus of the lesson, that a

salt is the product of a reaction of an acid with a metal. The learners' task in this case was to determine the salt that would be formed with a given acid and metal "... one of the products that will be formed is a salt and you will find this yourselves ...". The second objective was also quickly articulated in turn 28 below:

- 28 Teacher: The first group reaction of acid and metal ne? What you are going to do is you are going to write balanced chemical equations. Siyezwana ne? (Do we understand each other?) I need balanced chemical equations. This group and that group you do number 1 ne? That group and this group you do number 2. And you do number 3. And all of you each group you have to do this one. So each group is having three equations to balance.
 Class : two two
 Teacher: ah two two I'm sorry. Asiyeni ke. It mustn't be the work of one person or two people ... all of you.
 (*Reactions of acids Introduction; Turns 28-30*)

From the excerpts above it can be assumed that the focus of the lesson or the concept to be learned (determining the products of reactions of acids, the common one being a salt). However, the teacher also made clear the criteria ("I need balanced equations" and "... each group is having two equations") as well as the norms of social engagement during the small group discussions, collaborative engagement ("It must not be the work of one person or two people ... all of you"). According to Berland and Reiser (2008) learners engage more effectively in discussions and argument construction if they understand the objectives for engaging in the discussion. Here the teacher did not only make the objectives known to the learners but also the criteria or expectations for acceptable performance or achievement.

In the next excerpt the same class was now analysing the first group's answer on the board. They had put up the equation $2\text{HCl} + \text{Na} \rightarrow \text{NaCl}_2 + \text{H}_2$

- 4 Teacher: ok here are the responses. This group *siyabona* (do we see?) ok HCl plus sodium. Sodium chloride with a 2 there plus hydrogen. Ok let us analyse this one. Is it correct? Yes?
 Mary: Why do they have 2 for the Cl?
 Teacher: Why do you have this substitute NaCl₂ Why do you write sodium Chloride like this?
 Mary: *Angithi i valency ka sodium ngu 1 ne chloride nayo ngu 1*
 Teacher: Na is plus. Why is it plus because it is in group 1 ne? So its having a plus Cl minus. So the two they balance you don't need a 2 *uyabona* (do you see)? You don't need a 2 because *ma ufaku 2 la uyabona* you don't add the ions. This one is plus that one is negative. One plus one negative and that is a balance we write NaCl we don't write it as NaCl₂ but as NaCl this is sodium chloride and it gives us hydrogen and hydrogen. Is it balanced?
 Class: yes no yes no
 10 Teacher: hah
 Peter: No
 Teacher: its not balanced?

- Class : no yes no
 Teacher: aha?
 15 Andile: (*inaudible*) there are 2 chlorines there and
 Mbongeni: this side (*inaudible*)
 Teacher: aha there are 2 chlorines here which means we need a 2 there 2
 Sodiums we need a 2 there.
 Class : yes
 Teacher: Let us check this one they've written sodium chloride correctly
 hydrogen?
 20 Siphosihle: Oh Maam (*inaudible*)
 Teacher: ok so they said they have forgotten to write a 2 there. Is it
 balanced?
 Class : Yes
 Teacher: Yes. So do we see that when an acid reacts with a metal the
 products that we get its salt and water *siyabona* (do we see?).
 This is salt and that is water
 Chris: *yi water kanjani* (how is it water) Maam?
 25 Teacher: agh awu I'm sorry salt and hydrogen. I'm sorry. ok the second
 Group number 2 ... number 2 please write yours too
 (*Lines 4-25; Reactions of acids Feedback*)

The teacher opened the interaction with an invitation to “analyse” (turn 4) their peers’ solution on the board and throughout this episode the teacher seemed to be guiding the analysis towards reaching a consensus. This is evident from the repeated use of the expression *uyabona* or *siyabona* which is “do you see?” or “do we see”? However, there seems to be an apparent lack of consensus as evident from turns 9 and 13 where learners’ answers were not in agreement. When Andile and Mbongeni together offered an acceptable answer (that the equation was not balanced) in turns 15-16 the teacher affirmed (with a “aha”) and proceeded to complete the answer by showing how to balance the equation. The class reached consensus on the second group’s equation much quicker in turns 19-22 and then to summarise the teacher engaged in what Scott et al. (2011) call pedagogical link-making for continuity at the micro level, reviewing the main concept of the lesson, that a salt is produced during a reaction of an acid.

- 22 T: Ok let us come to the last one. (*Still writing on the board*) The reaction of
 acids and a base. An acid reacts with a base. Can you give me an example
 of a base?
 T: (*wait time*) uhm?
 Sensile: Potassium hydroxide
 25 T: Potassium hydroxide. That O-H ne? It’s an indication that that thing its a
 base ne? When an acid reacts with a base one of the products will be salt.
 You will find the other products. We call this type of reaction we call it
 neutralisation when an acid reacts with a base that is neutralisation.
 (*This was followed by about two minutes of assigning equations to groups*)
 T: And all of you each group you have to do this one. So each group is
 having three equations to balance.
 Class : two two
 28 T: jah two two I’m sorry. Asiyeni ke (*let’s go then*) It mustn’t be the work of
 one person or two people . . . all of you.
 (*Lesson 1 Introduction of Reactions of acids; turns 22-28*)

As seen earlier the introduction to reactions of acids Lesson 1 served several teaching purposes. First the teacher introduced the scientific story of the day (Mortimer & Scott, 2003) as (in turn 25) she highlighted the science concepts to be learned, “When an acid reacts with a base one of the products will be salt ... We call this type of reaction we call it neutralisation when an acid reacts with a base that is neutralisation”. Next, she articulated the objectives of the learner discussions that would follow, again in turn 25, “You will find the other products”. Finally, she made explicit the criteria (each group had to work with two equations) and expected norms of engagement that this was to be a collaborative exercise. An examination of the teacher interventions in this and the next excerpt taken from the feedback session on the neutralisation task again reveals the teacher’s attempts at achieving a dialogic discourse while trying to open up opportunities for learners to engage in different forms of link-making or establishing connections between the scientific concepts being discussed. Although all six groups had worked with the neutralisation reaction task only two had put up their solutions on the board:

- 76 Teacher: ok let us look at this one acid and a base which is neutralisation sulphuric acid plus potassium hydroxide we get potassium sulphate do we write potassium sulphate like this?
 Class: Yes
 Teacher: Yes because S-O-4 is two minus K its one plus so you need another K *ukuthi zibe wu* (so that they can be) 2 ne? so its K-2-S-O-4 and water. Is it balanced?
 Class : Yes
- 80 Teacher: yes its balanced. Is it balanced? Two-four (*counting*) yes its balanced
 Class : (*Clapping*)
 Teacher: so then can anyone explain to me how does a salt come about? How is a salt formed? Look at all these reactions how is a salt formed? Look at this one acid metal NaCl how is a salt formed how does it come about?
 David: (*inaudible*)
 Teacher: from an acid? Can you explain it in terms of an acid? (*Wait time 11sec*)
- 85 Teacher: Hmm look at this one HCl (pointing to learners equations on the board) all of a sudden that H is no longer there it’s been displaced we now have a sodium look at this one MgSO₄ we still have an S-O-4. H is no longer there you now have the magnesium.
 Star: I think because (*inaudible*)
 Teacher: (*to a different learner*) You wanted to say?
 Carol: *Maam bengicelukubuza ukuthi ma ukhombayina* (*inaudible*) (Maam I have a question, when you combine ...?)
 Teacher: *Ma u khombayina ini?* (When you combinewhat?)
- 90 L: (*inaudible*)
 Teacher: How does that salt come about how does it form? *Kwenzekani la?* (What happens here?)
 Tony: Maam the acid is a substance that gives away a hydrogen so (*inaudible*)
 Teacher: yes it gives away this hydrogen ne? And that hydrogen is displaced *kungena ini* (what takes its place)? A metal *uyabona* (*do you see*)? You had H-2-S-O-4 H-2 is now gone you now have M-g-S-O-4 *siyabona*? You had here H-N-O-3 H is now gone what do you have? That metal it comes here and forms a salt you now have sodium nitrate you no longer have that

H-2 that metal it comes here you now have magnesium sulphate that metal it comes here H is gone you now have sodium chloride. So do you see that hydrochloric acid it forms a chloride salt *siyabona* (do we see)? You cannot have HCl plus Na and then you have here Na-2-S-O-4 it's just impossible you will have Na-2-S-O-4 if you use sulphuric acid. So hydrochloric acid it forms a chloride salt sulphuric acid it forms a sulphate salt. Any question?

(Turns 76-93; Lesson 1 Feedback on Reactions of acids)

The teacher started this discussion with a review of the main concept, that the reaction of an acid with a base is a neutralisation reaction and as usual invited the class to analyse the equation and decide if the formula of the salt is correct and then if the equation is balanced. However, she again provided the answers to her own questions (see turns 77-80). Then in turns 82-85 she adopted an authoritative stance and led the class through interactive-authoritative communication to make the connections between the equations they had been working on and the main scientific concept for the day, how a salt forms during acid reactions. This would be pedagogical link-making to support knowledge construction (Scott, et al., 2011) or conceptual understanding (Hewson, et al., 1998; Scott, Asoko, & Driver, 1992). As the discussion continued in turns 86-92 the teacher maintained an authoritative stance selecting and overlooking (in turns 86-87 she ignored Star's contribution) or taking up learner ideas (in turn 93 she affirmed and took up Tony's idea) as she developed the scientific story (Mortimer & Scott, 2003; Scott & Mortimer, 2005). In the elaborative feedback in turn 93 she explained displacement of hydrogen by the metal and formation of specific types of solids by given acids. This way she provided the necessary scaffolding for learners to make the connections and get to the main objective of the lesson.

In the feedback session on neutralisation I also found evidence of unsolicited learner questions. As an aside while the next group were putting up their solution on the board Zinhle and Thanda asked the teacher if there is a method of determining the valencies of compound ions to which the teacher replied that they simply had to know and remember the valencies of the different compound ions:

- 26 Class : (The two Group 2s put their answers up on the board)
 Zjnhee&Thanda: (aside as the other group is writing their answer on the board
 Maam (inaudible)
 T: You need to know that S-O-4 is 2 minus N-O-3 is 1 minus
 C-O-3 is 2 minus *uyabona* (you see)?
 Thanda: (inaudible) no other way?
 30 T: C-O-3 2 minus *wazinje lokho* (just know that) 5min 09
 (Lines 26-30; Reactions of acids Feedback)

This interaction had the potential to develop into Brodie's (2007) reversing IRE if the teacher had taken up the learners' ideas and presented them to the rest of the class for discussion. This would have served two purposes. First, it would provide an opportunity for more learners to engagement with the question and secondly it might reveal other learners' conceptions or misconceptions. However, as the discussion unfolded, it became evident that the teacher was not sure of the explanation. The next excerpt taken from another interaction later in the same lesson illustrates this. Another learner also in an unsolicited question wanted to know why –carbonate was CO_3 and not CO_4 as in SO_4 :

- 71 T: ok the third one an acid reacts with a carbonate. Can you give me the formula for a carbonate carbonate carbonate C-a-r-b-o-n-a-t-e
-ate sulph-ate carbon-ate
Class : commotion
Mammelo: C-O-4?
T: no
75 Stha: C-O-3?
T: C-O-3 that ate it indicates that there is oxygen. Ne?
Max: *Maam ngiceluyenze njengoba uyenze i-magnesium sulphate kube ne3 oxygen kwi1 carbonate* (please do it as you did for magnesium sulphate to show that there are 3 oxygens in 1 carbonate)
T: ukuthi why is it C-O-3? (*asking Max to clarify his question*)
Max: Yes
80 T: it's a carbonate why not C-O-4 why C-O-3?
Tumelo: *uthi iC-O-4 yini igama layo?* (Does he want the name of C-O-4?)
T: *no uthi siyi balance sibone ukuthi* (no he says we should show that) its really C-O-3
Class : (*commotion*) (10sec wait time)
T: Hah? why is a carbonate C-O-3? (*Wait time 13sec*)
85 Class : (*commotion*)
Sbu: *Maam mina ngazi ukuthi u O ma eyi 1 iyatshintsha ibayi oxide* (what I know is that when there is only 1 O it becomes an oxide)
Lbs: *i-oxide yi 2* (an oxide is 2) (*meaning it has 2 oxygen atoms*)
T: (*to R interrupting Lb mid sentence*) Can you help us?
(*Reactions of acids whole class lesson; turns 71-88*)

This is an example of what Scott et al (2011) refer to as pedagogical link-making to support knowledge building and this incident seems to span a number of approaches to this type of link-making. The learners' questions in these two episodes demanded that the teacher helps the learners to make links between scientific concepts or to show them the connections between concepts and also to make links between modes of presentation in this case linking a verbal explanation to the chemical symbol. Scott and colleagues describe the teacher's role in this form of pedagogical link-making as:

“ ... the challenge for the teacher is to support students in learning how to integrate the various representations of scientific concepts. In our terms the challenge is for the teacher

to make pedagogical links, which involve moving between different modes of representation in order to support the link-making processes of their students” (p10)

Clearly to be able to guide learners through these forms of link-making the teacher herself needs to be confident in the subject matter knowledge concerned, which was not the case with Mrs Thoba in these two episodes. There were various other examples of such lack of grounding in content knowledge and this was important for my study for two reasons. First, the teachers who volunteered to participate in the ICC project admitted upfront their lack of understanding of much of the content they were expected to cover, hence the subject matter related workshops run during the course of the project. Thus, the co-teaching model used in the ICC Project was designed to support teachers with such challenges of subject matter knowledge. However, there was no intention then to assess teacher content knowledge. Secondly, some of the difficulties that teachers in the ICC Project had with taking up and trying out the teaching strategies identified (science talk and argumentation in this case) are obviously due to a lack of grounding in the subject matter as shown. This has implications for the outcomes and findings of my study. This, in my opinion is a potential area for further investigation, that is, how science talk could be useful in developing teacher subject matter knowledge so as to address this perennial challenge for the South African education system.

7.2.2.2 Incidences of active learner involvement or participation

One of the aims of science teaching is to get learners involved. Studies investigating this issue have shown that the best way to get learners involved is to show respect for their opinions and individual experiences acquired prior to the lesson (Keogh & Naylor, 2007; Scott, 2008). The teacher can achieve this either by opening up for learner questions or taking up (not ignoring, talking down or making derogatory remarks to) learners’ contributions. Learner involvement and participation was deepened by a) learner questions whether solicited or unsolicited by the teacher and b) teacher uptake of learner contributions, that is, whether the teacher overlooked learner ideas or took them up and allowed them to influence the direction of the discussion.

Some of the ways in which a teacher creates a conducive environment for learner participation and engagement include making the norms of engagement explicit, or helping learners negotiate the rules and terms of participation. Nystrand and colleagues summarised this as:

classroom discourse is shaped by structures of participation and relationships of authority (Schultz, Erickson, & Florio, 1982) that reflect the character of reciprocity, whether procedural or substantive, or some combination of the two, between the conversants (Nystrand, 1986). Unlike conventional conversation, whole-class discourse typically models a participation structure predictably controlled by a single conversant, the teacher. Teachers ask most of the questions and typically maintain the right to call on students and allocate turns, “in essence organizing and orchestrating the discussions” (Greenleaf & Freedman, 1998, p. 466). As such, the character of classroom discourse shapes the learning context in important ways. (Nystrand, et al., 2001, p. 3)

The following example of how a teacher created a conducive environment for learner engagement comes from one of Mr Far’s lessons. Mr Far used meta-talk quite often in all his lessons. In this case he asks the question, “So what am I saying? I am asking, what is a mixture?” (turn 27) to make explicit the objectives of the interaction as well as the criteria for learner achievement:

27	Teacher:	Right while you are still thinking about a gas. I am looking at hydrogen and I am looking at oxygen. Can we classify hydrogen or oxygen as a mixture? So what am I saying? I am asking what is a mixture? (<i>Writes "mixture" on the board</i>)
	Sobuka:	adding ... adding
	Teacher:	Sobuka?
30	Sobuka:	adding different things
	Teacher:	adding different chemical substances together.
	Class:	Yes
	Teacher:	that is a mixture. So how does a mixture differ from a compound? if there is a difference? Siviwe?
- (Lesson on properties of compounds. Turns 27-33)*

Mr Far first asked the class how they would classify oxygen and hydrogen and then to clarify the question he engaged in meta-talk making explicit the core concept that he was exploring. He then used Sobuka’s contribution to make pedagogical link-making move for knowledge building. He used Sobuka’s answer to make a connection between the answer and the next question about compounds.

Another way of enhancing learner active participation is by allowing or encouraging learner questions. Brodie (2005) referred to a type of dialogic interaction driven by learner questions which she termed reversing IRE/F (see Chapter 5). Instead of the teacher making the initiate move it is the learner who does so with a question to which the teacher may respond directly or call upon peers to answer. The E or F move can take several different forms. It could be a true evaluation or elaboration move by the teacher or another learner contribution. Also learner questions may be a response to the teacher’s call for questions, which I am calling solicited questions or they may be initiated independently by a learner, which I am calling

unsolicited questions. All three teachers in my study solicited questions from learners at different points during the lesson and Mrs Thoba's learners often did ask questions in response to the teacher's call. Occasionally both Mrs Thoba and Mrs Nkosi's learners asked some unsolicited questions as well. There were very few unsolicited questions in Mr Far's lessons. In terms of uptake of learner contributions, there was a trend among all three teachers. When engaging in authoritative styles of communication the teachers tended to overlook or ignore some learner contributions, especially if they did not seem to be moving towards the correct or expected answer. As a result the bulk of the interaction in all teachers' classrooms tended towards the traditional IRE/F discourse. However, there was evidence of teacher uptake of learners' ideas, especially where the communicative approach was Interactive-Dialogic but also in some Interactive-Authoritative episodes as well. In such cases the teacher used learner ideas as resources to influence the direction of the discussion.

Often in Mrs Thoba and Mrs Nkosi's lessons learners volunteered information or asked questions without the teacher soliciting them. These are illustrated from Mrs Thoba's lesson on reactions of acids, Lesson 1 and from Mrs Nkosi's lesson on owl indigenous knowledge:

- 30 Sbu: Maam ... i-sodium chloride is a salt?
 T : yah it's a salt
 Sbu: (*inaudible*)
 Class: (*in response to Sbu but inaudible*) commotion
 Thamu: Maam why we say plus hydrogen. Like *ingabikhona i-Na-H-Cl* (why isn't there Na-H-Cl?)
- 35 T: Na-H-Cl?
 Thamu: Na-H-Cl like sodium hydrochloride? Angithi its sodium chlorine plus hydrogen?
 T: Yah because an acid when it reacts with a metal a salt is formed. The thing that you are saying it's not the salt. So the salt that is formed is sodium chloride and that *H le yila mabubbles la* (is those bubbles) that will come out it's a gas which is hydrogen. Ok do we see now that when an acid reacts with a metal salt and a gas hydrogen are going to be formed. Always when an acid reacts with a metal a salt and hydrogen are going to be produced.
 Thamu: *akhona amanye ama salts?* (Are there other types of salts?)
 T: yes *uzobona ma silokhu siqhubeka* (You will see as we proceed). We not only having sodium chloride we've got many types of salts.
 (*Reactions of acids Lesson 1 Lines 30-39*)

In this case Sbu and Thamu engaged the teacher with unsolicited questions about the nature of the salts formed during the reaction the class had been discussing. Sbu wanted to know if sodium chloride was a salt to which the teacher quickly responded in the affirmative. Next Thamu wanted to know why sodium chloride was the only possible product and not "sodium hydrochloride" and then whether there were other salts other than sodium chloride. While

these learners' contributions could have opened up classroom interactions to Brodie's reversing IRE, their potential was not realised. For example, if the teacher had invited the rest of the class to respond to the three questions a true learner-learner dialogue could have emerged. However, in all three cases the teacher quickly provided answers some of which had the effect of closing down dialogue as in the case of turn 39 where the teacher simply stated that there many types of salts without elaborating or challenging the learner to find out. Also from turn 37 it is not clear if the teacher had sufficient subject matter knowledge to address Thamu's question.

Other examples of active learner participation came from Mrs Nkosi's lessons again in the form of unsolicited learner contributions. At the beginning of the lesson on owl indigenous knowledge the teacher struggled to get learners talking about their knowledge of owls. However, once they gained confidence learners were able to volunteer information. The excerpts below are examples of learners making unsolicited contributions and of their peers responding without the teacher's prodding:

- 291 Ayanda: Maam what I know is that an owl gives you direction when you are lost
Teacher: heh?
Class: *(commotion as learners take Ayanda on)*
T: Shh if it gives me direction then it means if I am getting lost somewhere particularly in the rural areas now when it appears it actually leads me
295 Class: *(commotion)*
Sista: Ayanda ushukuthi if mina ngiyale and kusuka iskhova la esihlahleni kumele ngijiek ngiye le? (Ayanda are you saying that if I am walking in one direction and an owls flies off a tree in the opposite direction must I turn around?)
Class: *(commotion in agreement with Sista)*
Muntu: ulahlekile i (it means you are lost)
(Turns 291-298 Lesson on owl indigenous knowledge and conservation)

Ayanda volunteered the information about owls assisting a lost person to find direction. The class reacted immediately with much talking among themselves and when the teacher revoice Ayanda's contribution Sista responded with a question directed at Ayanda himself challenging his statement. More learners joined in, some to defend Ayanda (e.g. Muntu in turn 298) and others concurring with Sista (turn 297). Again this interaction had the potential to develop into the ternary interaction discussed below from Mrs Thoba's lesson. After a few more turns another learner Phumuzile also asked a direct question to Ayanda and those that supported him:

- 311 Phumuzile: Nithini? Nithi asithi ke ngiyazi ukuthi kithi ngiyale mara sengikhohliwe sekushinshile le phambili ok? (are you saying that

- if I know where home is and I know the general direction but it is no longer familiar are you saying I must ?)
- Class: (boys interrupt her and a noisy exchange ensues)
- T: (clapping hands to stop the exchange) alright alright shh. Now what are we learning from this? Oh before .. you have something to say?
- Ayanda: Yes Maam I think Maam *ngifunukutshela uPhumzile cha hayi ukuthi ukhohlwindlela eya kini sithe ma udukile wadukela le ebhara hayi ukuthi ulandeliskhova*. (I want to tell Phumzile we are not talking about you losing the way to your home but we are saying if you happen to be really lost like you are out at Bara no that you should follow the owl)
- 315 T: alright alright alright now can we summarise? Can we summarise now? Ok Bandile you have got something
- Bandile: *ngivumelana noAyanda. Phumzile hayi ukuthi mhlawumbe* (I agree with Ayanda. Phumzile we are not saying...)
- Class: Yoh yoh (noisy interruption)
- T: ah ah keep quiet and listen to him
- Bandile: *bekathi hayi ukuthi mhlawumbe ma ulahlekile izokuthatha ikubekendlini straight izokuthatha ikubeke mhlawumbe* to the nearest place (he says that if you are lost it will lead you to)
- 320 Lb: yes
- Bandile: *la nawozoya khona wazi* (a familiar spot ...)
- Lb: *khonuzobona* (yes where you can see)
- Bandile: *ukuthi ngiya laphayana* (where you can now make out your way again)
- Class: yes
- 325 T: order please
- Lb: *Bandile mfowethu ushukuthi mangabe ngilahleke ebusuku ngifune ... (inaudible)?* (are you saying that if I am lost at night I must find ...?)
- Class: (loud and prolonged laughter and talking by all) 40sec
- T: right the issue here is if it is only found at night it can only direct you at night.
- Class: yes
- 330 T: don't expect that to happen during the day during the day you can actually ask.
- (Turns 311-330 Lesson on owl indigenous knowledge and conservation)

The learner-learner interaction intensified in this excerpt with learners responding to each other a lot more making it difficult for the teacher to manage the discussion. This is evident from the teacher's attempts in turns 312, 315 and 325 to control the noise and confrontational nature of the interaction. This may speak to the question of the role of context and cultural capital on patterns of student participation as well as to the notion of student autonomy or students taking responsibility for their own learning. It may also be an indicator of the teacher's role in creating a conducive (safe or comfortable?) learning environment and hence opening up the dialogic space for student engagement.

This form of teacher-learner interaction was evident also in at least one of Mrs Thoba's lessons. Instead of the traditional IRE, teacher-learnerX-teacher-learnerY discourse pattern

there emerged a teacher-learnerX-learnerY type of interaction, similar to Mortimer and Scott's IRRF chains. However, this did not take the form of true learner dialogues as observed by Brodie (2007) in that although the learners' comments and arguments were directed at their peers or were in response to their peers ideas they channelled them through the teacher. This was the case with Owen, Tahari and Thinta in the excerpt below taken from the bond energy lesson as the teacher tried to get the class to resolve a misconception that had arisen from Tahari's answer:

- 86 T: When does a po...when does a negative charge form? When does an atom become negatively?
Owen: When two atoms collide?
T: Hah?
Owen: When two atoms collide.
90 T: And?...
Owen: it becomes negative charged...they have one electron
Tahari: Eh Maam *manje angithi seziya kholay...seziyahlangana angithi...*(because now they are colliding...coming together)
Class : (shuffling and whispering)
Owen: That's what we think...
95 T: Let me give you a chance
Thinta: Madam I disagree with the statement coz Maam I think when the two (inaudible) the chemical potential energy will increase
T: Why...(inaudible)...why do you disagree with the statement?
Thinta: Its because Maam...when the...the...the two atoms Maam interact its impossible for them to be negatively charged.
Tahari: Maam didn't you say...
100 T: Why?
Thinta: *Azikathintani* (they have not yet touched) Maam.
Class: Yes...yes
Tahari: Maam didn't you say when they get closer to each other when they attract the potential energy it will decrease *angithi* Maam?
Thinta: Its like this... (holding pen and set square apart in each hand)
105 Tahari: It will decrease...
Thinta: *Azikathintani* (they have not yet touched) Maam.
(Turns 86-126 Bond energy lessons)

While it was clear from the dialogue that the utterance was meant for the peer it seemed that there was a classroom culture of speaking through the teacher. Where learners began to address each other directly the discourse became disputational and chaotic often prompting the teacher to call for silence or order. This may have to do with traditional pedagogies of classroom control and management or with cultural norms of respect for an elder's presence in the room. This question was borne out by the fact that where learners continued with the discussion outside class (often as they were leaving at the end of the lesson) they did confront each other directly and did not need another peer to be an intermediary (Msimanga & Lelliott, 2008).

7.2.2.3 Occurrence of argumentation (mainly co-constructed arguments).

(Although argumentation came through as a theme here it has been discussed at length in Chapter 7 and I only summarise the key aspects that relate to the themes discussed in this chapter)

In argumentation the aim is to be able to use evidence to support one's own claims or to evaluate, question or challenge others' claims. I was interested in both the cognitive and social aspects of argumentation and I identified four general trends in argumentation:

- Most arguments were co-constructed by the teacher and learners.
- Although at first, learners had difficulty supporting their arguments in time they did begin to provide evidence for their claims as well as rebuttals for their peers' arguments.
- The nature of arguments also varied. Some arguments focused on the task, others were negotiations of procedures and others still were negotiations of the norms of social engagement.
- Spontaneous arguments seemed to develop where a need to resolve a disagreement was perceived. In other words where the participants were seeking consensus, to persuade or be persuaded. However, there were also arguments to articulate understandings and for meaning-making (as discussed in Chapter 6).

Although for the most part teacher intervention tended to constrain argumentation, in at least one of the lessons the teacher successfully fostered learner argument construction. I show how each teacher's communicative approach constrained or encouraged learner argument construction. (This speaks to the questions of increased student participation; student autonomy - students taking responsibility for their own learning; the teacher effort/ willingness/ ability to open up the dialogic space for student engagement)

It appears that those teacher interventions that opened up for negotiated understandings and encouraged learners to evaluate and critique own and/or peers' thinking were conducive to argument construction. Of note was the role of teacher questioning and the type of question asked. For instance, Mrs Thoba and Mr Far often asked open-ended thinking questions such as "what do you have to say about this?" or "how else would you do or say this?" Mrs Nkosi, on the other hand asked a mix of questions ranging from closed recall type questions to rhetorical and occasionally some thinking questions such as "why do you think this is correct or incorrect?" Thus, the nature of arguments that developed in each of their lessons varied.

Mrs Thoba and Mr Far did not plan for argumentation both in terms of task design and pedagogical strategy. The arguments in their classrooms were spontaneous and the teachers' responded and supported the process by their questioning styles. Mrs Nkosi did use some tasks designed to stimulate argumentation but often did not provide sufficient support for the ensuing arguments.

Pontecorvo (1993) pointed out that classroom talks or discussions activate argumentative operations through which students carry out epistemic operations, that is, cognitive procedures which characterise the language of the domain, in this case science knowledge construction. By being engaged, students could reach more advanced levels of understanding about the examined knowledge object (Mason and Santi, 1998). This was the case, particularly in Mrs Thoba and Mrs Nkosi's lessons. The teachers created a social space in which learners could engage according to the cognitively procedures of scientists in scientific argument construction.

7.2.3 Engagement within hybrid spaces or “unconventional” forms of engagement

The teacher-learner and learner-learner interactions that I observed conformed in many ways to known “conventional” forms of engagement. However, there were also some that differed from the conventional in interesting ways that suggest complexities of discussion in multicultural, multilingual classrooms. As Aikenhead and Jegede (1999) observed, learning science in these multicultural environments involved movement between everyday life and school world which they describe as a form of cultural border crossing. They assert that “culture is a shared way of living which includes knowing, valuing, interaction with others, feelings, etc” (p3) and that science is therefore another culture within which learners have to interact bringing their individual baggage.

7.2.3.1 Combinations of scientific, formal academic engagement with informal context-based forms of engagement

Although it was not prevalent, there were incidences of informal talk and small talk in all the three teachers' lessons. In all cases the small talk and/or informal talk happened during the Interactive-Dialogic episodes when the teacher was eliciting and working with learners' ideas. I illustrate this point with one or two episodes from each teacher's lessons. The first two were taken from Mrs Thoba's lesson on waves:

- 53 Teacher: yah but just discuss the movement. How does it move? Does it move straight?
Class: Nooo (*Excitement, commotion, talking at the same time*)
55 Teacher: (*points to a male learner*)
Sandile: its like a wave Maam its like a wave
Teacher: its like a wave?
Class: amanzi ... (*water...*) (*Inaudible*)
Teacher: how does it move? Like a frog? (*making movements with her hand*)
60 Class: (*more excited talking all at the same time*)
Teacher: ok others say it moves like a snake. How does a snake move?
(*Teacher and learners together imitate movement with hands*).
Teacher: ok lets say this is our spring (*drawing a horizontal line on the board with two vertical lines at either end*) ok we create a pulse it is going to move up down up down to that ... direction
(*Lines 53 – 62 from transcript of lesson on Waves*)

The ID episode followed learner simulations of wave forms using the slinky spring. The teacher now engaged them in a whole class discussion to describe what they had observed. In this section they were trying to describe the movement of the wave. The learners obviously knew what they had seen and when the teacher playing devil's advocate, described the movement as "straight.." in turn 53, they unanimously chorused "No". When Sandile suggested that the movement was like a wave, other learners added the word "water" probably corroborating Sandile's idea that the movement was like water waves. In a manner that was not usual in her communication with learners, Mrs Thoba allowed this informal throwing in of ideas even joining in herself in turns 59 and 61, she and the learners making snake-like movements with their hands. However, in turn 62, she went up to the board to write, signalling the end of this playful episode. Taking an authoritative stance, she changed the tone of the talk and engaged the learners step by step in construction of the diagram to represent the wave form. A little later when she asked the learners to name the wave, she again opened up for dialogic interaction:

- 171 Teacher: It has a special name what is its name? that ... (*imitating the snake-like movement from a previous episode*)
Senzo: (*inaudible*)
Teacher: up and down pulse? (*still imitating with hands*)
Class: noooh
175 Teacher: No
Mandla: (*inaudible*)
Teacher: bouncing pulse? (*still imitating with hands*)
Class: (*general laughter*)
Teacher: ok we call it a transverse pulse.
180 Class: pulse
Teacher: We call it a ... transverse pulse
Melo: transverse pulse
Teacher: ok write quickly because this is class work. You have to finish it.
(*Lines 171 –183 from transcript of lesson on Waves*)

This time it seemed that Mrs Thoba herself started the informal engagement. She took on a non-serious, inviting tone which probably signalled to her learners that it was safe to hazard any answer, which they did. Although the recorder did not capture what Senzo (turn 172) and Mandla (turn 176) said, I picked it up when from the teacher's revoicing and imitations (turns 173 and 177). In the same mood the class chorused, "Nooo" as the teacher repeated Senzo's answer that the wave is called the "up and down pulse" and again burst out in laughter when she repeated Mandla's "bouncing pulse". Once again, to close the episode she shifted to an authoritative stance, provided the correct scientific term for the wave type and gave an instruction for learners to write.

In Mr Far's lessons there were more episodes of small talk between the teacher and learners. He sometimes drew on learners' everyday experiences to make a science point or to insert a moral lesson in the course of the lesson. In the first excerpt below, the teacher weaved small talk into his development of the scientific story, thus lightening the mood for learner engagement:

- 295 Teacher: Lerato what does the word diatomic stand for?
 Lerato: *(muttering to a friend)*
 Teacher:: She is asking you Melo she is saying you will give us the answer
 Melo: *(muttering to the teacher)*
 Teacher: What does di- mean?
 300 Melo: *(muttering)*
 Teacher: *(to the class)* someone is screaming it out. They are afraid. Why are you afraid? *(to a learner whispering 2)* Bongani? Have confidence and say that it is two
 Teacher: So diatomic means
 Bongani: two
(Turns 295-303 Lesson on properties of compounds)

When a learner whispers to a friend instead of answering the question, in the way Lerato did, the standard teacher's response would be to reprimand her. He would probably take on a sterner (more authoritative) tone in the process. However, Mr Far played along, transferring the responsibility for answering the question to Melo (turn 297) who it turned out did not know the answer either. When a different student shouted out the answer, the teacher again let go a chance to reprimand and addressed a social rule. Mr Far generally discouraged learners from shouting out their answers, thus suggesting that Bongani (a male learner) was afraid not only reminded him of the social rule but was also a further deterrent in future. In the end, though, the class arrived at the correct scientific information through an informal,

everyday form of interaction. In the next excerpt also from the lesson on properties of compounds, Mr Far engaged the boys in friendly (perhaps fatherly) small talk to insert moral lessons:

- 58 Teacher: And I need another volunteer. I would say someone that smokes. I know he is gonna come. See, I didnt have to ask. (*general laughter*) Right so let's observe. If I say Magnesium is flammable So if it is really flammable it is supposed to burn right?
- 60 Class: yes
- Teacher: (*signals to Musa and Sobuka who are up front trying to ignite the magnesium - one holds the magnesium ribbon and the other the matches to ignite it*) now they are starting to be afraid
- Methu: *ungathuki* (dont be afraid)
- Sani: *ngeke lishe* (you will not burn)
- Teacher: don't be afraid you will hear and you will see. Keep it stable. (*boys try and fail to ignite the magnesium ribbon*)
- Teacher: (*to Musa*) smoker!
- 65 Musa: ah sir
- Teacher: the reason I am saying you are smoking is there is a way you are igniting that match stick and you are holding that match in a specific direction
- Sobuka: ... (*inaudible*)
- Teacher: you boys should not even try these things ... once you start it is hard to stop ...
- Sobuka: ah sir
- Teacher: ok it seems that I will have to get another volunteer to come and do this or do it myself?

(turns 58-69 Lesson on properties of compounds)

The teacher had asked a learner, Sobuka, to come up front to perform the demonstration and sat the beginning of the excerpt above he indicated that he now needed another volunteer. In jest he said that he preferred to have a smoker (someone with experience in lighting matches, perhaps?). Musa, who I later found out actually smoked cigarettes, responded and went up to help Sobuka. In the same light hearted spirit, the teacher remarked, "See, I didn't have to ask", to general laughter by the rest of the class. This friendly banter continued as the boys tried to manipulate the magnesium ribbon, again with the teacher teasing them for failing to ignite it and the other boys, Methu and Sani joining in (turns 60-63). The teacher's lesson about smoking came in turn 68, following another four turns of teasing between the teacher and the boys (64-67). In the last turn, the teacher once again quickly shifted the interaction to a more authoritative on task episode.

Similarly Mrs Nkosi also occasionally brought in moral lessons to the discussion, as in the excerpt below from the lesson on population dynamics:

- 85 Teacher: yes what type of population is that? A declining population? What type of population is it? Is it growing is it increasing is it decreasing?
Class: decreasing
Teacher: it is decreasing yes to decline means the numbers are going down. Now if these numbers are go down what would be the reasons? Yes?
Noma: when the people become rejected to come into that area
(the rest inaudible)
Teacher: if people cannot come into the area if the mortality rate is high
90 Sandi: (inaudible)
Teacher: age as well the younger you are the more productive you are but elderly people do not produce any more children they have reached menopause. What is that? So now imagine a community where there are mostly elderly people. That's a dying community its no longer growing not just dying but its no longer growing.
Class: yes
Teacher: but the younger the people are in the area then it means the population there will be growing. *Angithi*? Ten years from now you will have completed your matric and graduated and then you will start your own families right? But you must study you study you abstain you study complete your matric graduate
Class: yes
95 Teacher: no messing around people. Yah you cant do that you should be focussing on your future right? yah otherwise hey things will go wrong. You see the pandemic HIV/AIDS?
Class: yes
Teacher: So you better take care of your selves people ok? Right now what about the carrying capacity ? who hasn't spoken to me? not you Phiri you have been talking so many times.
(Turns 84-97 Lesson on population dynamics)

This type of interaction happened from time to time in Mrs Nkosi's lessons. She often brought social issues into the general discussion. In this case she took up Sandi's answer (turn 90) about age as a factor in a declining population and elaborated on it, linking it to menopause (turn 91). In turn 93, she shifted the talk to a lesson on learner behaviour and finishing school and finally by turn 95 she was reminding them of the issue of HIV/AIDS.

The low incidence of social talk and/or informal talk in the three teachers' classrooms is not surprising considering that teacher communicative approaches were largely authoritative, taking the more formal teacher-controlled form perceived as typical of science discussions. However, the evidence of these localised forms of interaction in all three teachers' classrooms is also consistent with their tendencies to open up to dialogic forms of talk. It could also be an indication of the potential of its use in classrooms in this context if teachers and learners were sufficiently comfortable with their use and management during formal lessons.

I regarded informal and small talk as a way of providing a comfortable social space during classroom discussions. I imagine that they would enable the cognitive development that is targeted by the science activities in the way that Stylianou and Blanton (2002) observed it with mathematics students become comfortable with providing explanations and justification of their thinking in university mathematics lessons as they became comfortable with the social process.

7.2.3.2 Learner cultural differences and barriers

From some of my observations particularly in the lesson on indigenous knowledge of owls and conservation it seemed that there was an additional source of alienation between local knowledge and school science. This relates to perceptions of compromising one's personal safety if one engaged in a public social space with certain cultural knowledge. This relates to issues of taboos and beliefs around the sacredness of certain information. I illustrate this point using two excerpts from the lesson on owl indigenous knowledge:

- 165 Teacher: yes what is it that you know? maybe it something that you read in a book in a newspaper. Or you saw in the television? Or if its something that is er that you learnt from your parents or your grandparents or in your community. Remember different communities have different beliefs. So let's hear about that.
Iskhova ah isikhova ah (teacher imitating some learners' expression of reluctance to talk about an owl)
- Lindokuhle: *ah Maam isikhova ah (no Maam an owl no)*
Class: *(girls giggling)*
Lindokuhle: *isikhova?(an owl?)*
Teacher: you said No no no now tell us why
- 170 Lindokuhle: *isikhova? (an owl?)*
Teacher: no just be free. Oh someone wants to help him
Nanelo: er Maam because many people believe that owl are used to witch other people
Class: yes yes
Teacher: there you are
- 175 Class: yes yes
Teacher: oh now I can hear most of you are saying yes
Class: yes yes no
Themba: *(recording interrupted)*
Teacher: ok someone says it feeds on the mice as well so that's a positive effect but most of you are saying no no no do we believe in what people are whispering about? Because I can hear people are saying things but they don't want to come forward now come forward talk about these things
- 180 Class: *(whispering)*
Teacher: is it related to what I overheard people saying? bewitching?
Class: No
Teacher: ok he says no because he hasn't seen it but have you heard anything to that effect?
Class: yes
- 185 Teacher: that some people use it to bewitch other people? I remember as a

young girl I used to hear those negative things about owls. Let's hear some of you are from KZN
 Class: (noise & general commotion)
 Teacher: Lindokuhle you keep on talking but you don't want to share the information.
 (Turns 165-187 from Lesson on owl indigenous knowledge)

This episode followed one in which the teacher had tried and failed through a question and answer session to get the learners to talk about their beliefs or knowledge of owls. In the opening statement to this episode she tried to put the learners at ease by making suggesting possible sources of this knowledge that maybe deemed socially acceptable and therefore easier to discuss in a public forum. For instance, she suggested that learners may have read or seen on TV or heard from their communities. This might distance the learners from being associated with the owl's evil activities and help make it easier to talk about owls. This became evident later when most learners expressed the belief that owls were associated with witchcraft. Therefore, any profession of detailed knowledge of owls and their activities could be interpreted as evidence of some association with the bird and thus with witchcraft. Thus Lindokuhle and others found it difficult to open up to the discussion, yet they did talk privately in small groups as is evident from the teacher's words to Lindokuhle in turn 187 "Lindokuhle you keep on talking but you don't want to share the information". Another learner, Nelisiwe seemed to be struggling with a similar cultural difficulty in engaging with the topic:

189 Teacher: remember we are sharing information here. Yes Nelisiwe?
 190 Nelisiwe: about an owl?
 Teacher: Hhm
 Nelisiwe: *Eh Yoh Maam* (Oh no Maam)
 Class: (laughter)
 Nelisiwe: yoh Maam *li-violent igama lelo* (oh no Maam the word is violent)
 195 Teacher: say it in vernacular
 Nelisiwe: No Maam it is a sign of death
 Class: yes yes
 (Turns 189-197: Lesson on owl indigenous knowledge and conservation)

Like Lindokuhle, Nelisiwe did know and perhaps believe this about owls but would not have said it if the teacher had not probed. In turns 190 and 192 she seemed to be surprised that the teacher would even ask her to speak about an owl. The teacher suspecting that Nelisiwe had difficulty articulating her belief in English invited her to use her language but in response Nelisiwe stated her belief in English in turn 196. Again as Aikenhead and Jegede (1999) argued, success sometimes depends on how the teacher mediates or helps learners negotiate cultural border crossing. It could be argued though, that the challenge for the teacher is to be

able to discern the kind of border crossing a learner needs if the learner cannot articulate her cultural “position” in terms of knowledge and beliefs. However, as is the case in many of our classrooms learners either are not given the opportunity to talk or do not make use of it where it is provided and teachers will often struggle to mediate the border crossing. This strengthens the argument made in this and other research on classroom interaction to get learners talking a lot more in class so as to externalise some of their cultural and content based difficulties in achieving the necessary border crossing. Once the ice is broken and learners start talking they may provide each other with the necessary support to make the border crossing as is seen in the next two excerpts taken from an episode that happened later the same discussion about owls. Learners began to volunteer information and their peers started to respond without probing from the teacher:

- 263 Sandile: ah *mina* Maam what I know about owls Maam *into* that they use it for *ukuthi bayisebenzisa* to other people the traditional healers they catch it they kill it then they make *umuthi* Maam
Bahle: yaah
(Turns 263-264: Lesson on owl indigenous knowledge and conservation)

In turns 263 and 264 Sandile volunteered information about how healers used the owl in medicine and Bahle supported him. This was evidence of the shared or common cultural belief about owls by the two young men and a few others that also supported them in the next few turns. However, in turn 270 Nanelo, in an unsolicited contribution countered Sandile’s argument arguing that the healers did not use owls for “good” or curative medicine but that they actually used it in “bad” ways:

- 270 Nanelo: *mara mina into engiyaziyo ngale eshiwo wuSandile ukuthi lowo muthi lowo asuwenziwe ngalesoskhova* (what I know about what Sandile is saying is that the kind of *muthi* made from the owl)
Teacher: eh?
Nanelo: *akusiwona umuthi okuphilisa* someone (is not for healing)
Teacher: ok?
Nanelo: *wumuthi we ..* (its for ...)
275 Sihle: (*shouting*) *wokubulala* (for killing)
Nanelo: *wumuthi wokuloya* (its only for witchcraft)
Class: (*commotion*)
Nanelo: *vele wokubulala someone* (to kill someone)
Class: (*commotion*)
280 Teacher: Ok ok shh
Class: (*learners talking about how some healers are also witches*)
Teacher: Quiet er did you hear what she said?
Class: yes yes
Teacher: now on the contrary to what Sandile said she says those people use it to bewitch others
285 Class: yes
Teacher: and she is supported by someone who says that is true
(Turns 270-286 from lesson on owl IK and conservation)

In turn 274 it seemed that Nanelo was reluctant or afraid to articulate the bad way that healers use owls and Sihle comes to her rescue shouting that it is for killing. Nanelo continued in turn 276 and stated that it is for witchcraft and only later in turn 278 did she eventually get to the point about killing. As in the case of Nelisiwe in the excerpt discussed earlier Nanelo may have been constrained by her cultural beliefs about saying out the “bad” words in public. From my own personal experience this is a typical cultural way of talking about anything that has to do with death and the dead. One usually does not state outright the word “death” or “kill” but uses other more acceptable words to describe or provide an analogy for death and/or killing. The fact that Sihle could shout “for killing” in support of Nanelo’s contribution could be evidence of successful mediation by the teacher or Sihle’s background maybe such that it was easier for her to shout this. The former seemed to me to be the more plausible explanation since Sihle did not herself volunteer this information waiting until much later in the discussion to make it in support of someone else’s claim.

7.2.3.3 Teacher and/or learner engagement in the mother tongue or their languages

A measure of meaningful engagement that I used in this study was the level of argumentation evident during the interaction. In the excerpt below for instance, Kahle made some convincing arguments in isiZulu.

- 246 Kahle: er Maam *kahle kahle into nje okumele abantu bayazi ukuthi iskhova nje asidalelwanga ukuhamba emini sihamba ebusuku yikho nje abantu bethi iskhova siyathakatha* (Maam the truth is that an owl was made to be active at night not during daytime this is why people say an owl is a witch)
- Class: yes yes
- Teacher: oh ok
- Kahle: *asikwazi kahle ukuhamba emini* (it cannot move during the day)
- 250 Teacher: it is nocturnal not diurnal
- Class: yes
- Teacher: in other words what he is saying is people are justified
- Muntu: yes
- Teacher: to believe that it is used for a negative purpose because it is not seen during the day
- 255 Class: yes yes
- Teacher: and anything that is associated with darkness than light is usually er right believed to have an implication of what of using to bewitch other people
- Class: yes
- (Owl indigenous knowledge and conservation; turns 246-257)

In turn 246 he opened with an argument that the teacher later articulated in turn 252 that those who say an owl is associated with witchcraft are justified since an owl is only active at night and not during daytime. In turns 254 and 256 the teacher went on to provide the supporting evidence (warrants and backings) from (a shared) cultural background arguing that “anything that is associated with darkness than light is usually er right believed to have an implication of what of using to bewitch other people”. Another example is taken from Mrs Thoba’s lesson on bond energy. When the learner could not articulate her answer in English the teacher encouraged her to use her home language which she did:

- 53 Tahari: Because of there is no attraction...they are not...they are far distant...so they...they are...I cant explain Maam...
- Teacher: say it in your language its fine
- 55 Tahari: Maam in my language its so...ok (Class laughter) ok... fine Maam let me say it in my language...ok fine Maam *tinekule* Maam *atihlangananga ti* (inaudible) Maam but Maam *lokho tingahlangananga tahari* constant *tahari* net force *yatona tahari* zero and so *lokho tita atrakthana lokho setitangananga tiya atrakhta ke yikhona tingataba...tingataba...*
- Teacher: The forces will then attract
- Tahari: Yes
- Teacher: Ok what she means is...if they are as far distant apart then it means...their potential energy is zero because there are no forces that act between the...two atoms.

(Turns 53-58 from lesson on Bond energy)

The argument was that the potential energy between the two atoms was zero (claim) since there were no forces of attraction between them (warrant) because they were still at a distance from each other (data). Again, the teacher encouraged Tahari to give the explanation in her language, signalling that it was acceptable in her class for science to be discussed in a language other than English. This may help learners engage with and understand better the science concepts under consideration.

Research elsewhere has shown that science learners for whom English is a second language struggle with the challenges of building registers for the language of instruction and find it difficult to formulate high quality arguments on science concepts (Rojas-Drummond, et al., 2001; Rojas-Drummond & Zapata, 2004). Locally, in southern Africa, research in both mathematics and science classrooms has also shown that some learners who seemed to be struggling with the concepts tended to do better if provided the opportunity to engage in their own languages (see for example Rollnick & Rutherford, 1996; Setati, 1998; Setati, et al., 2002). However, this must be considered in the context of the ongoing language policy

debate in South Africa where the use of local languages in the classroom may be seen as detrimental to learner development of English language skills which they need to take their final national examinations (Setati, et al., 2009).

7.2.3.4 Teacher attempts to make language visible and/or invisible.

Research in mathematics education has investigated how language can be used as a visible and invisible resource to facilitate epistemological access (Setati, et al., 2008). That is, how teachers and learners switch between consciously engaging with the problem of language during the lesson (visible) and the unconscious use of their languages to engage with the mathematics (invisible).

I sought to understand how teachers and their learners dealt with the challenge of engaging in science talk in a language of teaching and learning that is different from their individual first languages. I was interested in the strategies they used to cope with the challenges of language as well as in the nature of learner engagement when they engaged in science talk using their home languages. The three teachers handled the issue of language in different ways. For example, Mrs Nkosi did not pay much attention to language and while she engaged her learners in English most of the time she did occasionally lapse into isiZulu. Mrs Thoba on the other hand, occasionally made language visible, inviting her learners to explain their thinking in their own languages. She only seemed to make language invisible when she engaged in less formal dialogue with learners. For instance when learners asked unsolicited questions they often did so in between activities, say, during an interval when the class was waiting for a learner who was writing something on the board. In these instances they asked their questions in their languages and often Mrs Thoba would respond in her language too.

Sometimes Mrs Thoba used her language when she (subconsciously) checked consensus or when she was emphasising a point. For example she used phrases like “siyabona?” (do we see?) quite often to check consensus. Mr Far on the other hand made language both visible and invisible in the manner that Setati et al. (2008) speak about language use in the classroom. This was in spite of the fact that he and his learners never used their languages in the lesson. Mr Far often engaged in meta-talk. That is, he would talk about the way in which he was using language or explicitly engage learners with meanings of English words, often pointing out to learners that, since English was not their mother tongue they needed to

consciously engage with and understand the meanings of English words. Thus, there were instances of code-switching in both Mrs Thoba and Mrs Nkosi's lessons but none in Mr Far's lessons. According to Mamotloang (2008) code-switching is commonly used by many South African teachers as a way of using more than one language to clarify meaning.

This example of learner engagement in the mother tongue was taken from Mrs Thoba's lesson on bond energy:

- 53 Tahari: Because of there is no attraction...they are not...they are far distant...so they...they are...I cant explain Maam...
Teacher: say it in your language its fine
55 Tahari: Maam in my language its so...ok (Class laughter) ok... fine
Maam let me say it in my language...ok fine Maam *tinekule*
Maam *atihlangananga ti* (inaudible) Maam but Maam *lokho tingahlangananga tahari* constant *tahari* net force *yatona tahari* zero and so *lokho tita atrakthana lokho setitangananga tiya atrakhta ke yikhona tingataba...tingataba...*
Teacher: The forces will then attract
Tahari: Yes
Teacher: Ok what she means is...if they are as far distant apart then it means their potential energy is zero because there are no forces that act between the two atoms. Yes let us start here therefore this means that the potential energy is zero because there is no interaction between the...atoms. So this gives us the potential energy being zero. Ok now they move closer in other words the distance between them decreases they move closer to one another. If they move closer to one another this means that the distance between them decreases. What do you think is going to happen?

(Turns 53-58 from Bond energy lesson)

The learner, Tahari articulated her argument in her mother tongue and the teacher interpreted for the other learners. This is interesting in terms of the difficulty of distinguishing between the components of an argument especially warrants and evidence. According to Toulmin (1958) and later Erduran et al (2004) one way to decide on warrants and data is to use words like *because*, *so* or *since* to analyse arguments. For example the data would be preceded by *because* and the claim by *so* while a warrant would be preceded by *since*. However, where the participants are not native speakers of English as in the case of Mrs Thoba's learners such words may not carry the same English language meaning that would provide the kind of guidance envisaged in Erduran's method of analysing argument structure.

Another way in which language played out in the lessons I observed was in terms of Setati's visibility and invisibility of language. The following excerpts taken from two of Mr Far's lessons I illustrate how he made language both visible and invisible by sometimes engaging

with issues of English language proficiency and at others just engaging with the language of science. The first example came from Mr Far's lesson on momentum:

- 103 Mariane: total kinetic energy
Teacher: say that word again
- 105 Mariane: total kinetic energy (teacher writes this on the board)
Teacher: the total kinetic energy is conserved. Now remember English is not my mother language Ne and I do not understand what the word conserve mean. So who would like to give us his understanding of conserve because I do not know then. Alison?
- Jenny: Sir isn't it like ... conserve is like to save... does conserve and conserve ... (inaudible)
- Teacher: No in this in this case conserve not conserve (different intonation)
- Thomas: like saved
- 110 Teacher: save are you saying saved?
Thomas : saved any other person? because we are about to (inaudible)
Sithembiso: (inaudible)
Teacher: say that Sithembiso
- 115 Sithembiso: stored
Teacher: stof?
Sithembiso: store
Teacher: store that actually makes more sense isn't it so?
Class: Yes
- 120 Teacher: we say stored conserved in some way so it remains there
Class: yes
Teacher: right so we are saying in elastic motion or movement or collision the total kinetic energy is conserved. What else did you notice about (teacher hitting at each other) this? what else did you notice about this (teacher hitting at each other) this? . I'm saying this is my left hand and this is my right hand my left my right please look at my frame of reference my left my right I am moving my left to my right and what's happening now?

(Turns 103-122 from lesson on Momentum)

Research into the role of language in science teaching and learning has investigated strategies to help English second language learners cope with learning science in English (e.g. Olugbara 2008; Pliiddemann, Mati & Mahlasela-Thusi 1998; Probyn 2006) as well as on the differences between everyday language and the language of science (e.g. Oyoo, 2009). Scientific language is not the same as common language that is used for communication purposes and although science is taught in English it is not the same as the English language either. Mr Far seemed to be well aware of this fact and consciously mediated language in his lessons. Here is another example from the same lesson on momentum:

- 140 Teacher: so what else do we notice? Because when we come to the second type of collision what else to we notice about this object?
- Thula: its inelastic
- Teacher: what do you mean inelastic? Explain to me inelastic (teacher rubs his fists together without separating them) inelastic?
- Thula: Sir isn't it when it collides
- Teacher: are you saying elastic?

- 145 Thula: no Sir inelastic
Teacher: Inelastic. Now she is using a different word inelastic (teacher writes word on board) and you are saying inelastic is what?
Xolani: when they collide and move together
Teacher: after the collision or during collision we will have the object move ... move as? Show that again (to student - who might be illustrating movement as one but was not caught by the camera)
Xolani: (inaudible)
150 Teacher: let me rather use the word stick together (teacher writing) stick together that is what she is saying she is saying in an inelastic collision the objects stick together. Now remember what you said here in yellow in elastic so what is happening now?
Senzi: the total kinetic energy is not conserved
Teacher: is not conserved so is it lost? Is the energy therefore being lost? Is it being lost? (teacher gestures like he is throwing away something with his hands) does it say there is no more this kinetic energy and it went away?

(Lesson on momentum; turns 140-152)

In two instances, turns 146 and 150 Mr Far specifically referred to the words that he and the learners were using. First, the word inelastic came from a learner in answer to his question and the teacher explicitly engaged the learners about the meaning of the word. He even wrote it on the board presumably to emphasise its importance. Later in turn 150 to further explain inelastic he said “let me rather use the word stick together...” making language visible in this case. Although Setati et al. refer to making the learner’s language visible in this case Mr Far was making the English language visible and using this strategy to explain the relationship between the language of science and day to day English language usage. Most of Mr Far’s learners were Afrikaans speaking and he seemed to sense a need to make word meanings explicit for them. Mr Far never used Afrikaans or any other learners’ languages in class but engaged with words in the English language as seen in the excerpt above.

7.2.4 Linking science talk with other forms of engagement

As noted earlier (Section 7.1.4) linking science talk with other forms of engagement has the potential to enhance learner experiences of science learning. It could also enrich the teacher’s repertoire of pedagogic tools. The three teachers in my study employed various pedagogical strategies together with science talk. For instance, Mrs Nkosi always got her learners to read and talk while Mrs Thoba and Mr Far combined science talk with note writing. All three teachers often had learners talking around demonstrations.

7.2.4.1 Talking, reading and writing

The combination of science talk with reading was only seen in Mrs Nkosi's lessons. In all her lessons she either read to the learners or made them take turns in reading a selected text. She had this to say in an interview:

- Mrs Nkosi: it is it is a barrier I think it needs a lot of practice. One area you know one area that maybe we have lost you know the issue of debate in high school
- Researcher: hhm
- Mrs Nkosi: those were the things you know that actually helped us as students. You know not talking mother tongue when you are at school
- Researcher: Hhm
- Mrs Nkosi: It was the thing during our times you wouldn't speak in Zulu but now ...
- Researcher: Hhhm
- Mrs Nkosi: Yah and the issue of knowing we used to write summaries you knew that I must write ten summaries I must read ten books in English
- Researcher: HHm
- Mrs Nkosi: ten books in Afrikaans ten books in Zulu
- Researcher: Hhm
- Mrs Nkosi: so those I think are the things that developed us which are no longer done
- Researcher: Hhm
- (Mrs Nkosi interview by the researcher on 18 October 2009, turns 38-49)*

Clearly, Mrs Nkosi believed that reading and writing were important skills that the current generation of learners were no longer given opportunities to engage in sufficiently. I illustrate below how she used reading to facilitate science talk in her lessons. The first excerpt is taken from the introduction of the lesson on gaseous exchange:

- 5 Teacher: So 11A here you are *(teacher distributes reading material)*
Class: *(talking among themselves)*
Teacher: Can you listen please we are going to be continuing. We ended up discussing the blood system the heart *angithi*?
Class: yes
Teacher: yah anyone else? *(still issuing out reading material)*
10 Class: *(still coming in, receiving handout and finding seats)*
Teacher: Anyone else without the handout?
(Turns 5-11 from lesson on gaseous exchange – distributing reading material)

In this short episode from the lesson on gaseous exchange Mrs Nkosi distributed the reading material at the beginning of the lesson. As usual she had enough copies for each learner and so learners could make notes and keep the text for reference later. Stoffels (2005b) makes the point that in situations like in South Africa where teachers are uncertain of the pedagogical shifts expected of them there is a tendency to rely on text. He goes on to support this with evidence from several other studies like Ball (1990) who argued that teachers would rather engage with curriculum-aligned texts and textbooks rather than a policy document. Although Stoffel's point is made in relation to the use of practical work in science classrooms (see

discussion of the link between talking and practical work later in this section) his point holds true for talking and reading. In situations where teacher science subject matter knowledge is doubtful as is the case for many South African science teachers it may be advisable to explore ways in which text can be used more effectively as Mrs Nkosi did in her lessons.

This episode was followed by a long session of demonstration and explanation during which Mrs Nkosi put up a diagram of the respiratory system and an alveolus on the board. For the rest of the lesson Mrs Nkosi referred to the demonstration (a learner up front whom she used to show location of various respiratory structures), the diagram on the board and the handout that she had issued to the learners. The next excerpt following the long demonstration session shows how she combined the different methods to scaffold learning:

326 Teacher: Right can we go through this quickly? (*teacher reads from handout*) "The mechanism of inhalation" er please note and highlight. Number one "the diaphragm contracts and flattens" it contracts and becomes a little bit flat "and that will increase the volume of the thorax from top to bottom". Why must this volume increase?

Tefo: so that it may accommodate the oxygen

Teacher: good to accommodate the air that we breathe in and (*referring to handout*) point number two note that (*reads*) "the external intercostal muscles also" underline that contract underline external intercostal muscles and contraction there. Right (*continues reading*) "and that causes the ribs to be lifted up". In other words your ribs will also move up as you saw as she was demonstrating and a bit outward as uHlatshwayo was saying over there (*reads*) "then the volume of the thoracic cavity increases sideways". Those are the issues to note. Number three number those points number three "the intercostal pressure through the pleura "What is a pleura? What is a pleura?

Mandla: pleura?

330 Thabo: *angazi mina* (I don't know)

Teacher: right the membrane protecting your lungs is the pleura (*writes on board*) membrane which surrounds and protects the lungs and also lines your thoracic cavity. Ok? So can we proceed?

Class: Yes

Teacher: (*reads*) "The interpleural pressure the pressure between the pleura decreases" right? underline that decreases "causing a decrease in the pressure in the lungs" less pressure there. This one is not so clear. The last point there. Let's see if that is clear (*referring to a learner's handout*).

Sipho: Yes

Teacher: oh yah yah since. If your copy is not clear the first word there is since (*reading*) "since the atmospheric pressure is now higher than the pressure within the lungs air rushes into the lungs through your nostrils". Air rushes in. Now if air rushes in there is something that you need to note there. It means there is more outside than inside your body. For instance the fact that we are inhaling oxygen from the atmosphere it means that there is more oxygen in the atmosphere than in our lungs. Where is this oxygen from? Particularly during the day?

(Turns 326-335: lesson on gaseous exchange)

In this episode the teacher used written text in the form of both the handout and the diagram on the board as well as the practical demonstration together with science talk, combining an array of tools to mediate learning. As she read to the class and explained again from the handout she further scaffolded learner understanding taking them once more through the process of inhalation while reading from the handout herself. Another example of the use of written text together with talk came from the lesson on owl IK and conservation. Instead of reading to the class herself Mrs Nkosi picked learners to read each task out to the class:

- 132 Teacher: right let's have someone reading
 Sihle: (*reads from role play of City Council notice*) "In the interest of ensuring animal diversity and species conservation, government now requires all residents to keep at least one owl in their backyard. Discuss the new notice. Remember that everyone's idea is important, so everyone must pa- pa- pa what?"
- Class: participate
- 135 Sihle: (*continues reading*) "par-ti-ci-pa-te. Everyone must say what they think. You must listen to what others have to say. You must always give reasons for what you say"
- Teacher: right here we are its a notice from the Council office. Ok let me start by asking you a question. Would you like to keep an owl?
- Class: yes no
- Teacher: oh there is yes and there is no. Ok let's stop right there and read. Now let's have Ayanda reading for us
- Class: obvious (*they want a learner whose name is Ayanda to read*)
- 140 Teacher: No anyone who opts to be Ayanda.
- Teacher: ok he is going to be Ayanda (*pointing at another learner*). right
- Monti: (*reads*) "Owls are useful harmless birds that occupy an important position on the food chain".
- Teacher: now that is how he feels that these are harmless useful birds and they occupy an important position in the food chain because they can feed on animals that destroy our crops. So if they feed on animals that destroy our crops it means they will actually help us because we will not need to do what? To use insecticides *angithi*? because insecticides destroy are actually poisonous. Now do you agree with this ?
- Class : yes
- 145 Teacher: they are useful they are harmless. Let's hear what Bonelwa says
- Muntu: (*reads*) "yah everyone must introduce them into their neighbourhood"
- Teacher: he says everyone he doesn't say those who want to he doesn't say its optional but he says everyone. How many people agree with that? Ok some people some people don't. So actually you are actually saying no I wouldn't want to keep it. I suppose you've got your own reason why you wouldn't want to keep an owl or owls. Ok? Now let's hear the view from from Chris
- Stella: (*reads*) "yes we must preserve owl populations and let them grow"
- Teacher: ok the last person Tumi
- 150 Mark: "Hhhm ..."
- Class : (*laughter*)
- Teacher: he says (*teacher reads*) "Hhhm no way I would never introduce owls to my neighbourhood". Now let's hear why wouldn't you introduce owls into your neighbourhood? You should be having

reasons why you are against it. You should be having reasons why. Lindokuhle why wouldn't you want to have an owl?
(Turns 132-152 from lesson on Owl IK and conservation)

As the learners took turns to read the teacher explained or questioned learners about their understanding of the content of the text they were reading. This episode happened at the beginning of the lesson and towards the end (turn 152) and for the rest of the lesson the teacher revisited these scenarios and invited learners to engage with the questions raised in the handouts. What was interesting with this exercise was the fact that although the focus of the interaction was the content of the handouts, the teacher also allowed for opportunities for learners to help each other with reading difficulties. The fact that this was a Grade 12 class bears witness to the observation in literature of the low levels of reading proficiency among South African learners. To close every discussion on each concept the teacher would call the learners' attention back to the handout and read (see turn 363 below) again the main concept or idea for that task:

363 Teacher: because you will be doing the researches you will be specialising maybe you will be the doctor in this field you will be telling us more about them. But the issue is conservation. There must be different types of animals. That is why the government has what? It has policies the laws to ensure that there is no extinction. If you go back to this (*reading*) "In the interest of ensuring conservation and species diversity government now requires all residents to keep some owls in their backyard ..." yes we heard that some people say yes I can keep it but some say no I won't keep that.
(Turn 363 from lesson on Owl IK and conservation)

Mrs Nkosi varied the method of engaging with text but always encouraged her learners to talk about the written text. In the lesson on population dynamics, for example, the class had copied the work into their note books during a previous lesson and now she took them through the material in a whole class discussion. So although she did not read out aloud to them the learners were reading and following from their books as seen from the teacher's remarks in the next excerpt:

318 Teacher: Right now that the period is over I suppose we've gone through most of the content that we wanted to (*paging through the exercise book*) but not exactly right? for instance I still see here the carrying capacity. What is that? The carrying capacity? who hasn't spoken to me? Phiri you have been talking so many times. Yes?
Sisa: the of organisms that can be ... (*inaudible*)
(Turns 318-319: lesson on population dynamics)

While Mrs Nkosi faithfully used written text to stimulate science talk, Mrs Thoba and Mr Fars used science talk to help learners think through and articulate ideas in writing, although this combination was less frequently in Mrs Thoba's lessons than in Mr Far's. Both teachers

had their learners writing either before or after engaging in science talk. The first two excerpts below came from Mrs Thoba's lesson on waves. After the learners engaged in a small group practical activity creating their own pulse the teacher and learners talked together about learner observations and to finish up the teacher instructed the learners to write the experiment:

- 92 Teacher: what I want you to do is now take out your class note and write this practical *ne*?
 Sipho: yes
 Teacher: you write the method and then answer the questions
(Turns 92-94 from lesson on waves)

While the learners were busy writing the teacher interrupted them to discuss the angle between the pulse and the direction in which the pulse is moving. Again after this talking episode she instructed her learners to continue to write:

- 127 Teacher: ok write quickly because this is class work. You have to finish it.
(Turn 127 from lesson on waves)

However, in spite of the teacher's explicit instructions to write the experiment down, of the eight students' books caught on camera only two had written the "Method" that the teacher put up on the board. A third student had left spaces for the method, one had only the heading "Class-work" and another had the date only. Three students did not have either the date or the title for the lesson, although they had started writing out the "Method". Mrs Thoba hardly moved around to check that the learners were indeed writing. This was in complete contrast to the way Mr Far supervised the writing in his lessons. Mr Far frequently instructed learners to write and he would walk around checking that they did write. He also interspersed talk, writing and practical demonstrations as seen in both the lessons on momentum and on compounds. The first excerpt is from the lesson on momentum:

- 73 Teacher: I will give you time to *write down what you observe or notice*
 Class: *(writing 17sec)*
 75 Teacher: right all of you are done with writing what you are writing? your observation? Walter what's wrong?
 Walter: ... *(inaudible)*
 Teacher: *(imitating Walter) Meneer ...*
(Lesson on momentum, turns 73-77)

Mr Far not only expected his learners to write but he also gave them time to do so, checking progress and allowing more time for those who were not yet done. Also, he explained what

he expected them to write, thus scaffolding the tasks and making the links explicit for the learners. Also, by so doing he made the performance criteria explicit to the learners (Bernstein 1990).

The next excerpt also from the momentum lesson illustrates the teacher's summary of the proceedings of the day, but the main point I want to highlight again is the fact that learners were once again writing:

- 164 Teacher: So we know (*inaudible*) what does the word conservation mean? change from one form in terms of energy into another so it's not being lost Nikita so the kinetic energy is merely being taken from this specific form of energy into? A different form of energy. Please make sure you are writing this down. My notes on the board is not everything that we want to see you write down isn't it so?
- 165 Class: yes
Teacher: now ... few seconds to write that down your summary then we come back to our experiment briefly because our experiment is about momentum what I want to do which is in two dimensions (*writing on the board*) when total kinetic energy is not being conserved in a total inelastic collision and that is when they stick together when they stick together it is a total inelastic. While you are still thinking about this please note that the shape of the object can change. The shape of the objects think about two cars colliding does the shape remain the same after that collision especially they are stuck together?
- Mpho: No Sir
- Teacher: so please make sure you include that in your notes (*writing 20sec*)
- 170 Teacher: now as you are writing down just think about this - what is this object having and is applying to this object?
(*Lesson on momentum, turns 164-170*)

Mr Far had put up notes on the board as the lesson progressed and every time he urged his learners to write them. However, in addition to his notes he encouraged his learners to make their own notes from the discussions pointing out that, "My notes on the board is not everything that we want to see you write down isn't it so?" (Turn 164) and "... few seconds to write that down your summary" (Turn 166).

Prior to this writing episode the teacher had the learners tossing coins, causing collisions and observing the changes in movement of the coins. He also took them through several episodes of talking about their observations and linking them to the scientific story of momentum. To conclude every short practical activity and talk about a specific concept he had them write down their observations and/or explanations as in turn 165 "write that down your summary".

Again, Mr Far specified what exactly the learners should include in their writing e.g. turn 167, “make sure you are including that in your notes”.

The last excerpt is taken from a different lesson, on properties of compounds. Mr Far again had his learners writing between sessions:

- 170 Teacher: and while he is doing that I will walk around and see if everyone has completed it and I see some of the girls have not even started
Teacher: everyone has except for these girls here they have’nt started yet.
Kgotso: *(inaudible)*
Teacher: Thank you Kgotso. We will have a look at it just now. I am having a look at some of the girls
(Lesson on properties of compounds, turns 170-173:)

In this case, the teacher had three learners up front to conduct the experiment on combustion of magnesium so as to demonstrate the properties of magnesium oxide, a compound of magnesium and oxygen. While these learners prepared to conduct the experiment the teacher had the rest of the class write their predictions of the outcomes of the experiment. While his learners were writing Mr Far walked around to “see if everyone has completed ... ” and he found that “ ... some of the girls have not even started”. Mr Far’s strategy of walking around checking that learners did indeed write was effective in scaffolding learning.

7.2.4.2 *Talking through practical activities and demonstrations*

Mr Far used demonstrations and practical activities frequently. Mrs Nkosi also used demonstrations and in one case she brought samples of actual medicinal plants as examples of traditional medicines for the lesson on respiratory diseases. Mrs Thoba only occasionally used demonstrations e.g. she used the slinky spring in the lesson on waves.

Here is an example from Mr Far’s lesson:

- 67 T: Now this is what I want you to do. Take out anything you have in your pocket. Either you have two pens in your pocket take it out you have two coins you have two Pritt whatever you have take it out put it in front of you. This is the task you need to have those two objects that you have in front of you an make a collision make a collision then if you do that you have to look what type of collision can you have with your experiment whatever you have in front of you. So I will just walk around and see if you are with me. So put your objects two of them and then you collide those objects and look at the type of collision. *(teacher walks around)*
Nikitha :*(inaudible)*
T: Nikitha is asking why do we need two? ...
70 Nikitha: *(inaudible)*
T: yes just throw it just let it collide Nikita...

- T: money money throw your money away and remember always what do we need to do? We need to write down isn't it so? what we are seeing or what we are observing ... then we work from there.
- T: right I will just give you time to write down what you observe or notice right all of you are done with writing what you are writing your observation? Walter what's wrong?
- Walter : ... (inaudible)
- 75 T: ... (inaudible) Meneer
- Walter: Sir my observation Sir I had a two rand in one hand Sir
- T: yes different objects
- Walter: so when I collide them the one rand went away which means the two rand is heavier than the one rand
- T: now describe to me exactly what you mean going away
- 80 Walter: the two rand pushes the one rand away Sir
- T: so someone else
- Matt: equal masses I had two pens
- T: you had two pens of equal masses so we have one scenario different masses then we have the second scenario with same masses
- Matt: ... (inaudible) different direction
- 85 T: so you had (*inaudible*) this way and then it went different direction. Any other person? Yes P?
- P: ... same as his
- T: how can it be same like his? How is it possible?
- P: and they had the same mass ...(*inaudible*)
- T: right (*raised voice*) he is saying he's doing this and I actually like this he says this might be his two pens throw them together they collide and they went opposite direction. Do you all see this?
- 90 Class: yes
- T: now describe this type of collision this type of collision (*teacher hitting his fists together and moving them apart in opposite directions*)
- (Turns 67-91: Lesson on momentum)

In turns 67-72, Mr Far opened this episode with an instruction for learners to use any objects in their possession to simulate collisions and observe the movement. In turn 73, he asked them to write down their observations and then from turn 74 onwards he engaged them in talk about their experiences. Mr Far's practical activity combined the hands on experience with writing and talking, stimulating learner involvement.

Where the teachers used these combinations of teaching strategies it was evident that learners found them useful in helping them think and talk from the concrete examples to the more abstract science concepts. This is in line with the Vygotskian notion of using learner prior knowledge and personal experiences to mediate construction of understandings. Also the combination of the three strategies created a rich social space in which explanation and justification skills could be developed as argued by Stylianou and Blanton (2002).

7.2.4.3 Talking outside the classroom

Other evidence of meaningful engagement came from learner arguments constructed during the negotiations of outside the classroom. A case in point is an observation I made very early in the study. Mr Far had tried with much difficulty to get the learners to engage meaningfully with science concepts in class. They struggled to explain their reasoning, to give evidence for their claims or to justify their thinking. However, I observed that as soon as they left the classroom they engaged in heated debates mostly about other topics and not the science content but they were able to provide convincing evidence for their arguments. My dilemma at the time was that I could not within the scope of my study make any observations or audio recordings of these informal out of class arguments. I did, however, listen into some of them after I explained to the learners my interest in their engagement outside of the science lesson. The context of the discussions as explained in greater detail in Msimanga and Lelliott (Msimanga & Lelliott, 2008) was the wave of deaths of popular singers in the preceding months and the learner arguments were attempts to explain the events. As speakers advanced their theories their peers insisted that they justify their reasoning. Learners were able to provide evidence ranging from recent media reports, popular gossip in the media and on the streets as well as common knowledge about the lifestyles of some of the stars. I was persuaded that learners were able to talk and make sound arguments if the conditions were right and this motivated my desire to understand what the conditions for classroom talk might be. Also of interest to me in some of these negotiations were the informal ways of talking that learners engaged in. It is highly likely that learners would not use this language in class discussions for example, for the express reason of the teacher's presence and yet it was evident that this form of talk was part of learner engagement with the science content. It is language that the youth would use among their peers and away from adults in the community. This is an unusual/unconventional resource for classroom interaction which the learners seemed to use effectively to facilitate their learning. Again future research could explore these informal ways of learner interaction to explore their potential for science talk.

7.3 Conclusion

Generally, classrooms were interactive with largely authoritative communication and some tendency towards dialogic interaction. In two cases there was evidence of emergence of teacher-learner argument co-construction albeit to a limited extent. Teacher intervention did often achieve sufficient opening of dialogic spaces for substantive learner engagement with

own or others' claims and evidence. There were several cases of lost opportunities for such deep engagement. All four themes were observed in the three teachers' lessons but with much variation. All teachers tended to open up to different viewpoints (engaging in elicitation and asking some authentic questions). However, not all took up learner ideas, quite often ignoring or overlooking learner contributions. For the most part teacher feedback was evaluative with instances of elaborative feedback (follow up, marking, probing and/or clarifying). Cases of explicit negotiation of understandings were also observed in some lessons, that is, foregrounding asking thinking questions, seeking consensus). Interesting exceptions also occurred such as look alike Interactive-Authoritative discourse and/or drill sessions in one teacher's lessons as well as spontaneous argumentation sessions in another teacher's lesson.

All three teachers, Mrs Thoba, Mrs Nkosi and Mr Far adopted a variety of pedagogical approaches and practices that either afforded or constrained learner effective engagement and link making. Interesting differences often emerged in the way teachers responded to learner ideas or questions and in the nature of their interventions. The teachers often had to respond to learners' ideas and/or contributions that were unexpected or unplanned for. As illustrated in the paragraphs above, Mrs Nkosi often seemed to be taken off guard and would then engage in apparently unfocussed interventions that were not well co-ordinated with either the learner's contribution or the objectives of the lesson.

In turn, both Mrs Thoba and Mr Far often encountered these unplanned for or unexpected learner contributions and questions but they often reacted in a more open manner with more focused interventions. The difference between them was that Mrs Thoba sometimes ignored or shut down learner questions, perhaps because she was not sure of the answer but often it was to proceed with the more important/urgent business of the scientific story being pursued at the time. Mr Far on the other hand, responded differently to learner's questions or contributions that were not in line with the present focus of the discussion. Sometimes he would divert the focus of the lesson to address the learner's idea or thinking and at other times he would revisit the question a little later in the same or subsequent lesson. These responses were evidence of emergence of dialogic pedagogical practices particularly in Mrs Thoba and Mr Far's classrooms and to a lesser extent in Mrs Nkosi's classrooms.

The interventions that produced the various communication styles were a mix of elaborative and evaluative teacher responses to learner contributions in response to various contextual factors. Contextual factors that seemed to influence pedagogical decisions included learners contributions, prior knowledge, misconceptions; teacher ability to adopt appropriate pedagogical link-making approaches which in turn was linked to teacher subject matter knowledge.

In all three teachers' classrooms interaction also happened in hybrid spaces comprising formal scientific talk as well as informal talk or social talk and small talk. It seemed that the hybrid space provided the safety that the participants required in order to successfully negotiate the social and disciplinary rules of engagement. This is an area of classroom interaction that is not yet well researched in science education both locally and abroad.

Nystrand and Gamoran argue that a teacher who operates at the recitation end of discourse spectrum all the time creates an impoverished classroom experience for her learners and that a dialogic discourse is more desirable for learner substantive engagement (Nystrand & Gamoran, 1991). However, it is quite evident from the discussion in this chapter that it is not easy for teachers to create the desired dialogic discourse in the science classroom. I argue that it is in fact the ability of the teacher and her students to move back and forth along the continuum that seems to enrich the classroom discourse in the classrooms observed in Soweto. These and my other findings are summarised in the next chapter.

Chapter 8

Talking science in Soweto classrooms: My conclusions and recommendations

“... on the one hand experience is seen as the source of our prior knowledge and on the other hand it is seen as those social settings through which we construct and develop knowledge. In a school context this means that the teacher provides settings that are appropriate for particular and desired learning experiences and at the same time assumes appropriate roles to ensure that those experiences result in learning. Teachers therefore ... are at times transmitters of information, at others are facilitators and at yet others are scaffolders ... and even co-learners” (van Harmelen, 1988, p. 7)

8.0 Introduction

I started in Chapter 1 with the argument that science talk is a tool for teachers to address the problem of lack of meaningful classroom discussions that is lamented in education research literature. I argued that science talk had the potential to create learning opportunities and facilitate for effective meaning-making through dialogic discourse between teachers and learners and among learners. I then identified the challenge in Soweto in particular and South Africa in general, of the diversity of teacher and learner contexts, cultural backgrounds and levels of preparedness for the envisaged dialogic interaction. In my study I set out to understand the dynamics of science talk in the specific contexts of the Sowetan classrooms. I defined science talk as all verbal interaction during the lesson, all speech addressing the teaching or learning of science concepts. I wanted to know how teachers mediated science talk and to understand the attendant patterns of interaction and emergent discourse types.

The main question that guided my research was “How do teachers use science talk to stimulate learner participation and engagement in high school science classrooms and what is the nature and quality of ensuing teacher-learner interactions during science talk?” The question was broken into three sub-questions:

- How do teachers shape science talk in high school classrooms?
- What patterns of interaction emerge as teachers and their learners engage in science talk?
- What is the quality of the interactions that emerge with science talk?

To address these questions I took a socio-cultural view of learning and acknowledged the role of the teacher in creating appropriate settings for mediation of learning, the importance of social interaction (whether teacher-learner or learner-learner), the central role of language in mediating the social interaction as well as the notion of the ZPD as manifested in shifts in individual and group understandings. As explained in the methodology in Chapter 3, I performed purposive sampling of teachers who showed a keen interest in trying out talk strategies in their classrooms. The story I am telling in this thesis is therefore, by its very nature, a success story. I am not in any way suggesting that the intervention produced only positive outcomes, neither that only positive results would be observed all the time with similar interventions. What I am intentionally doing is to highlight some pockets of success in teacher uptake of pedagogical strategies for implementation of South Africa's reform curriculum. Also, the theory by Mortimer and Scott (2003) that my study was based on is not about good or bad teaching but about identifying evidence of effective teaching and in the process, effective learning.

8.1 Overview of my findings

Generally lessons in all the classrooms I observed were interactive, that is, there was evidence of learner participation. The variation was in the way each teacher fostered the interaction and how they achieved (or did not) learner substantive engagement with science concepts under discussion. I have summarised my findings below to show how my research questions were answered. Answering my first question, "*How do teachers shape science talk in high school classrooms?*" was relatively straight forward as I examined only that data relating directly to teacher practices that resulted in whatever forms of talk that emerged. However, the answers to my second and third questions were not as easily separable as I had anticipated. I found that as I identified and characterised teacher communicative approaches, I was also exposing the patterns of interaction and some features of their quality also became evident. That is, teachers' four communicative approaches were associated with certain specific patterns and quality of interaction. This was particularly so, with argumentation and with those patterns of interaction that were unexpected, those that I had not determined *a priori* from literature, but emerged from the contexts. For example, although I initially intended to use argumentation as a tool to measure the quality of talk, it emerged as a form of interaction that took on a pattern not yet reported in literature. I therefore, recorded

argumentation both as a pattern of interaction in answer to my second question and as a measure of the quality of talk.

Also, argumentation occurs as a finding for both the second and third research questions. Firstly, argumentation did not occur as frequently as anticipated in the bigger project, the ICC project. However, in the case of the three teachers that I worked with, two, Mrs Thoba and Mrs Nkosi, managed to stimulate substantial argumentation in at least one lesson each. There was also evidence of learner argumentation in Mr Far's lessons, albeit to a more limited extent than in the other two cases.

In the next few sections I present my findings for each research question. I then discuss some of the findings in terms of what I view as the key theoretical and methodological insights from my study. Next, I consider the implications of my findings for various interest groups. Finally, I consider the limitations of my study and raise some issues that still need further clarification and/or research.

8.2 Summary of my findings and how they answered my research questions

8.2.1 Research question 1: How do teachers shape science talk in high school classrooms?

All three teachers took an authoritative communicative approach most of the time in their lessons, with an aim to get learners to participate (in science talk) and also be on task (talking in scientific ways). However, there was some evidence of emerging dialogic discourse in all classrooms. That is, genuine teacher interest in and use of learner ideas in understanding learner thinking and in developing scientific story. Teachers took one of four communicative approaches: Interactive-Authoritative (IA); Interactive-Dialogic (ID); NonInteractive-Authoritative (NIA) and NonInteractive-Dialogic (NID). Each communicative approach resulted in different patterns and quality of interactions as shown in research questions 2 and 3 findings below. Teacher communicative approaches both opened up and shut down learner talk, depending on the nature of teacher interventions:

- Teachers tended to ask mostly questions aimed at channelling learner thinking in teacher determined directions, as reported in literature.

- However, there was also evidence of teacher questioning that surfaced learner thinking. Learner reflective engagement was stimulated with questions like “why do you agree/disagree?” or “what do you think about that?”
- While teacher feedback tended to be evaluative, indicating to learners whether or not their answers were acceptable, there was evidence of teacher attempts at elaborative feedback.
- Teacher feedback was elaborative if it opened up for exploration of learner thinking and afforded learners themselves opportunities to reflect on their own and their peers thinking. Where teacher intervention included genuine questions and elaborative feedback, learners did attempt to construct, support and challenge each other’s arguments.

8.2.2 Research question 2: What patterns of interaction emerge as teachers and their learners engage in science talk?

Each of the four teacher communicative approaches produced specific patterns of interaction:

- Interactive-Authoritative (IA) communication yielded mostly traditional IRE/F discourse, with some episodes of Mortimer and Scott’s (Mortimer & Scott, 2003) IRPRP ... E or IRPRRP ... E closed chains comprising teacher-learner probe-response sequences ending with a teacher evaluative move. Other forms of interaction emerged during Interactive-Authoritative communication, such as chants and look-alike IA, in which learners seemed to be involved but were simply completing teachers’ statements or repeating them verbatim for extended episodes.
- Interactive-Dialogic (ID) communication resulted in near conversation like discourse in the form of IRPRP or IRPRRP open chains comprising teacher-learner and/or learner-learner sequences ending with either a teacher elaborative move or a learner move.
- NonInteractive-Dialogic (NID) communication involved teacher monologues, in which learner ideas and other views were incorporated into explanations, reviews and/or summaries of lessons or episodes.
- NonInteractive-Authoritative (NIA) communication produced mostly what I called telling episodes with long teacher utterances in which he/she delivered information or explanations.

Argumentation emerged during some episodes of Interactive-Authoritative and Interactive-Dialogic communicative approach in some lessons.

- A significant finding of my study on argumentation was the notion of co-construction of arguments. Argumentation emerged in the form of co-constructed teacher-learner and learner-learner arguments through a process of collaborative negotiation of understandings of concepts. Most studies on argumentation have so far described the structure of arguments (TAP) constructed by individual participants in a discussion. In my study, arguments were jointly constructed. Learners made tentative claims without supporting them and their co-participants (the teacher or peers) provided the evidence or warrants to support the claim, thus moving the argument forward. I suggest that this collaborative form of argumentation may be consistent with contexts of emerging learner talk. The second significant finding about argumentation was that it served different purposes depending on learner understanding of the objectives of science talk at the time. This is discussed in findings for RQ3.

Science talk was often linked to other forms of engagement such as reading, writing, demonstrations and learner practical activities. Again research has shown the important link between talking, reading and writing in conceptual development (Halliday, 1993; Rivard & Straw, 1999). Research into the dynamics of this link in science learning is indicated, especially in multi-lingual situations like those in many South African classrooms.

8.2.3 Research question 3: What is the quality of the interactions that emerge with science talk?

The second important finding of my study on argumentation relates to the fact that different forms of argumentation served different purposes in the development of the scientific story. According to Berland and Reiser (2008), learners use arguments to make sense of science concepts (sense-making argumentation), to articulate their understandings of the concepts (articulating argumentation) or to persuade others of these understandings (persuasive argumentation). In one of Mrs Thoba's lessons, the teacher was able to guide learner-learner talk such that learners either provided the evidence to support their peers' claims or advance rebuttals to the arguments. Analysis of the interaction yielded all three forms, articulating, persuasive and sense making argumentation in that lesson. This evidence suggests that with careful mediation even untutored learners can and do provide rebuttals for each other's arguments.

These findings have been published in the African journal for Research in Mathematics and Science Education, AJRMSTE (Msimanga & Lelliott, 2012). See Appendix 3.04

Science talk also happened in unconventional ways or what Berland and Hammer (2011), called “hybrid spaces”:

- In two of the teachers’ classrooms, talk sometimes happened in a multiplicity of languages, which were shared by most learners and teachers. Participants also engaged in informal social talk while negotiating the norms of participation. Small talk was also common and two of the teachers inserted moral lessons into the science discussions.
- Participants cultural and everyday experiences either helped facilitate or constrain science talk. For example, rebuttals were often made as tentative questions or suggestions premised with terms like “I think ...”. While this can be explained in terms of learner uncertainty of the process of argument construction or even a lack of requisite science content knowledge to be able to make strong rebuttals, it could also be a cultural way of engaging. This could be linked to the notion of *ubuntu* as reported in other South African research on argumentation. Scholtz et al (2008) explained the notion of inclusive argumentation which they observed among adult participants (teachers among themselves) who were reluctant to offer direct rebuttals in terms of the concept of *ubuntu*. They argued that within the worldview of *ubuntu* confrontational arguments were avoided and disagreement had to be in terms of cultural consideration of the other person. In the case of my participants there was no reluctance in providing rebuttals once they gained confidence in the skill. It is the collaborative construction of arguments in my study that could be linked to the notion of *ubuntu*. In my culture for example, *ubuntu* precludes “telling” an adult – one can tell a child but usually not an adult, particularly someone older. Thus, a child can never tell an adult, hence disagreements, especially with an adult, have to be made as tentative suggestions or questions.

8.3 Theoretical findings

In discussing the theoretical findings of my study I refer to the conceptual framework of my study as articulated in Chapter 2, Section 2.9.1. I reproduce the diagrammatic representation of my conceptual framework given as Fig 2.04 in Chapter 2, now Fig 8.01 below.

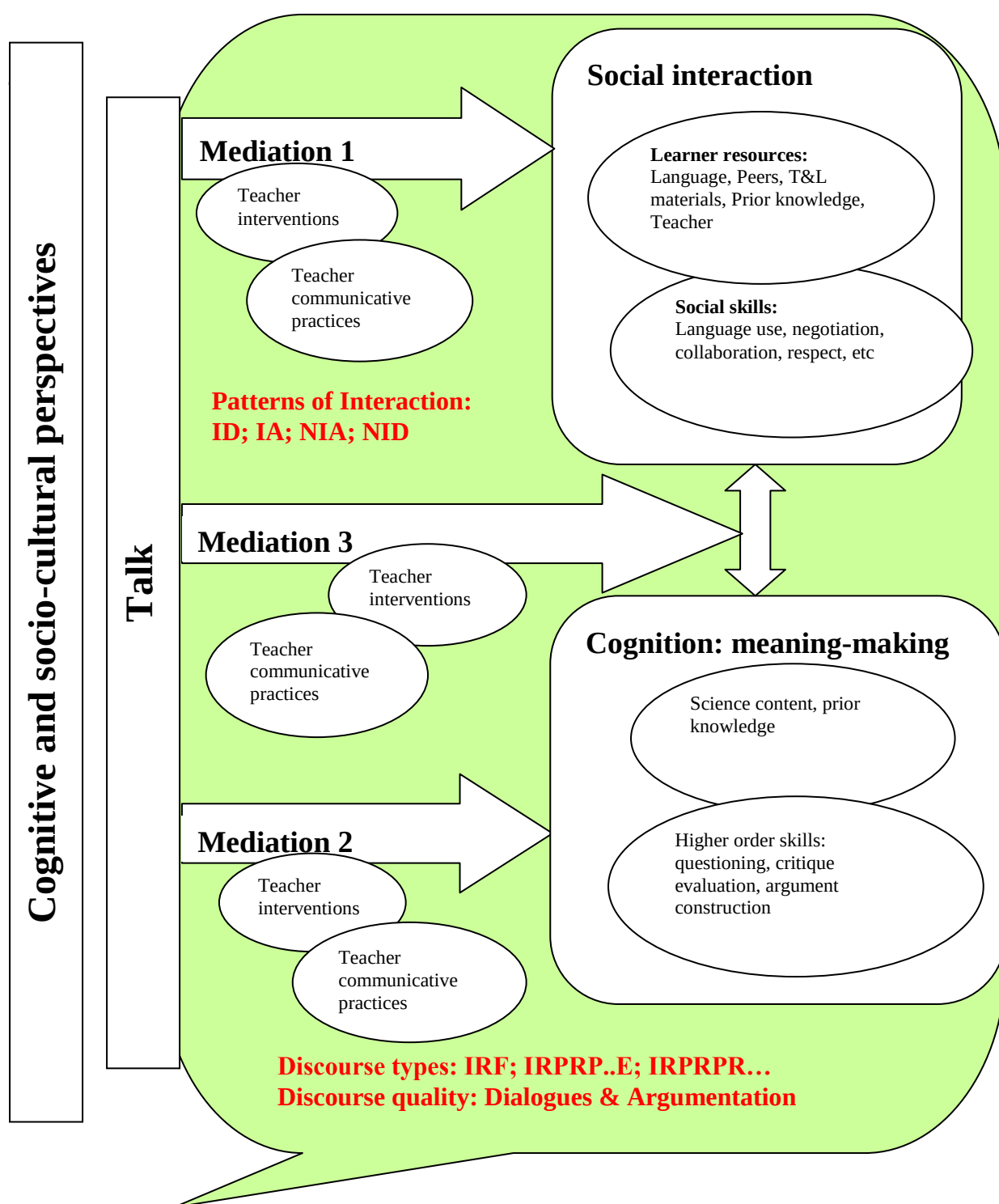


Figure 8.01 The Conceptual Framework of my study

One of the problems I was dealing with concerned the nature of the pedagogical practices expected of the teacher in order to stimulate and mediate learner participation and engagement, that is, mediation of talk to facilitate meaningful social interaction in the

classroom. First, I wanted to understand teacher communicative practices that mediate learner social interaction, that is, strategies that facilitated optimal use learners' social skills and other resources available to them in their contexts (Mediation 1, in Fig 8.01). Secondly, I was interested in the way teachers mediated learner cognitive engagement or meaning-making during science talk (Mediation 2, in Fig 8.01). Thirdly, I sought to identify combinations or patterns of teacher communication that mediate the interplay between the two domains of social interaction and cognition (Mediation 3, in Fig 8.01).

Following engagement in an extended programme comprising researcher-teacher collaborative interaction in context specific workshops, modelling of teaching strategies as well as sustained school-based support the three science teachers in my study took up and adapted the strategies for their own contexts. While the extent to which teacher communication shifted towards the desired interactive form varied between the teachers, there was evidence of emergence of dialogic discourse ranging from strongly framed Interactive-Authoritative (IA) sessions to NonInteractive-Dialogic (NID) and Interactive-Dialogic (ID) almost conversation-like interactions. At the dialogic end of the continuum were incidences of implicit as well as explicit argumentation sessions in which teachers and learners together co-constructed arguments with a variety of structure and levels of complexity.

Mortimer and Scott's model of the four classes of communication in classroom discussion was a useful tool for categorising the three teachers' communicative styles. However, there were some interaction types that could not be neatly categorised into the four classes prescribed in the model. For example, there was in one classroom what I termed look-alike Interactive-Dialogic (ID) interaction in which at first glance learners seemed to be participating but on close inspection it was evident that the teacher was controlling and subtly directing the interaction in an authoritative manner and learners were simply providing expected answers on cue.

A visual representation of the shifts in classroom discourse is given in Figure 8.02. I consider the Interactive-NonInteractive axis first. While there was evidence of NonInteractive engagement in all eleven lessons for each teacher, there were also episodes of Interactive engagement in all eleven lessons for each teacher. Thus, while NonInteractive teacher-

centred practices persisted, there was evidence of shifts to increased involvement of learners in science talk in all eleven lessons in all three cases. A more important shift for my purposes was observed on the Authoritative-Dialogic axis. While episodes of authoritative teacher approaches were recorded in all lessons for all the teachers, there was evidence of dialogic discourse in all three teachers' classrooms. The highest record of dialogic interaction was in Mr Far's lessons, with some episodes of dialogic engagement in all his eleven lessons. This is borne out by the fact that Mr Far incorporated individual, group or whole class practical activities and demonstrations in his lessons. His learners interacted with each other more

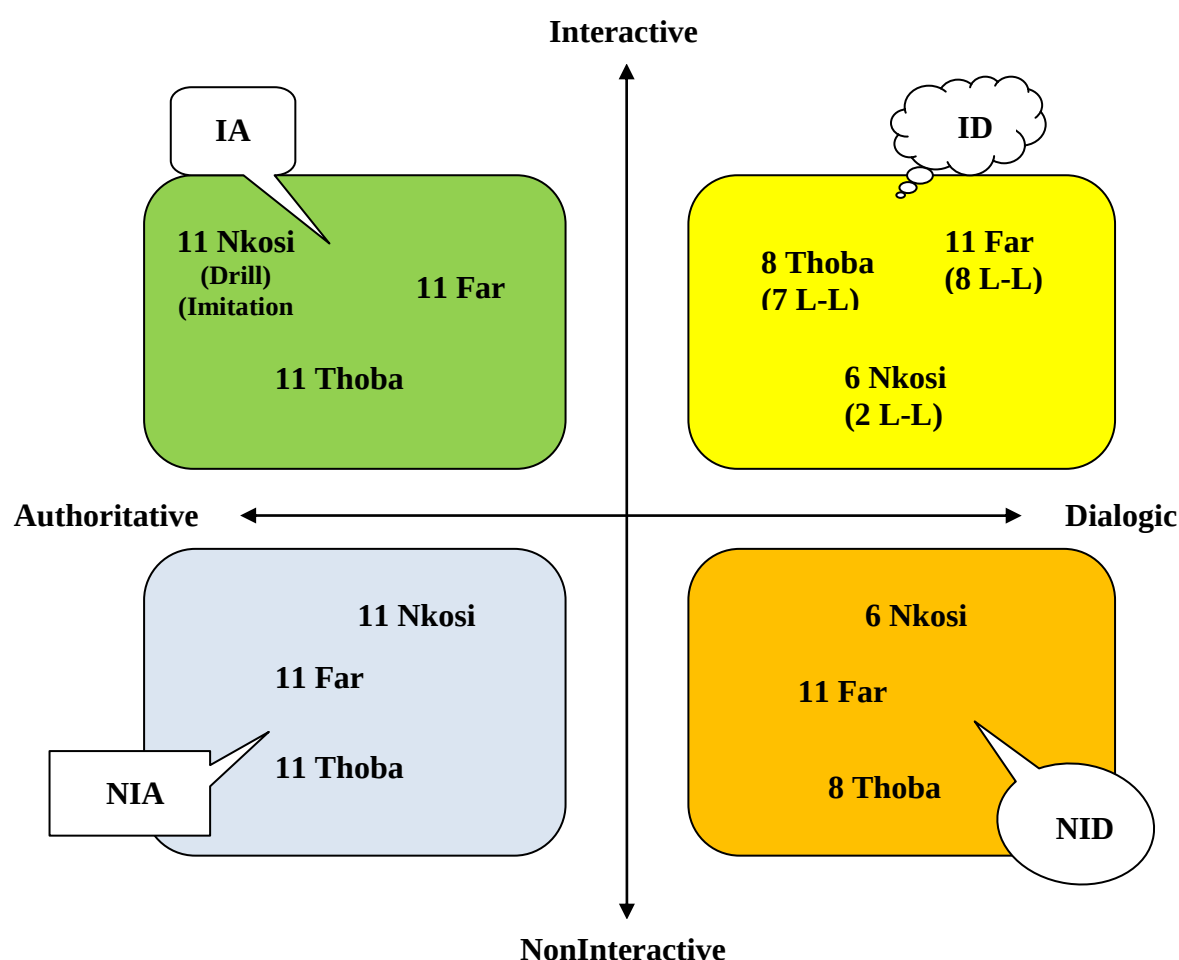


Figure 8.02 My categorisation of classroom talk in three Soweto classrooms along Mortimer and Scott's (2003) dialogic-authoritative/interactive-noninteractive continuums

frequently than was the case in the other two teachers' classrooms. In Mrs Thoba's case there was evidence of dialogic interaction in eight of her eleven lessons, while six of Mrs Nkosi's eleven lessons included some episodes of dialogic discourse. Thus, there was variation in the

combinations of teacher communicative approaches adopted by each teacher. Mr Far seems to have been able to use all four approaches in all his lessons. Mrs Thoba tended to take more IA and NIA communicative approaches, with an inclination towards the NID and ID in some lessons as seen in Chapters 5-7. Mrs Nkosi, on the other hand seemed to work at both extremes, adopted largely IA and NIA communicative approaches, including drill, in some lessons, but also effectively fostering learner argumentation in others.

Mortimer and Scott (2003) observe that different teaching purposes could be addressed through any combination of the four communicative approaches. The teacher might be exploring students' views in an Interactive-Dialogic communicative approach, working with students' views in an Interactive-Authoritative communicative approach and maintaining the scientific story by reviewing and summarising through a NonInteractive-Authoritative communicative approach and then returning to the Interactive-Dialogic communicative approach. Mortimer and Scott did however, acknowledge that there were many possible combinations of these four communicative approaches. In Mrs Thoba's case one variety was in the way she used an Interactive-Authoritative communicative approach both to explore learner ideas in addressing a misconception and to maintain the scientific story.

A related theoretical observation from my study was that although the classrooms were dominated by the traditional IRE/F triads there were many examples of extended learner contributions within Mortimer and Scott's IRPRPR...F closed chains as well as IRPRPR ... open chains. In fact, the examples of argumentation discussed in Chapter 7 came from those sessions in which discussions tended towards dialogic discourse with closed and open chains, in the form of both extended utterances by individuals and co-constructed arguments, respectively. In the closed chains teacher feedback was more evaluative as happened when Mrs Thoba or Mr Far took an Interactive-Authoritative communicative approach whereas the open chains would be more characteristic of elaborative feedback during Interactive-Dialogic communicative approach seen in one form or another in each of the three teacher's classrooms. It was in such situations that co-constructed arguments emerged. However, this does not mean that there were no NonInteractive-Authoritative sessions where teachers engaged in long telling episodes. These were quite prevalent but they served different purposes. In many cases they simply represented the traditional ways in which the teachers and learners were used to and more comfortable with. However, there were several telling

episodes that seemed necessary in order to provide the science content or information that would lead to the desired interaction. This too was in agreement with Mortimer and Scott's observations that

“... if students are to learn the social language of science, then somewhere ... there must be an authoritative introduction to the scientific point of view. Students will not stumble upon, or discover, the key concepts of social language of science for themselves. It follows, therefore, that 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 dialogic and communicative approaches.” (Mortimer & Scott, 2003, p. 106)

It seems therefore, that the various combinations of approaches by the three Soweto teachers are evidence of the adaptations of the strategies for their contexts. As observed by both Brodie (2007) and Scott and Mortimer (2005) not only is it difficult but it may not be desirable for the teacher to focus on attaining a completely conversational discourse in the classroom. I argue that it was in fact the ability of each teacher and his/her students to move back and forth between different discourse types that seemed to enrich the classroom discourse in the classrooms observed in Soweto.

8.4 The ICC Project findings relating to teacher professional development

In the next section I make some observations relating to the ICC Project intervention and their implications for professional development. Although my PhD study was only a small part of the bigger intervention, I was responsible for the entire science component of the intervention. I was in charge of development of the teaching and learning materials, some of which were used by the three teachers in my study. I also organized and ran teachers' workshops at which and introducing the target teaching strategies which included argumentation. The objectives of the ICC Project included both teacher professional development and improved learner performance. However, for my study I did not focus on learner performance and I will thus only comment on the findings of the intervention which relate to teacher professional development.

8.4.1 The ICC Project collaborative research approach and materials development

The ICC Project adopted a collaborative approach in which as Project researcher I worked together with the teachers for a period of three years, to explore and reflect on their practices. One of the Project objectives was to explore strategies that teachers could employ to achieve

effective teaching and learning of science within a context of continual curriculum change. Although the data analysed for this thesis came from a cross sectional examination of the three cases, the teachers had been involved in intervention for two years when my first data set was generated, and three years by the end of my study.

In the first year the workshops provided both the teachers and me an opportunity to explore the challenges they faced as they implemented the new curriculum. Together we identified teaching and learning strategies that we could develop and trial together. Over the two years six workshops were conducted, initially focusing on learner-centredness and creation of interactive, dialogic learning environments using argumentation techniques. Subsequently, the team collaborated in development of teaching materials which some of the teachers later took up and used in the lessons analysed in this thesis. The owl indigenous knowledge lesson is a case in point.

Materials were developed for selected topics and concepts according to teachers' needs but guided by DoE curriculum documents. Materials included both mainstream science and IK related activities in selected content. They included exemplars of activities that promote talk in the classroom including concept cartoons, which Mrs Nkosi subsequently used in her lesson on owls reported in Chapter 6. While the team's thinking about materials development was guided by observations in literature about possible influences on the potential for tasks to open up or close talk and/or argumentation in classroom discussions, my observations were not always in agreement with other research. For example, Braund and his colleagues observed that students found it easier to construct arguments on a science based task, classification of *Euglena*, as opposed to a moral or ethical issue, organ trafficking (Braund, Lubben, Scholtz, Sadeck, & Hodges, 2007). One of the reasons was that the evidence for the ethical issue was much more fluid including both the learners' ethical or moral positions and the underlying science. In a study on arguments on the role of nature, in Denmark, Nielsen (2012) found that student arguments comprised uncritical appeals to nature, rarely involved science facts as evidence.

8.4.2 *Modelling of teaching strategies*

Another feature of the ICC project approach was modelling of the teaching strategies. In addition to workshops introducing teachers to the strategies, the project team worked with

teachers in their classrooms to model and adapt the strategies for their different classrooms. This provided opportunities for the researcher and teachers to try out together and see what was realistic and what was not in terms of the teachers' contexts and situations. Sometimes researchers' ideas of what works do not match the realities of the classroom and this makes it difficult for teachers to take up and try out new strategies. As far as possible pre- and post-teaching conferences were conducted at which we (the teacher and me) planned together and later reflected together on the lessons taught.

While at the beginning it was difficult for teachers to have their practice observed, the fact that they could observe me teaching and to be able to critique my lessons did act as an ice breaker. Also, teaching together with them afforded me an opportunity to model the strategies that we were considering. There were both positive and negative implications from my involvement, though. The concept of argumentation was just as new to me as it was to the teachers at the beginning of the intervention. However, because I had a vested interest in the Project I endeavoured to learn as much as I could from the outset and soon became confident in working with the activities designed in the workshops. When the teachers also came on board and started trying out the strategies in their lessons we engaged in our own shared understanding of the strategies and how they could be modified for the contexts we were applying them in. A further outcome of this collaborative exercise was that when I volunteered for the teachers to critique my teaching an important message was relayed to them that I was not an expert who had come from university to teach them. I was a co-teacher exploring my own teaching practice together with them, coaching each other as peers. From the UK, the work of Showers and Joyce (Showers & Joyce, 1999) on peer coaching has produced evidence of considerable teacher uptake with systematic support.

The collaborative co-teaching model was structured along the lines of other projects such as the work of Simon and colleagues on teacher professional development and argumentation (Simon et al., 2006) and the Cognitive Acceleration through Science Education (CASE, 1984-1987) before it. The CASE methodology also involved collaborative work between teachers and researchers (Adey & Shayer, 1994; Shayer, 1999) and its success was largely attributed to sustained collaboration and support provided for the teachers. Like the ICC Project model, CASE also involved joint planning of lessons and post-teaching conferencing sessions for group reflection on lessons. Also, teacher support and mentoring was gradually

reduced as the programme progressed. This allowed for teachers to gain confidence gradually as they implemented the ideas with less and less support from the project team.

Teacher professional development could adopt this approach and create opportunities for teacher educators to model teaching strategies either in tertiary contexts in the various methodology courses or on site at the schools. The trainee teacher would have an opportunity both to observe the educator practice the strategy and to receive the support of the more experienced academic as he/she takes up and adapts the strategy for his context. This way student teachers develop a custom-made strategy for their specific contexts, thus, accumulating relevant pedagogical content knowledge in the process.

8.4.3 *Duration of intervention*

Literature suggests that teacher uptake of new innovations is implied where there is extended school-based teacher support. Features of effective intervention programmes which incorporate teacher professional development include coaching and follow up programmes, collaborative engagement with peers, recognition of teachers as professionals and adult learners, opportunities for individual reflection and group inquiry into practice, as well as duration of the intervention (programmes must be ongoing). Such observations have been made in the UK from the work of Showers and Joyce (1999) and in the USA, by Garet and colleagues (Garet, Porter, Desimore, Birman, & Yoon, 2001; Ismat, 1996). Similar evidence has emerged from research in mathematics in South Africa. Brodie and colleagues observed that school-based teacher support improved the chances of teacher uptake of new thinking and strategies (Brodie, 2008; Brodie, et al., 2002a, 2002b). Observations from my study corroborated the South African findings.

One of the concerns raised by the teachers in my study in the early stages of the project was that new innovations were usually complicated and time consuming. Strategies like argumentation, in particular, might take away from the limited time to cover the content heavy curriculum that they were implementing. As a result they might fall behind district or departmental requirements in terms of the teaching schedules and time frames. Also, there were concerns about the time needed to implement such innovations in the light of the content-heavy curriculum that teachers have to deliver and the limited time in which to do it.

As observed in the UK and USA, critical factors for success included the duration of the intervention as well as the continuous and consistent researcher availability to support the teachers during the course of the intervention (e.g. Adey & Shayer, 1994; Garet, et al., 2001; Showers, 1999; Simon et al., 2006). In the ICC project the duration of the intervention and a continuous project team presence in classrooms for the first half of the project seemed to have a positive effect. From the representation of the ICC Project time frame in Fig 8.03 for example, it can be seen that the team was present continuously in classrooms from February 2007 until October 2008. In that period materials were developed and tried; teaching strategies were discussed and modelled; there was intense co-teaching and teacher support at first and then gradually reduced from February 2008.

An important lesson from these observations is that teacher up-take is possible but it requires sustained on site intervention programmes. The uptake and adoption of talk strategies by the teachers in my study is evidence of pockets of success in sustained teacher support programmes. Teacher professional support initiatives in South Africa have reported findings from mostly pre-service teachers and practicing teachers enrolled in various continuous professional development programmes. The teachers in my study were not enrolled in any study programme when they volunteered to participate in the ICC Project. They were not compelled to stay on the programme in the way that student teachers seeking an academic qualification would. Thus, their commitment to the programme could be viewed as an indication of the will among practicing teachers to obtain support and assistance in implementing the new curriculum. In all three cases school administration buy in to the programme was a positive factor for teacher commitment to the project.

8.5 Teacher uptake of innovations

One of the concerns raised often in literature on teacher professional development is uptake of new strategies. For example, studies have shown that in South Africa teachers struggle to understand the requirements of new curricula (Chisholm, 2004; Fleisch, 2008; Hattingh, et al., 2007; Rogan, 2007) and that therefore, teacher uptake takes diverse forms (Brodie, et al., 2002b; Scholtz, Braund, Hodges, Koopman, & Lubben, 2008). I made similar observations from my study. According to the model by Mortimer and Scott (2003) which I used to

			A				B				C				D				E				F				G	
Date	June 2006	Aug 2006	Oct 2006	Dec 2006	Feb 2007	April 2007	June 2007	Aug 2007	Oct 2007	Dec 2007	Feb 2008	April 2008	June 2008	Aug 2008	Oct 2008													
Workshops (WS)	WS June 2006				WS March 2007		WS June 2007	WS Sept 2007			WS Feb 2008	WS May 2008		WS Aug 2008														
Co-teaching (CT)					CT	CT	CT	CT	CT		CT																	
Data collection for my study							Data July 2007	Data Aug 2007 Data Sept 2007			Data Feb 2008	Data April 2008 Data May 2008		Data Sept 2008	Data Oct 2008													

Note: A-G are project phases, thus:

A: Needs analysis

B: Development of materials, modelling strategies, intensive teacher support and co-teaching;

C: Adapted materials and strategies, intensive teacher support and co-teaching

D: Less intensive teacher support and co-teaching;

E: co-teaching by invitation

F: no teacher support or co-teaching

G: final data collection

Figure 8.03 Timeline for the ICC Project model indicating teacher workshops (WS), co-teaching and data collection (Data).

identify emerging communicative approaches four possible approaches can be expected. My data analysis however, surfaced a mix of communicative approaches including forms that could not be easily categorised into Mortimer and Scott's InteractiveAuthoritative, IA; NonInteractiveAuthoritative, NIA; NonInteractive Dialogic, NID and Interactive Dialogic, ID. For example, in Mrs Nkosi's lessons I identified what I termed look-alike IA, which was a form of authoritative communicative approach that seemed to allow for learner participation (Interactive) but all the learners did was complete the teacher's statements or engage in drill. Within the IA and ID episodes various forms of engagement in argumentation emerged. Some of the argument patterns detected resembled what other researchers in South Africa and elsewhere have observed. For example, in Mrs Nkosi's lesson, arguments resembled those observed during discussions of socio-scientific issues and in the context of the South African (perhaps African) notion of *ubuntu* (e.g. Scholtz et al., 2008).

In other cases, however, argumentation took unprecedented forms, as in the case of sense-making argumentation on a core science concept in Mrs Thoba's lesson on bond energy. The argument was co-constructed by the teacher and learners in a teacher-led whole class as opposed to small group discussion. In this case, argumentation was used as a tool for shared meaning-making. Teacher interventions facilitated student argument construction through probing questioning and insertion of scientific information to mediate conceptual understanding. Whereas TAP has been used mostly to analyse argument structure in science classrooms, I was able to adapt it for analysis of the process of argument construction picking up variations in complexity and elaborateness of the arguments constructed as sequential extensions of each others' arguments. This form of interaction could be important for constrained teaching and learning environments in South Africa and elsewhere. Further, I observed argumentation in the learners' languages, again an unprecedented form of interaction. This finding has implications for teacher education programmes designed to prepare teachers for multi-cultural contexts such as prevail in most South African classrooms.

My data provided additional evidence with adequate mediation South African learners can and do argue and provide rebuttals for their peers' arguments (see also Lubben et al., 2010). Evidence of learner argument construction attests to shifts to more dialogic engagement in the three teachers' classrooms. However, there was very little evidence of reverse IRE or learner initiated conversations in all cases. Further research is implicated into forms of

teacher communication that according to Engle and Conant (2002, p400), “give students authority” and foster the requisite levels of learner autonomy for learner initiation of dialogues.

The way teachers modified the teaching strategies in these contexts also has implications for research, professional development and teacher education in general. For example, research into factors for uptake of new innovations in curriculum change situations suggests that teachers often make pragmatic more than epistemically based (e.g. Stoffels, 2005a). For example, Mrs Thoba had to make such a pragmatic decision when after using argumentation with one class she realized that she had fallen behind in terms of coverage of content and she made a decision to revert to a teacher-centred method with the next class (Lessons on reactions of acids discussed in Chapters 5 and 7). *In order to save time she* engaged the class in a whole class discussion in which she took charge of the pacing to make up for lost time. Similar observations were made in Mr Far’s lessons and he often declared that “I am not going to waste time ...”

These findings have implications for conceptualisation and design of intervention programmes for both initial and continued teacher professional development. Also, future research would benefit from data on longitudinal studies of individual teachers so as to understand the effects of sustained support that lasts until the teachers gain confidence.

8.6 Argumentation and the role of the nature of tasks

The way argumentation played out in Mrs Thoba and Mrs Nkosi’s lessons in Chapter 6 not only affirms the ICC Project team’s literature based rationale for choice of activities but also revealed previously unreported trends.

In Mrs Nkosi’s case the activity was based on the concept cartoon of IK on owls and biodiversity conservation illustrated in Fig. 8.04. The learners were asked to say whether they agreed or disagreed and give reasons for their answers.

It was to be expected that the owl task in Mrs Nkosi’s lesson would stimulate much learner talk. According to literature tasks that are based on controversial societal issues tend to



Figure 8.04 Concept cartoon of IK on owls and biodiversity conservation

stimulate much learner debate in class (see for example, Albe, 2008; Jimenez-Aleixandre, 2002; Lewis & Leach, 2006). Also, the use of a concept cartoon was an additional factor for learner participation. Studies in the UK and in South Africa have demonstrated that concept cartoons can stimulate learner discussion. Concept cartoons have been used together with other strategies such as puppets to develop science talk and argumentation in primary science classrooms in the UK (e.g. Keogh, Naylor, de Boo & Feasey, 2002; Naylor et al., 2007). In South Africa, Paul Webb and his colleagues investigated the use of concept cartoons to stimulate talk in Grade 9 science classrooms (Webb, Williams & Meiring, 2008). They found that using concept cartoons in conjunction with argumentation writing frames did stimulate learners' thinking and argumentation in classrooms where there had been very little talk previously.

What was even more interesting about Mrs Nkosi's lesson was the mix of argument types that the task stimulated. While most of the learner arguments were the usual emotional, morally based type alluded to by Braund and colleagues, which hardly appealed to the science of the task there were a few that did draw on scientific knowledge. For example, Sandile's first contribution hinted at an understanding of nature of science as he presented an argument that scientists worked with evidence and not mere belief. Later he backed up

another argument of his with biological facts on the owl's role as a predator. Suggestions have been made for teachers to consider separating the discussion into two components, a morally based and a scientifically based one. However, Braund cautions that while this would make it easier for teachers to mediate argumentation it would be misleading to learners, suggesting a separation of scientific from moral issues. Mrs Nkosi achieved a mix of the two forms of reasoning largely by paying attention to both the learners' contexts and the objectives of the lesson, thus drawing on their cultural capital to develop the scientific story, Mediation 3 in Fig. 8.01.

The arguments on the bond energy task in Mrs Thoba's chemistry lesson on the other hand, were interesting for a different reason. For the first time, argumentation was observed from a lesson that was not initially designed with the precise aim of stimulating argumentation. This was a traditional lesson, largely teacher-centred as Mrs Thoba focused on introducing a new and for her, difficult topic. However, because she had become attuned to her learners' ways of talking about their thinking she was able to pick up a misunderstanding. She then adeptly mediated an argumentation episode (Mediation 2 in Fig. 8.01) which resulted in shared meaning-making in a whole class discussion. Thus, further research to understand the relationship between task type and teacher intervention styles is implicated.

One of the challenges that teachers cited at the beginning of my study was that learners were not proficient in the English language and might find it difficult to engage in argumentation. However, my observations of learner discussions disproved this fear. Learners were not only able to engage in meaningful discussions but they also constructed sophisticated arguments in their own languages. Learners made claims, supported them with relevant warrants and provided rebuttals for their peers' arguments, all in their own languages. This is an unusual/unconventional resource for classroom interaction which the learners seemed to use effectively to facilitate their learning. It seems that opening up the classroom interaction spaces such that learners can draw on "unconventional" communication resources, like the use of their own languages, could enrich their experience and enhance the learning of science.

The way argumentation played out in the classrooms I observed is particularly relevant to the debate on the role of language in multi-lingual science classrooms. In South Africa the debate centres around the dichotomy of on the one hand, the challenge of teaching and learning

science in English, a language that most learners (and some teachers) are not confident in and on the other hand, meeting the perceived need for English as a language of power and access to social goods. The dilemma for science teachers meanwhile, is how to afford their learners opportunities for meaningful engagement for conceptual understanding. Evidence from this study suggests that teachers could create separate spaces for learners to first use their own languages to engage with the science for meaning making and conceptual understanding before engaging in the language of teaching and learning to articulate these understandings.

My findings also suggest a need for further investigation of the role of argumentation as a teaching strategy and a learning tool in teacher-led whole class discussions which literature shows are prevalent in South Africa's science classrooms. It seems that while teachers do take up and adapt innovative teaching strategies such as argumentation little is known about the dynamics of verbal interactions and learner engagement in their local contexts. In South Africa the teaching and learning of science happens mostly in constrained environments such as large classes or overcrowded classrooms where it is not always possible for teachers to use the small group discussion strategies. If argumentation is only indicated for small group discussions then it would not appeal to teachers in such constrained environments. When some of my findings on the potential for argumentation in whole class teaching were presented at a SAARMSTE conference they generated much interest among the participants (see Appendix 3.04).

8.7 Implications for professional development programmes

Professional development programmes could also draw both from methodological and theoretical the findings of my study. For example, important lessons could be drawn on the effects of the duration of professional development interventions. Firstly, the positive effects of intensive on site teacher support were corroborated in my study. Secondly, the duration of the intervention (three years) resulted in a nuanced understanding of the contexts within which the teacher development programme played out.

Findings on development of the talk strategies themselves can inform teacher professional development. For example, argumentation has been slowly incorporated into some undergraduate and postgraduate courses in the university under which my study was conducted. For two years argumentation has been modelled in one or two sessions in the

undergraduate physics methodology course as well as one of the masters courses in science education. Findings relating to Mortimer and Scott's teacher communicative practices have for the first time this year been incorporated into a general pedagogy course at the undergraduate level. There is scope for more innovation in this regard. For example, teacher professional development could be linked with research into ways to link development of teacher content knowledge to development of argumentation skills. Teachers could be taught how to decide on appropriate communicative approaches and/or interventions when teaching selected topics. This way they would develop both the target teaching skills and the content knowledge about the selected topics. Where such programmes are extended to practicing teachers then collaborative teacher-researcher communities could result creation of what Anastopoulus, Smith and Nystrand (2008) referred to as horizontal expertise, or the knowledge gained by teachers, students and academics together as a result of collaboration. These findings have implications not only for teacher education in South Africa, but also in situations of curriculum change further afield.

My findings address some of the challenges identified during the ICC Project workshops which included multi-lingualism, the nature of the exit examinations at high school level as well as variation in school contexts and school ethos. Teachers' concerns about multilingualism relate largely to the final examination which is given in the LoLT (commonly English or Afrikaans). Teachers felt that learners needed time to practice the use of English during the lessons so as to be able to articulate their thinking adequately in the final examination. There were also fears that learners may not take the activities seriously if they were done in their home languages as this was not the traditional way of doing science. However, observations from learner use of their own languages contradicted these fears. Learners were able to engage with science concepts and articulate well supported arguments for meaning-making in their home languages. Teachers and learners are already engaging in their own languages in some science classrooms and teacher professional development programmes need to take this into consideration in preparing teachers for South Africa's multilingual classrooms. Teachers can then be empowered with the requisite skills to prepare for and/or manage class discussions that involve use of learners' languages.

8.8 Further research on science talk

One of the challenges of science talk in classrooms was related to language, both in terms of the LoLT and the language of science. As observed in Chapter 7, while the language debate rages on, teachers and learners are using their local languages to understand science concepts. Research on how teachers and learners are currently using their local languages in the science classroom could shed some light on the dynamics of classroom interactions during such lessons. The role and potential of allowing learners to use their local languages for conceptual development could be determined.

My study focussed on teachers and how they adapted new innovations for their contexts in a curriculum change context. While my findings indicate pockets of success in teacher adoption of the new teaching strategies, the true test of success would be in terms of learner gains. Future studies should explore the effects of long term school based collaborative interventions like the ICC Project model on learner achievement. While it is true that the correlation between interventions and changes in learner performance is not obvious, it is equally true that the success of an intervention that targets teaching and learning has to be judged by changes in both teaching and learning.

In terms of my own research what still needs to be done is to refine and disseminate the materials developed by teachers during the study. Also, there is a need to extend the study to other teaching and learning contexts. More could be done with learners rather than just with teachers. For example, in my study only the teachers were introduced to argumentation as a teaching tool. Further work could include explicit teaching of argumentation skills to learners as well and observing the dynamics of argument construction in that case. Since the ultimate goal of any intervention in education is to improve learning, it would be interesting to gather evidence of improvement in learner performance with science talk. I would also want to conduct more research that can deepen my understanding of cultural and other contextual issues for science talk.

8.9 Limitations of my study and unresolved issues

I now turn to a discussion of the constraints under which the research was undertaken. First, my research deliberately targeted three teachers in disadvantaged contexts who had shown an interest in trying out the new strategies. By focusing on three cases my study would only

provide an understanding of science talk in the limited contexts, which would not be readily generalisable to other South African contexts. However, the detailed observations over an extended period of time, would yield rich data that could provide a good understanding of development of science talk in those contexts. Also, teachers and learners in disadvantaged contexts may find it harder to take up new strategies for various contextual reasons. For example, some researchers have reported that teachers encounter difficulties with lack of appropriate resources, poor learner preparation, the teachers' own poor training in the Bantu education of the previous government (Chisholm, 2003; Jansen, 1999).

My study targeted talk in classrooms where it was generally reported to be missing, where multi-lingual and multi-cultural factors militated against meaningful engagement in talk. The ICC project intensive support programme was influential in facilitating my study in these contexts. Precisely because of the conditions of disadvantage there were expectations, at least at the outset of the study, by participants for their other needs to be met through the project. I call these non-target teacher needs since they were not in the project agenda. Some of these non-target needs related to poor content knowledge which, although it was not part of the project agenda, was eventually adopted by the ICC Project team onto the agenda. Special workshops targeting teacher content knowledge were conducted on request by the teachers during the needs analysis sessions. Teachers were struggling with very demanding workloads and large classes (or lack of textbooks and other teaching and learning materials) which were legitimate needs but that the project could not help them with. Later in the programme when the teachers got involved in materials development there was a sense that their need for teaching and learning resources was being met. The curriculum itself was reviewed and revised twice during the course of my study and this was quite challenging as teachers had to make adjustments every time the curriculum changed. This threatened the teachers' commitment to the use of science talk strategies in their lessons. The fact that they did continue trying out the strategies could be viewed as a sign of the authenticity of the strategies and their adaptability to the different forms of the curriculum.

One of the difficulties that Mortimer and Scott (2003) admit to is that of transcribing oral discussions in learner's languages to English written text. The main difficulty is communicating to the English reader as accurately as possible the meanings of the utterances. Being aware of these difficulties I tried to find English expressions that are closest to those

being translated and also maintained the transcriptions of talk in the learners' languages. However, although maintaining transcriptions in the learners' languages might reduce the effects of translation they introduce a new difficulty, the fact that the excerpts do not make sense to the English speaking reader who is a non-speaker of those languages.

Another limitation of my study relates to the adjustments that I had to make to the data collection methods due to the increased need to spend more time in the classrooms modelling teaching strategies and providing the necessary support to teachers and learners. While I had intended to interview teachers about their lessons and their thinking in those lessons, it was not possible to do so for each lesson, due to timetabling and other constraints.

Finally, I had a personal limitation of my own. When I first enrolled for my PhD study and decided that I was going to work on argumentation I was immediately declared an argumentation expert on the ICC project. Within three months of enrolling I had to conduct workshops to introduce teachers to argumentation and six months later I was to embark on the modelling of the strategies in schools. I had to learn fast, so in addition to reading large volumes of literature on argumentation I consulted very heavily in those first few months. What started as a limitation for me turned into a strength in that within the first year of my study I had the privilege to communicate with the experts in the theories I intended to use in my study. During the initial stages of my data analysis I had a further privilege of consulting the experts about my thinking about the use of the selected models to analyse my data. In the process I did indeed become something of an expert in argumentation and in teacher communicative approaches.

8.10 Conclusion

In this chapter I have highlighted what I see as the key findings of my study. I categorised my key findings into empirical, theoretical and methodological findings. Empirical findings relate to my actual observations of teacher practices in the use of science talk and the resultant discourse patterns. I observed that lessons were largely interactive although teachers tended to a more authoritative communicative approach. There was evidence of dialogic discourse in all three teachers' classrooms with an emergence of argumentation particularly in Mrs Thoba and Mrs Nkosi's lessons. In both cases arguments were co-constructed by the teacher and learners or by a learner and peers. In Mrs Thoba's case an unusual form of

argumentation was observed in which learners used argumentation skills to make sense of conventional science concepts as opposed to the usual argumentation on socio-scientific issues as observed in other South African studies so far. This relates to my theoretical findings about argumentation. Whereas most argumentation research has reported findings on the structure of usually shorter simpler arguments by individual participants or long written arguments, I observed long arguments co-constructed by several participants being either the teacher and several learners or a learner and several of his/her peers. It was hard to categorise arguments as simple or complex as other researchers have done, rather as more or less sophisticated. My methodological findings relate largely to the possible factors for success of the ICC project model which could be related to sustained on-site teacher support, modelling of strategies as well as systematic teacher-researcher collaboration. I also, talked about how science talk happened in hybrid spaces of multilingualism and other various cultural influences. In some cases talk happened together with other forms of engagement such as reading and/or writing, evidence of incorporation into the general scientific literacy development practices in those classrooms. Finally, I also considered some limitations of my study and how I addressed them.

8.11 End piece: Some personal growth

Since I started this discourse with a story I would like to end it with another story. Although the story itself is taken from my own life experience it has very strong parallels to my PhD experience and the findings of my study.

A story is told of a woman who converted to Christianity and started attending the local church. Every Sunday she was in church on time, she sat and listened attentively to the Pastor's sermons. The Pastor soon came to know her as one of his regular members and every Sunday after service he would greet her and offer words of encouragement. He also talked to her about specific passages from the Bible that he felt would help grow her faith. However, as time went by the Pastor noticed that the woman did not remember much, neither the sermons nor the passages that he discussed with her on their one-on-one sessions after church. One Sunday after talking to her for a while the Pastor exclaimed in frustration, "It is a waste of time teaching you these things. You don't remember anything I teach you. So what is the point of you coming to church at all every week?" In a calm voice the woman replied, "Pastor, have you ever observed what happens when you wash a tea strainer? It takes a lot of

water to clean a tea strainer and it does not keep any of the large volumes of water that you run through it but in the process it gets cleaned. The words you say to me every week may not stay inside me but they are making me clean”.

When I started on this study I received many words of advice on what it means to do a PhD study. Some of the statements that stand out clearly in my mind include: “Your study must make a meaningful contribution to knowledge” or “At PhD level your study must contribute something new” or “A PhD study must make a difference”. In the course of my PhD study I read large volumes of literature and talked to many esteemed education researchers and gurus to see how my study could “make a difference”. I do not know how much difference this study is going to make but what I do know is that it has made significant contribution to the science education research community, the making of a brand new science education researcher - me! This study has been a journey of enlightenment through questioning, searching and articulating my own understandings of issues around science talk. Most of what I read and heard never made it into this thesis and a lot of it is not even in my head anymore. However, none of it has gone to waste, it may not be inside me but it has truly transformed me - from a Biologist and a science educator to a science education researcher and an academic!

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Appendix 3.01

Interview schedule

Appendix 3.01
Protocol for teacher interviews on science talk

TEACHER INTERVIEW

Demographic Information

Date:	Age:	Sex:
Qualifications		
Specialisation		
Teaching experience		
Grade(s) taught		
Learning area		
Number of learners	Male:	Female:

THANK YOU FOR YOUR TIME.

Appendix 3.01

Protocol for teacher interviews on science talk

Interview schedules to address Research question 1: How do teachers use Science talk in FET science classrooms?

Interview schedule for use at the beginning of the study

Key: Science talk = all science related speech
IK = Indigenous knowledge

Interaction = verbal communication (T-L & L-L talk) T = teacher L = learner
MS = mainstream science FET = Further Education and Training Band (Gr10-12)

Research Question	Why is the information needed?	Main Question(s)	Follow up Questions	Prompts/ Probes
How do teachers (view and) use Science talk in FET science classrooms?	To establish if and how teachers use Science talk in their classrooms.	How do you use Science talk in your classroom?	a) What is your understanding of Science talk? b) For which type of lessons would you find Science talk most useful? Can you give me an example? c) What are the challenges of using Science talk? d) How might the use of Science talk in class affect/be affected by learner talk outside the classroom?	a) Ah, ha b) Tell me more c) Do you think this will work? d) Is it practical? e) Why not?
	To obtain teachers' views of the use of both IK and MS concepts in FET science classrooms?	What is your view on the use of both IK and MS concepts in science classrooms?	a) Can you tell me briefly what IK you think can be used in science lessons? You can use examples. b) How would you use IK concepts in a science lesson? c) How would you combine IK and MS concepts in a science lesson? d) What are the challenges of using IK concepts in science lessons?	a) Ah, ha b) Tell me more c) Do you think this would work? d) Is it practical? e) Why not?
	To obtain teachers' views of use of Science talk to address IK and MS concepts.	What is your understanding of Science talk as a teaching strategy?	a) What might be different/similar between learners talk in a lesson using Science talk on MS and a lesson using Science talk on IK? b) Why would learners (not) enjoy a lesson using Science talk? c) Why would a Science talk lesson (not) provide for effective learning?	a) OK b) Yes c) And then? d) Sorry, I did not quite understand could you repeat that or reword that?

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Appendix 3.01
Protocol for teacher interviews on science talk

Interview schedule for use at the end of the study

Research Question	Why is the information needed?	Main Question(s)	Follow up Questions	Prompts/ Probes
How do teachers (view and) use Science talk in FET science classrooms?	To establish individual teachers' views on how they used Science talk in their classrooms.	How did you use Science talk in your classroom?	a) What is your understanding of Science talk? b) For which type of lessons did you find Science talk most useful? Can you give me an example? c) What were the challenges of using Science talk? d) How do you think the use of Science talk in class affected/was affected by learner talk outside the classroom?	a) OK b) Yes c) And then? d) Sorry, I did not quite understand could you repeat that or reword that?
	To assess any changes in teachers' views of the use of both IK and MS concepts in FET science classrooms?	What is your view on the use of both IK and MS concepts in science classrooms?	a) Can you tell me briefly what IK you were able to use in science lessons? b) Please give me one example of a lesson using IK. c) How did you combine IK and MS concepts in a science lesson? d) What challenges did you encounter in using IK concepts?	a) Ah, ha b) Tell me more? c) Do you think this would work? d) Is it practical? e) Why not?
	To obtain teachers' views of use of Science talk to address IK and MS concepts.	What is your view of Science talk as a teaching strategy?	a) What was different/similar between learners talk in a lesson using Science talk on MS and on IK? b) Why did your learners (not) enjoy Science talk lessons? c) Why do you think that Science talk lessons (did not) provided for effective learning?	a) Tell me why you feel that way. b) What makes you confident?
	To establish individual teachers' perceptions on interactions in lessons involving Science talk.	1. How did the use of Science talk affect learners' interactions with you during the lessons?	a) What difference did you observe in learner contributions? b) Did the same learners talk, ask, answer questions? c) What did you observe with learners who normally do not participate in discussions? d) How did you maintain order during Science talk? e) What could be done to improve its usefulness?	a) Tell me why you feel that way. b) Can you think of a possible reason for the way you feel?
		2. How did the use of Science talk affect your learners' interactions with each other during the lessons?	a) How different was it from ordinary discussion? b) What difference did you observe in learners' discussions when you used Science talk? Did learners talk more/less? c) What concepts did learners find difficult/easy to discuss? d) What changes did you observe in discussions in class and those outside class?	a) OK b) Yes c) And then? d) Could you repeat that or reword that?

THANK YOU FOR YOUR TIME.

Appendix 3.02

Samples of field notes – raw data

22/08/07 Gr12 Phy Sc.

- topic } Intro - for Trs.
- review }

- notes.

- notebooks (nt) => At beginning

* 2 sides of classroom < Yesterday it favored Today "ft"

- example of outstretched hands
(Force field => explain extension

beyond fingers => force ^{effect} does not
end at fingers) Misconceptions *

* - elaboration of inherent concepts
e.g. mass / wt.
units.

* - are we in a field? Y

- do we experience force? Y

- which? F_w (weight)

- whose field are we in?

- N. Law (each other, the earth, etc)

* - converting units to SI (reasons?)
hence g

* Questioning => to elicit ans. (uncomfortable
silences)

Participant Obsv. ?

Non - " " .

- how to deal
with this??

Today I went back to Mr Far's school to see another Grade 12 physics lesson. He taught the same class yesterday to introduce magnetic fields. Today's lesson was on Force field. The teacher asked the learners to take out their notebooks and then started with a review of yesterday's lesson and then introduced Force fields.

As an illustration, Mr Far stood in front of the class and spread his hands out, explaining that the force effect does not end at the fingers. He then engaged the learners in a discussion of the inherent concepts like mass, weight and the units of each as well as units of force field.

He then engaged the learners in a question and answer session and some of the questions he asked were:

Are we in a force field?

Why?

Do we experience force?

Why?

Which force do we experience? (his target answer was Fw. weight)

Whose field are we in?

At this point he took the learners through a review of Newton's laws and dwelt on the third law. He explained that we exert forces on each other, on the earth and vice versa, hence g , the gravitational force.

He then asked for reasons why it was necessary to convert units to SI units? After that question and answer session he engaged learners in a process to actually do the conversion.

At this point in the lesson, the learners were not responding. There were extended silences and I wondered what would be the best way to deal with such silences.

Occasionally he called on me to help explain a concept and I wondered about my role – clearly I am not a non-participant observer – that makes me a participant observer

On the whole this was an interactive lesson, except for the awkward silences towards the end of the lesson.

There was also something interesting about the teacher's response to learners. Yesterday I noticed that he tended to ask the learners on his right hand side. Today he focused more on the learners on the left hand side of the class. I did not interview him because he had another class immediately after this and I was going to see a lesson in another school. But when I joked about it he said that he had not noticed that. This was what he did, he just wanted to get them involved as much as possible so he looked around to see who had not said anything so far.

Appendix 3.03

Sample of inter-rater 1 analysis for teacher communicative approaches

Mrs Nkosis's lesson on Inhalation and gaseous exchange

- 40 Teacher: inferior vena cava yes that is going to be bringing in deoxygenated blood from the lower parts of the body. And from the upper parts...?
- 41 Class: (*chorus*) superior vena cava
- 42 Teacher: superior vena cava right so where will that blood be getting to? From the body to...?
- 43 Sindi: the heart
- 44 Teacher: the heart yes why is it supposed to get to the heart?
- 45 David: to get purified
- 46 Teacher: to the heart? It is purified somewhere else it goes from the body to the heart and it enters into the right what?

This excerpt shows an **Interactive Authoritative** approach. The focus here is on the teacher's point of view and learners are giving responses that simply consolidate this view. This is further evidenced by the fact that the teacher (in turns 40 and 41) does not actually ask questions but rather gives learners an opportunity to complete her sentences. In 'turn 44' the teacher probes the learners to give an explanation (which could be read as ID) but immediately responds to the learner's response in turn 46 by giving the correct answer herself without further probing the learner to explain themselves. Therefore the teacher missed an opportunity to be interactive dialogic in her approach.

- 76 Teacher: right so (*holding learner's face*) oxygen then diffuses I am going to use the term and note those terms ok? The oxygen diffuses from the atmosphere through the two nasal cavities that you see so this is the part that we are talking about ok?
- 77 Class: Yes
- 78 Teacher: now you've got to note then you know when we talk of a cavity its something like a room ok? a room has the sides ok? (*points at walls*) it has windows the walls it has the ceiling as you can see as well as the floor ok?
- 79 Teacher: (*back to learner's face*) I can right say the same thing here the nasal cavity has the sides which are formed by the cheek bones and then this bone here can someone tell me what this bone is called? Do you know what this bone is? (*fingers around learner's nose*)

In lines 76 to 79, the teacher is using a **non-interactive authoritative** approach, as only the teacher's view is given without any meaningful input from the learners.

Mrs Thoba's lesson on bond energy

- 121 Teacher: She says that if they come closer the hydrogen is going to become negative because of the attraction force. What do you think about that?
- 122 Mlondi: Er Maam I much agree
- 123 Teacher: You agree?
- 124 Mlondi: Yes Maam coz Maam when they bond covalently they are bonding to achieve the nearest noble gas right?
- 125 Class: Yes yes
- 126 Mlondi: ok then, so ...
- 127 Class: *(general laughter)*
- 128 Mlondi: soon as they reach the noble the nearest noble gas both of them what they share and then soon as they are sharing er both of these er they become negatively charged

(Lines 121-128 Transcript of Bond Energy lesson)

From the beginning of this excerpt (lines 121 to 128) learners are encouraged to express their opinion when they are asked probing questions. The approach is therefore **Interactive Dialogic** in nature although only to a limited extent as learner's ideas are only explored but not compared and contrasted as required for this approach.

- 166 Teacher: Ok the statement is if the potential energy decreases then the hydrogen atoms are going to be negatively charged. Are they going to be negatively charged?
- 167 Class: No no yes no yes no
- 168 Teacher: When does a negative ion form?
- 169 Mlondi: Its whereby Maam it gains er electrons
- 170 Teacher: Do we have any gaining of electrons here?
- 171 Class: No
- 178 Teacher: So how can a negative ion form?
- Thabang: Yes

(Lines 166-181 Transcript of Bond Energy lesson)

The last part (lines 166 to 173) shows an **Interactive Authoritative** approach as the teacher steers the learner's responses and ideas towards a particular point of view. The nature of the teacher's questions is to help learners arrive at a specific point of view; there is no room for them to express their own ideas.

Appendix 3.04

Sample of inter-rater 2 analysis for teacher communicative approaches

Mrs Thoba's lesson on bond energy

- 121 Teacher: She says that if they come closer the hydrogen is going to become negative because of the attraction force. What do you think about that?
- 122 Mlondi: Er Maam I much agree
- 123 Teacher: You agree?
- 124 Mlondi: Yes Maam coz Maam when they bond covalently they are bonding to achieve the nearest noble gas right?
- 125 Class: Yes yes
- 126 Mlondi: ok then, so ...
- 127 Class: *(general laughter)*
- 128 Mlondi: soon as they reach the noble the nearest noble gas both of them what they share and then soon as they are sharing er both of these er they become negatively charged

(Lines 121-128 Transcript of Bond Energy lesson)

- Teacher: When does an atom become negatively charged?
- Teacher: *(pointing to a boy)* Let me give you a chance
- Bandile: Maaam I disagree with the statement coz Maam I think when the two atoms *(inaudible)* the chemical potential energy will increase
- Teacher: Why do you disagree with the statement?
- Bandile: Its because Maam when the the two atoms interact its impossible for them to be negatively charged.
- Sundani: Maam didn't you say...?
- Teacher: Why?
- Bandile: They are not yet touching Maam.
- Class: Yes yes yes
- Sundani: Maam didn't you say when they er when they get closer to each other when they attract each other the potential energy it will decrease
- Bandile: Its like this... *(Holding a pen and set square in each hand and moving them towards each other)*
- Sundani: It will decrease...
- Bandile: They are not yet touching Maam.
- Sundani: Maam you said you said the potential energy will decrease and therefore those atoms are going to be negatively charged

(Lines 151-164 Transcript of Bond Energy lesson)

- Teacher: Ok the statement is if the potential energy decreases then the hydrogen atoms are going to be negatively charged. Are they going to be negatively charged?
- Class: No no yes no yes no
- Teacher: When does a negative ion form?
- Mlondi: Its whereby Maam it gains er electrons
- Teacher: Do we have any gaining of electrons here?
- Class: No
- Teacher: So how can a negative ion form?
- Thabang: Yes

(Lines 166-181 Transcript of Bond Energy lesson)

The talk here is Interactive/authoritative. The authority of the teacher is clear though learners are participating in meaning making. Learners use "Maam you said" quite often. The teacher's prompts like "why", "you agree" and "what do you think" merely receive learners' views about what she told them about bond energy. They regurgitate the science view. The class is negotiating round one view – the school science view. Though some would say "I disagree" or "I think", they all are trying to make meaning only of the

scientific view. There exist no alternative views that are put forward on the social plane to be explored. The learners are battling to make meaning only around what the teacher said to them about bond energy. This is clear from what Sundani twice stresses:

Episode 1

Sundani: Maam didn't you say when they er when they get closer to each other
when they attract each other the potential energy it will decrease

Teacher: inferior vena cava yes that is going to be bringing in deoxygenated blood from the lower parts of the body. And from the upper parts...?

Class: *(chorus)* superior vena cava

Teacher: superior vena cava right so where will that blood be getting to? From the body to...?

Sindi: the heart

Teacher: the heart yes why is it supposed to get to the heart?

David: to get purified

Teacher: to the heart? It is purified somewhere else it goes from the body to the heart and it enters into the right what?

Class: *(talking loudly among themselves)*

Nombi: atrium

Teacher: right atrium so from the right atrium right what will happen it goes down when the muscles contract and a specific valve opens up which valve is that? So that it can

Class: *(talking loudly among themselves)*

Teacher: wait wait wait so that it can move from the right atrium into the right ventricle?

Mtha: tricuspid valve Maam

Teacher: tricuspid valve will have to open up right so then the blood will flow from the right atrium into the ...? right ventricle

Thembi: right ventricle

Teacher: then from there we said there is this specific artery now a specific artery which is going to transport this deoxygenated blood from the right ventricle to a specific part where something specific is going to happen what will that be?

Class: pulmonary artery

Teacher: good we are all clear about that the pulmonary artery will transport deoxygenated blood from the heart to ...?

Class: the lungs

Teacher: good why is this blood getting to the lungs

Class: to be purified

Teacher: so that it can be purified
(Turns 40-61 Lesson on Inhalation and gaseous exchange)

Teacher: right she is going to be our model. You said we inhale oxygen from the atmosphere which means that oxygen will enter through?

Class: nose nose nose

Teacher: her two openings *(touching learner's nose)* what are these openings?

Class: nostrils nose nostrils

Teacher: the nostrils right? The two are separated by this part and we call this part the nasal septum right? The nasal septum *(writes it on the board)*

Teacher: right so *(holding learner's face)* oxygen then diffuses I am going to use the term and note those terms ok? The oxygen diffuses from the atmosphere through the two nasal cavities that you see so this is the part that we are talking about ok?

Class: Yes

Teacher: now you've got to note then you know when we talk of a cavity its something like a room ok? a room has the sides ok? *(points at walls)* it has windows the walls it has the ceiling as you can see as well as the floor ok?

Teacher: *(back to learner's face)* I can right say the same thing here the nasal cavity has the sides which are formed by the cheek bones and then this bone can someone tell me what this bone is called? Do you know what this bone is? *(fingers around learner's nose)*

Dineo: which one?

Teacher: *(teacher moves her fingers from learner's nose up to between the eyes)*
 Class: *(commotion)*
 Teacher: ok this is the nasal bone ok? Forming the roof of your nasal cavity here
 Class: *(loud talking among themselves)*
 Teacher: and then this is the floor down here as you can see. You can just refer to the upper jaw ok? Then the cavity is here, *(touching each part in turn)* the sides the roof the floor. Now before even this air that we are inhaling reaches the lungs right certain things have to happen to the inhaled air right? For instance when it is cold obviously the air will be very cold
 Class: yes
 Teacher: and very irritating. Now that air is not supposed to reach your lungs in state. So the air that she inhales *(indicating to learner to inhale)* Hhmm do so let's see *(learner inhales)* right so the air that she draws in if the temperature is low it is obviously very cold and very irritating so which means that this inhaled air must be warmed.
 Class: warmed
 Teacher: right? The inhaled air must be warmed. Now the question is what will warm this inhaled air?
 Musa: the blood capillaries lining the nasal cavity
 Teacher: wow good that's good. In other words when this inhaled air comes into contact with what with the blood capillaries lining your nasal cavity then it will be warmed. Why is it warmed?
(Turns 71-96 Lesson on Inhalation and gaseous exchange)
 Teacher: *(indicates for learner to breathe in)* again yes what did you see here?
 Teacher: *(points to a learner who is demonstrating to his friends)* yes Hlatshwayo explain what you have just demonstrated?
 Hlatshwayo: the the the lungs Maam
 Teacher: not the lungs the chest cavity you can't see the lungs yes what happened?
 Hlatshwayo: the chest cavity Maam
 Teacher: what happens to it?
 Hlatshwayo: iye (it) you know *(demonstrates by moving his hands in and out from his chest)*
 Class: *(laughter)*
 Teacher: it goes up and...? forward
 Class: yes
 Hlatshwayo: Yes
 Teacher: good now if that happens what do you think happens to your ribs and intercostal muscles?
 Sharon: they are raised
 Teacher: they are also raised.
 Teacher: Right can we go through this quickly? *(Teacher sends learner back to her seat and starts reading from handout)* The mechanism of inhalation er please note and highlight. Number one the diaphragm contracts and flattens it contracts and becomes a little bit flat and that will increase the volume of the thorax from top to bottom. Why must this volume increase?
 Lb: so that it may accommodate the oxygen
(Turns 312-327 Respiration anatomy)

The talk is highly non-interactive/authoritative in nature. It is heavily dominated by the teacher. There is serious regurgitation of the school science view – no other ideas are presented. Frequently the teacher praises her learners with utterances of “good”. Though, understandably, there are instances in the science classroom

Appendix 3.05

Samples of inter-rater 1 analyses for argumentation

Task: What do you think is going to happen if 2H-atoms move closer together?

3104 3C1 Atoms get negative charge (109+113)

• 3W1 Atoms are attracted to each other (117)

X 3S1 They are close together (118/9) evidence

request for general ~~rebuttal~~ counterclaim (122) or general rebuttal (124)

rebuttal
but
starting
with
I agree (126)

3B2 Covalent bonding aims at formation of noble gas (130/1)

• 3W2 When reaching noble gas, electrons are shared (135/6)

repeat 3C1 when sharing, both atoms become negatively charged (136/7)

request for specific rebuttal 3W1 and 3W2: when does atom become negative? (142/3)

3W3 ~~when atoms collide~~ they have only one electron (148)

3S3 ~~they only have one electron~~

3B3 collision makes atoms loose an electron (149/50)

Counter
~~claim~~

to 3C1 3C2 atoms don't get neg charge (157)

Strong rebuttal to 3W1 3W4 increased pot chem energy $\neq$ neg charge (155)

3W5 electron exchange is possible only if atoms touch (161)

3E2 models with pen & set square (165)

rebuttal against 3W2 3W6 closer distance decreases pot chem energy (164)

3E3 graph (164)

repeat 3C1 decreasing pot chem energy $\rightarrow$ neg charge (170/1)

3 rebuttal repeat 3C2 atoms don't get neg charge
same 3W7 no charge when electron is shared
as L1 3B4 covalent bonding ~~but electron sharing~~
there's sharing of electrons.

Appendix 3.06

Samples of inter-rater 2 analyses for argumentation

Excerpt	Argument components and functions
T: She says that...if they come closer the hydrogen is going to become negative because of the attraction force. What do you think about that? L8: Er...Maam I much agree... T: You agree? L8: Yes Maam... coz Maam...ok fine...when they bond covalently they are bonding to achieve what the nearest noble gas... L8: soon as they reach the noble the nearest noble gas both of them what...they share...and then soon as they are sharing... both of these... electrons they become negatively charged... T: What becomes negatively charged? L7: Those atoms... T: The hydrogen? L8: Yes Maam T: When does a ...when does a negative charge form? When does an atom become negatively? L10: When two atoms collide. L11: Maam...I disagree with the statement ... I think when the two atoms meet...the... chemical potential energy...will increase	Teacher repeats claim, C1 L8 drawing on evidence of covalent bonding Foregrounding C1 Calling for clarification L8 provides W1/link between D1 and Restates C1 Foregrounding W1 Calling for R L11 makes Cc/ new claim, C2/provides data, D2/Appeals to evidence on PE

T: Why...(inaudible)...why do you disagree with the statement?	T overlooks D2/ Redirects to C1
L11: Its because Maam...when the two atoms interact its impossible for them to be negatively charged.... <i>Azikathintani</i> (they have not yet touched)	Provides W2 B1- support for evidence D2 in C2
L7: Maam didn't you say when they ...er...when they get closer to each other when they attract each other the potential energy it will decrease <i>angithi</i> Maam?	Cc to C2/D3/R1/RefuteD2/Appeal to PE evidence
T: ok...our statement...the statement is...if the potential energy decreases then...the hydrogen atoms are going to be negatively charged. Are they going to be negatively charged?	ForegroundingC1/Redirecting to claim under consideration
T: When does...when does a negative ion form?	Calling for rebuttal
L8: Its whereby Maam it gains...er...electrons	Rebuttal, R2- Why C1 does not hold true here
T: Do we have anything about gaining of electrons here? Class: No T: So how can a negative ion form?	Foregrounding Cue for Ls to link rebuttal R2 to C1
L13: I don't think of any...negative charge forming coz we are dealing with covalent bonding... the electrons they share...so I think negatively charged electrons (sic) only form when you are dealing with ionic bonding	L13 counters C1 with Cc/provides data D3/warrant W3 and rebuttal R4.

Appendix 3.07

List of publications and conference presentations from my PhD study

Publications in peer reviewed research journals:

1. Msimanga A & A. Lelliott. (2012) Making sense of science: Argumentation for meaning-making in a teacher-led whole class discussion. *ARJMSTE 16(2): 65-79*
2. Otulaja F., Cameron, A. & A Msimanga (2011). Rethinking argumentation-teaching strategies and indigenous knowledge in South African science classrooms. *Cultural Studies of Science Education, 1(1)*, 693-703. ***My contribution was on argumentation-teaching strategies.***
3. (In prep) Msimanga A & A Lelliott. Talking science in the mother tongue: possibilities and challenges for learner engagement. ***In preparation for submission to Journal for Research in Science Education, JRST by November 2012***
4. (In prep) Msimanga A. & N. Gumede. A review of research on language in South African science classrooms 2000-2010. ***November 2012 submission to AJRMSTE***

Conference presentations:

- 2013 (Abstract submitted) SAARMSTE Conference** (Southern African Association for Research in Mathematics, Science and Technology Education). Oral presentation on *Exploring learner engagement within hybrid spaces: "unconventional" forms of interaction in the science classrooms* Western Cape University, 17-21 January 2013
- 2012 CICE**, Canada International Conference on Education. Oral presentation on *Student social interaction and meaning making: negotiating the norms of science talk in small group discussions*. Guelph, Ontario, Canada 18-22 June 2012
- 2012 NARST Annual International Conference** (National Association for Research in Science and Technology Education, Indianapolis, USA). Virtual presentation: *Talking science in the mother tongue: possibilities and challenges for substantive engagement*. 22 March 2012
- 2012 SAARMSTE Conference** (Southern African Association for Research in Mathematics, Science and Technology Education). Oral presentation on *Dialogic pedagogic practices in a science classroom: Opening and closing verbal interaction*. Lilongwe, Malawi 16-20 January 2012
- 2011 SAASTE Conference** (Southern African Association of Science and Technology Educators). Oral presentation on *The teacher's role in getting learners talking in the science classroom*. Mafikeng 11-15 July 2011
- 2010 The ICE, International Congress of Ethnobiology**. Oral presentation on *What indigenous knowledge do students in urban schools have? Ideas for using students' knowledge of owls to implement the new science curriculum in South Africa* Vancouver Is., Canada 7-14 May 2010
- 2010 SAARMSTE Conference**. Oral presentation on *Modelling argumentation in whole class discussion: a novice teacher's adaptation of a strategy*. Pinetown, South Africa 18 - 22 January 2010.
- 2009 SAARMSTE Conference**. Oral presentation on *Bite size chunks: The challenges and potential of working with learners' ideas in science classrooms*. Grahamstown, South Africa 19 - 23 January 2009.
- 2008 ESERA**, European Science Education Research Association Summer school. Oral presentation: *Talking Science in SA high schools*. University of York, UK. 24-29 Aug 2008
- 2008 SAARMSTE Conference**. Oral presentation on *The potential for argumentation in the implementation of the science curriculum in South Africa*. Maseru, Lesotho. 13-18 Jan 2008.

Appendix 3.08

Ethics clearance of my study by the University of the Witwatersrand



Wits School of Education

27 St Andrews Road, Parktown, Johannesburg, 2193 • Private Bag 3, Wits 2050, South Africa
Tel: +27 11 717-3007 • Fax: +27 11 717-3009 • E-mail: enquiries@educ.wits.ac.za • Website: www.wits.ac.za

STUDENT NUMBER:
Protocol: 2008ECE07

1-Apr-08

Mrs. A Msimanga
C/O Marang Centre
WSOE

Dear Ms. Msimanga

Application for Ethics Clearance

The Ethics Committee in Education of the Faculty of Humanities, acting on behalf of the Senate has considered your application for ethics clearance for your proposal entitled:

Talking Science in South African classrooms: a case study of grade 10 and 11 classes in Soweto

The following comments were made:

- The application to the HREC contains mention of the video recordings only under pt.7, *not* (as one would expect) under pt. 1: here, only audio recordings are mentioned.
- In addition, what happens to all these recordings once the study has been completed? Are they among the 'data' that 'will be ... destroyed'?
- In appendices 3-8, the frequent assertion that 'no negative consequences will result' is both too vague and unscientific. Too vague, because 'negative consequences' remains undefined/unillustrated. Unscientific, because the applicant is in no position to make this claim with any certainty. I suggest adding 'foreseeably' or "in all likelihood".

Recommendation:

Ethics clearance should be granted, provided that these omissions are taken care of.

The supervisor needs to inform the office of the Wits School of Education's Research Ethics Committee that the above mentioned amendments have been made to the proposal for ethics clearance to be granted.

Yours sincerely

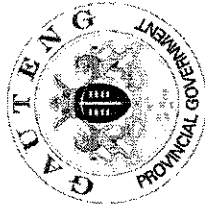
Matsie Mabeta
Wits School of Education

Cc Supervisor: Dr. AD Lelliott (via email)

Appendix 3.09

**Application for permission to conduct my study in schools in the
jurisdiction of the Gauteng Province Department of
Education (GDE).**

GAUTENG DEPARTMENT OF EDUCATION



RESEARCH REQUEST FORM

REQUEST TO CONDUCT RESEARCH IN INSTITUTIONS AND/OR
OFFICES OF THE GAUTENG DEPARTMENT OF EDUCATION

1. PARTICULARS OF THE RESEARCHER

1.1	Details of the Researcher	
Surname and Initials:	Msimanga A.	
First Name/s:	Audrey	
Title (Prof / Dr / Mr / Mrs / Ms):	Mrs	
Student Number (if relevant):	0719386X	
ID Number:	E296830 pp no.	
Gender (Male/Female):	Female	

1.2	Private Contact Details	
Home Address	Postal Address (if different)	
705 Brisk Place	Same	
195 Bree Street		
Johannesburg		
Postal Code: 2001	Postal Code:	
Tel: (011) 717 3260 (Supervisor – Dr Lelliott's number)		
Cell: 0761577153		
Fax: (011) 717 3259		
E-mail: Audrey.Msimanga@wits.ac.za		

2. PURPOSE & DETAILS OF THE PROPOSED RESEARCH

2.1	Purpose of the Research (Place cross where appropriate)	
	Undergraduate Study - Self	
	Postgraduate Study - Self	X
	Post-Doctoral Study	
	Private Company/Agency – Commissioned by Provincial and/or National Government Department/s	
	Private Research by Independent Researcher	
	Non-Governmental Organisation	
	National Department of Education Commissioned Study	
	Commissions and Committees	
	Independent Research Agency	
	Statutory Research Agency	
	Independent Study by Higher Education Institution	

2.2	If Post-Graduate Study – Please indicate by placing a "X" in the appropriate column	
	Honours	Masters
		Doctorate
		X

2.3	Full title of Thesis / Dissertation / Research Project
	Talking science in South African classrooms: A case study of grade 10 - 11 science classes in Soweto

2.4	Value of the Research to Education (Attach Research Proposal)
	Proposal attached

2.5	Student and Postgraduate Enrolment Particulars (if applicable)
Name of institution where enrolled:	University of the Witwatersrand
Degree / Qualification:	PhD
Faculty:	Humanities
Department:	Education
Name of Supervisor / Promoter:	Dr Anthony Lelliott

2.6	Employer (where applicable)
Name of Organisation/School:	N/A
Position in Organisation:	
Head of Organisation:	
Street Address:	
Postal Code:	
Telephone Number (Code + Ext):	
Fax Number:	
E-mail:	

2.7	PERSAL Number (where applicable)

N/A						

3. PROPOSED RESEARCH METHOD/S

(Please indicate by placing a cross in the appropriate block whether the following modes would be adopted)

3.1 Questionnaire/s (If Yes, supply copies of each to be used)

YES		NO	X

3.2 Interview/s (If Yes, provide copies of each schedule)

YES	X	NO	

3.3 Use of official documents

YES		NO	X
If Yes, please specify the document/s:			

3.4 Workshop/s / Group Discussions. (If Yes, Supply details)

YES	X	NO	
Workshops to familiarise teachers with the teaching strategy under investigation and to agree on TLM to be used.			
Learner group discussions of selected topics.			

3.5 Standardised Tests (e.g. Psychometric Tests)

YES		NO	X
If Yes, please specify the test/s to be used and provide a copy/ies			

4. RESEARCH PROCESSES

4.1 *Types of Institutions.* (Please indicate by placing a cross alongside all types of institutions to be researched).

INSTITUTIONS	Mark with "X" here
Primary Schools	
Secondary Schools	X
Technical Schools	
ABET Centres	
ECD Sites	
LSEN Schools	
Further Education & Training Institutions	
Other	

4.2 *Number of institution/s involved in the study.* (Kindly place a sum and the total in the spaces provided).

Type of Institution	Total
Primary Schools	
Secondary Schools	4* (+3)
Technical Schools	
ABET Centres	
ECD Sites	
LSEN Schools	
Further Education & Training Institutions	
Other	

GRAND TOTAL	7

* NB: Science Educators in 4 schools have so far expressed interest in participating in the research. Educators from three more schools are yet to be approached.

4.3 *Name/s of institutions to be researched.* (Please complete on a separate sheet and append if space is deemed insufficient).

Name/s of Institution/s
Noordgesig High School
Senaoane High School
Bopasenatla High School
Mncube High School
Educators from the following schools will also be invited to participate in the research:
Kwadedangendiale High School
Ibhongo High School
Jabulani High School

4.4 *District/s where the study is to be conducted.* (Please mark with an "X").

District
Johannesburg East
Johannesburg South
Johannesburg West
Johannesburg North
Gauteng North
Gauteng West

District
Tshwane North
Tshwane South
Ekurhuleni East
Ekurhuleni West
Sedibeng East
Sedibeng West

If Head Office/s (Please indicate Directorate/s)

NOTE:

If you have not as yet identified your sample/s, a list of the names and addresses of all the institutions and districts under the jurisdiction of the GDE is available from the department at a small fee.

4.5 Number of learners to be involved per school. (Please indicate the number by gender).

Grade	1	2	3	4	5	6
Gender	B	G	B	G	B	G
Number						

Grade	7	8	9	10	11	12
Gender	B	G	B	G	B	G
Number				60	60	60*

* Learner numbers are only estimates.

4.6 Number of educators/officials involved in the study. (Please indicate the number in the relevant column).

Type of staff	Educators	HODs	Deputy Principals	Principal	Lecturers	Office Based Officials
Number	6					

4.7 Are the participants to be involved in groups or individually? Please mark with an "X".

Participation	
Groups	X
Individually	X

4.8 Average period of time each participant will be involved in the test or any other research activity (Please indicate time in minutes)

Participant/s	Activity	Time
Educators	Workshops	7.5 hours
Educators	Science lessons	8 hours
Learners	Science lessons	8 hours

4.9 Time of day that you propose to conduct your research. Please mark with an "X".

School Hours	During Break	After School Hours
X		

4.10 School term/s during which the research would be undertaken. Please mark with an "X".

First Term	Second Term	Third Term
X	X	X

DECLARATION BY THE RESEARCHER	
1. I declare that all statements made by myself in this application are true and accurate. 2. I have read and fully understand all the conditions associated with the granting of approval to conduct research within the GDE, as outlined in the GDE Research Briefing Document, and undertake to abide by them. 3. Should I fail to adhere to any of the approval conditions set out by the GDE, I would be in breach of the agreement reached with the organisation, and all privileges associated with the granting of approval to conduct research, would fall away.	
Signature:	
Date:	6 February 2008

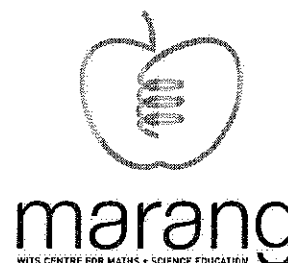
DECLARATION BY SUPERVISOR / PROMOTER / LECTURER	
I declare that: - 1. The applicant is enrolled at the institution / employed by the organisation to which the undersigned is attached. 2. The overall research processes meet the criteria of: • Educational Accountability • Proper Research Design • Sensitivity towards Participants • Correct Content and Terminology • Acceptable Grammar • Absence of Non-essential / Superfluous items	
Surname:	Lelliott
First Name/s:	Anthony
Institution / Organisation:	University of the Witwatersrand
Faculty:	Humanities
Department:	Education
Telephone:	+27 (0) 11 717 3260
Fax:	+27 (0) 259 6756
Cell:	+27 (0) 82 8504720
E-mail:	Anthony.Lelliott@wits.ac.za
Signature:	<i>A. Lelliott</i>
Date:	6 February 2008

N.B. This form (and all other relevant documentation where available) may be completed and forwarded electronically to Ebrahim Farista (ebrahimf@wits.ac.za) or Nomvula Ubisi (nomvulaubisi@wits.ac.za). The last 2 pages of this document must however contain the original signatures of both the researcher and his/her supervisor or promoter. These pages may therefore be faxed or hand delivered. Please mark fax - For Attention: Ebrahim Farista at 011 355 0512 (fax) or hand deliver (in closed envelope) to Ebrahim Farista (Room 911) or Nomvula Ubisi (Room 910), 111 Commissioner Street, Johannesburg.

Appendix 3.10

**Sample of letter of request for Principal's permission to conduct the study
in his/her school**

Appendix 3.10
Letter of permission from Principals



Research study on "Talking science in South African classrooms: A case study of grade 10 -
12 science classes in Soweto"

My name is Audrey Msimanga. I'm a Doctor of Philosophy student at the University of the Witwatersrand's School of Education. I am also a researcher in the Implementation of Curriculum Change Project (ICC) of Wits Education Policy unit in which your school is involved. Researchers in the ICC Project work together with teachers to explore strategies that they can use to improve the ways in which learning opportunities are created within the local contexts of the schools.

I am carrying out a study to investigate the use of *Science talk* as a teaching strategy to get learners talking science in implementation of the new science curriculum, with special focus on Learning Outcome 3. The use of *Science talk* addresses the requirements of the new science curriculum to engage learners more and encourage greater participation in science classrooms as well as to shift responsibility for learning to the learners themselves. Also, research indicates that *Science talk* is both a legitimate teaching strategy and a learning tool through which learners can construct scientific knowledge as they debate on concepts and issues in the classroom. I am interested in how teachers can use both mainstream science and indigenous knowledge concepts to stimulate discussion in the classroom. I will also observe how learner participation and engagement may be influenced by the nature of concepts used (e.g. topics being covered; whether mainstream science or IK science concepts are being discussed; whether it is Life Science or Physical Science concepts).

I will carry out classroom observations in 6 grade 10 - 12 science classrooms in 4 schools and will conduct interviews of the teachers and learners in those schools.

I would like to invite your school to participate in this study. Your participation means that you will allow me to interview your Life Science and Physical Science educators (pending their consent) and to make classroom observations of their Grade 10 - 12 classes as they use *Science talk* as a teaching strategy during the 1st, 2nd and 3rd terms.

My research will benefit your school in several ways:

- Your Grade 10 - 12 Life and Physical Science educators will participate in workshops in which they could gain insight on approaches to enhance learner participation and stimulate effective discussion of science concepts. They will have an opportunity to reflect on their teaching.

Mrs Audrey Msimanga Marang Centre, Wits University PBag 3, Wits 2050
Tel : 011 717 3403 fax: 011 717 3259 cell : 0761577153
e-mail: audrey.msimanga@wits.ac.za

Appendix 3.10
Letter of permission from Principals

- Your school will receive workshop materials from which the science educators can select teaching and learning materials for use in teaching using *Science talk*.
- Your grade 10 - 12 science learners will participate in using *Science talk* as a tool for scientific knowledge construction and acquisition of argumentation and critical thinking skills.
- The responses from your school will contribute to an understanding of the potential of *Science talk* as a teaching strategy to provide the pedagogical shift necessary for the implementation of the new science curriculum and will hopefully assist science educators, learning area facilitators and others in the implementation of the science curriculum so as to encourage learner participation at FET level in South African classrooms.

If you agree to take part in my study, I'd like to make it clear that your participation is entirely voluntary, **no foreseeable negative consequences will result from your participation**, and all information will be treated with confidentiality. If you do choose to participate, your Grade 10 - 12 Life and Physical Science educators and learners may decline to answer any questions, and you may withdraw from the study at any time. I hope to publish the results of my study in academic journals and in order to protect confidentiality, I use will be fictitious names.

I will provide you with a summary of my research results on completion if you would like me to.

Thank you.

Audrey Msimanga

I agree/do not agree to let my school participate in the project and agree/do not to grant Audrey Msimanga permission to work with my science teachers and their classes to carry out collaborative research on *Science Talk* as a teaching strategy. I consent/do not consent to Audrey carrying out classroom observations involving audio and video recordings of lessons as agreed between the teachers, learners, parents/guardians and her.

Name

Designation (e.g. Principal / Deputy)

School

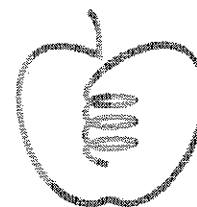
Tel:

Signature Date

Mrs Audrey Msimanga Marang Centre, Wits University PBag 3, Wits 2050
Tel : 011 717 3403 fax: 011 717 3259 cell : 0761577153
e-mail: audrey.msimanga@wits.ac.za

Appendix 3.11

Sample of letter of request for teacher consent to participate in my study



marang
WITS CENTRE FOR MATHS • SCIENCE EDUCATION

**DIVISION OF MATHS AND SCIENCE EDUCATION
SCHOOL OF EDUCATION**

Audrey Msimanga

Fax: 717 3259

E-mail: Audrey.Msimanga@wits.ac.za

Dear Mr/Ms/Mrs.....

The Wits Education Policy Unit and Marang Centre for Maths & Science are conducting a project on the Implementation of Curriculum Change (ICC). The main aim of the project is to engage researchers and educators in collaborative research in identifying and developing teaching strategies that can be used in the implementation of the new science curriculum, the NCS at FET Level. I hereby invite you to participate in the project to investigate the potential for Science talk to stimulate learner participation in the science classroom. Science talk includes all forms of verbal communication related to science topics. The project seeks to understand how we can encourage learners to talk about science and motivate them to participate and engage more with scientific concepts in the classroom. This will help develop both problem-solving and critical thinking skills as envisaged in the NCS.

I will ensure absolute confidentiality of the findings of this study, which will be used exclusively for educational research purposes where fictitious names will be assigned to you and your class/es.

If you would like to be part of this exercise, kindly sign the consent form attached to this letter and return it to the undersigned.

I thank you in advance for your commitment to this project.

Sincerely

Audrey Msimanga

PhD Research Fellow, Marang Centre for Maths & Science

University of the Witwatersrand

I wish to participate in the project and agree to grant the researcher, Audrey Msimanga access to my classroom to carry out collaborative research on Science Talk as a teaching strategy. I consent to Audrey carrying out classroom observations involving audio and video recordings of lessons as agreed between myself and her.

Name

School

Tel:

Signature Date

Appendix 3.12

Information sheet for Physical Sciences and Life Sciences teachers

Appendix 3.12

Information sheet for Life science and Physical Science teachers

Research: "Talking science in South African classrooms: A case study of grade 10-12 science classes in Soweto"

My name is Audrey Msimanga. I'm a Doctor of Philosophy student at the University of the Witwatersrand's School of Education. I am also a researcher in the Implementation of Curriculum Change Project (ICC) of Wits Education Policy unit in which your school is involved. Researchers in the ICC Project work together with teachers to explore strategies that they can use to improve the ways in which learning opportunities are created within the local contexts of the schools.

I am carrying out a study to investigate the use of *Science talk* as a teaching strategy to get learners talking science in implementation of the new science curriculum, with special focus on Learning Outcome 3. The use of *Science talk* addresses the requirements of the new science curriculum to engage learners more and encourage greater participation in science classrooms as well as to shift responsibility for learning to the learners themselves. Also, research indicates that *Science talk* is both a legitimate teaching strategy and a learning tool through which learners can construct scientific knowledge as they debate on concepts and issues in the classroom. I am interested in how teachers can use both mainstream science and indigenous knowledge concepts to stimulate discussion in the classroom. I will also observe how learner participation and engagement may be influenced by the nature of concepts used (e.g. topics being covered; whether mainstream science or IK science concepts are being discussed; whether it is Life Science or Physical Science concepts). I would like to invite your school to participate in this study. Your participation means that your school will participate in the following:

- Case studies (4 schools): You will allow me to visit your school and observe your Life Science / Physical Science classes during the 1st, 2nd and 3rd terms. I will record my observations of classroom activities using field notes, audio and video recordings.
- Interviews: You will allow me to interview you and some of your learners before and after you have completed your teaching using *Science talk*.

My research will benefit you in several ways:

- You will participate in workshops in which you could gain insight on approaches to enhance learner participation and stimulate effective discussion of science concepts. You will have an opportunity to reflect on your teaching.
- Your school will receive workshop materials from which you can select teaching and learning materials for use in teaching using *Science talk*.
- Your grade 10 - 12 science learners will participate in using *Science talk* as a tool for scientific knowledge construction and acquisition of argumentation and critical thinking skills.
- Your responses will contribute to an understanding of the potential of *Science talk* as a teaching strategy to provide the pedagogical shift necessary for the implementation of the new science curriculum and will hopefully assist science educators and others on how to encourage learner participation in science.

If you agree to take part in my study, I'd like to make it clear that your participation is entirely voluntary, **no foreseeable negative consequences will result from your participation**, and all information will be treated with confidentiality. If you do choose to participate, you may decline to answer any questions, and you may withdraw from the study at any time. I hope to publish the results of my study in academic journals. In order to protect confidentiality, all names I use will be fictitious. I will provide you with a summary of my research results on completion if you would like me to.

Thank you.

Audrey Msimanga

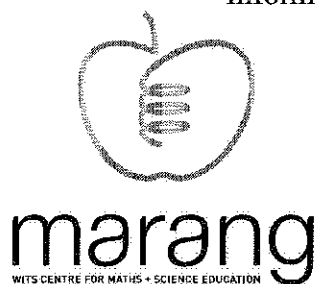
Mrs Audrey Msimanga Marang Centre, Wits University PBag 3, Wits 2050
Tel : 011 717 3403 fax: 011 717 3259 cell : 0761577153
e-mail: audrey.msimanga@wits.ac.za

Appendix 3.13

**Sample of letter of request for Physical Sciences learner consent to
participate in my study**

Appendix 3.13

Informed consent form: Physical Science learners observations



marang centre for maths + science education
university of the witwatersrand private bag 3 wits 2050 Johannesburg sa t+27 11 7173414 f+2711 7173259

Mrs Audrey Msimanga
fax: 717 3259 cell no : 0761577153
e-mail: audrey.msimanga@wits.ac.za

Using Science talk in teaching selected topics in Physical Sciences

I, _____ consent to participate in this study conducted by Mrs A. Msimanga of the University of Witwatersrand for her research on using science talk in teaching Physical Sciences topics. I realise that **no foreseeable negative consequences will result from my participation** in this study, and that the study is being conducted for purposes of improving the teaching of Physical Sciences in our schools. I give permission for the material to be used for research or teaching only. I participate voluntarily and understand that I may withdraw from the study at any time.

Observations:

I consent to the researcher observing my Physical Science classes and I consent to field-notes being made during classroom observation. I also understand I have the right to review these field-notes before these are used for analysis if I so choose. Everything I say will be kept confidential by the researcher. I will only be identified by a pseudonym in the transcript.

Name: _____

Signature: _____ Date: _____

Audio, video recording and photographs:

Audio recordings: I further consent to audio-recordings to be made of the interview. I understand I have the right to review the transcripts made from these audio recordings before these are used for analysis if I so choose. I can delete or amend any material or retract or revise any of my remarks. Everything I say will be kept confidential by the interviewer. I will only be identified by a pseudonym in the transcript. In addition, any persons I refer to in the interview will be kept confidential.

Name: _____ Signature: _____ Date: _____

Video recording: I do/ do not consent (please delete whichever is not applicable) to video recording of my lessons which serve to support the field notes. As with the field notes, these will be kept confidential.

Name: _____ Signature: _____ Date: _____

Photographs: I do/ do not consent (please delete whichever is not applicable) to photographs of the class at work which may be used to illustrate the doctoral thesis and may be used at research and teaching conferences to illustrate class activities in different schools. The names of the school will be kept confidential.

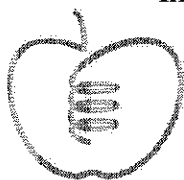
Name: _____ Signature: _____ Date: _____

Appendix 3.14

**Sample of letter of request for Life Sciences learner consent to participate
in my study**

Appendix 3.14

Informed consent form: learners for observation and recording



marang
WITS CENTRE FOR MATHS + SCIENCE EDUCATION

marang centre for maths + science education
university of the witwatersrand private bag 3 wits 2050 Johannesburg sa t+27 11 7173414 f+2711 7173259

Mrs Audrey Msimanga
fax: 717 3259 cell no : 0761577153
e-mail: audrey.msimanga@wits.ac.za

Using Science talk in teaching topics in Life Sciences.

I, _____ consent to participate in this study conducted by Mrs A. Msimanga of the University of Witwatersrand for her research on using science talk in teaching topics in Chemistry and Physics. I realise that no foreseeable negative consequences will result from my participation in this study, and that the study is being conducted for purposes of improving the teaching of Life Sciences in our schools. I give permission for the material to be used for research or teaching only. I participate voluntarily and understand that I may withdraw from the study at any time. I also understand I have the right to review field-notes, video and audio recordings and photographs before these are used for analysis if I so choose. Everything I say will be kept confidential by the researcher. I will only be identified by a pseudonym in the transcript.

Classroom observations:

I consent to the researcher observing me during Life Science classes and I consent to field-notes being made during classroom observation.

Name: _____

Signature: _____

Date: _____

Observations outside class:

I consent to the researcher observing and recording me as I talk about science related issues outside class.

Name: _____

Signature: _____

Date: _____

Audio, video recording and photographs:

Audio recordings: I further consent to audio-recordings to be made of the lessons and interviews. I understand I have the right to review the transcripts made from these audio recordings before these are used for analysis if I so choose. I can delete or amend any material or retract or revise any of my remarks.

Name: _____

Signature: _____

Date: _____

Video recording: I do/ do not consent (please delete whichever is not applicable) to video recording of me during the lessons which serve to support the field notes. As with the field notes, these will be kept confidential.

Name: _____

Signature: _____

Date: _____

Photographs: I do/ do not consent (please delete whichever is not applicable) to photographs of the class at work which may be used to illustrate the doctoral thesis and may be used at research and teaching conferences to illustrate class activities in different schools. The names of the school will be kept confidential.

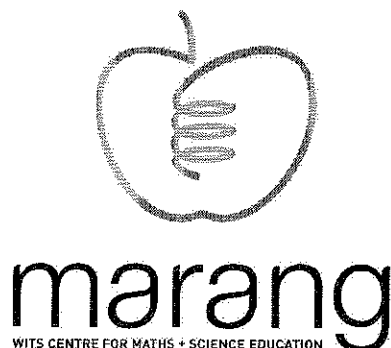
Name: _____

Signature: _____

Date: _____

Appendix 3.15

**Sample of letter of request for parental consent for their child/ward to
participate in my study**



Appendix 3.15
Informed consent form: Parent / Guardian

marang centre for maths + science education
university of the witwatersrand private bag 3 wits 2050 Johannesburg sa t+27 11 7173414 f+2711 7173259

Mrs Audrey Msimanga
fax: 717 3259 cell no : 0761577153
e-mail: audrey.msimanga@wits.ac.za

Research Project: Using science talk in teaching and learning in science

I, _____, parent/guardian of _____ consent to her/him participating in the study conducted by Mrs A. Msimanga of the University of Witwatersrand for her research on using science talk in teaching and learning science.

I realise that no harm is intended for my ward, and that the study is being conducted for educational purposes.

Everything my ward says will be kept confidential by the interviewer. My ward will only be identified by a pseudonym in the transcript. In addition, any persons my ward refers to in the interview will be kept confidential.

Verbatim quotes from my ward may be used in the research report, but they will be reported so that her/his identity is anonymous. Any specific individuals or courses my ward refers to will be given pseudonyms. I understand that the results of the study may be published, but my wards's identity will be anonymous.

I allow my ward to participate voluntarily and understand that s/he may withdraw from the study at any time.

Name: _____ Signature: _____ Date: _____

Audio recordings: I further consent to my ward being audio recorded as part of the study.

Name: _____ Signature: _____ Date: _____

Video recording: I do/ do not consent (please delete whichever is not applicable) to video recording of my lessons which serve to support the field notes. As with the field notes, these will be kept confidential.

Name: _____ Signature: _____ Date: _____

Photographs: I do/ do not consent (please delete whichever is not applicable) to photographs of the class at work which may be used to illustrate the doctoral thesis and may be used at research and teaching conferences to illustrate class activities in different schools. The names of the school will be kept confidential.

Name: _____ Signature: _____ Date: _____

Appendix 5.01

Description of interactions in Mrs Thoba's lessons

Appendix 5.01

Table 5.01 Description of interaction in Mrs Thoba's lessons

Lessons observed	Teaching purpose	Discourse	Teacher communicative approach	Teacher intervention style	Pattern of interaction
Gr 10 Physics Waves	Opening for learner ideas of pulse	Interactive	I/D	Elicits Open & closed questions	IRE IRPRP...E
	Learner experiments	Interactive	I/D	Uptake	IRE/F
	Developing the scientific story	Interactive	I/A; I/D	Foregrounds Explanation/exposition Some thinking questions	IRPRP...E IRE/F
	Closing down	Interactive Non-interactive	I/A some NI/A	Elaborates & Evaluates Explanation/exposition	IRE/F
Gr 11 Chemistry Bond energy	Prior knowledge	Interactive	I/A	Elicits Closed questions	IRE/F IRPRP...E
	Introducing bond energy	Interactive	I/A	Closed questions Explanation/exposition	IRE/F IRPRP...E
	Developing the scientific story	Interactive	I/A	Some thinking questions Evaluates	IRE/F IRPRP...E
	Addressing learner misconception	Interactive	I/A some I/D	Some thinking questions Foregrounds; maintains Uptake; Elaborates & Evaluates Explanation/exposition	IRE IRPRP...E IRRR...E Unsolicited learner contributions
Gr 11 Chemistry	Introducing new & exploring learner	Interactive	I/A I/D	Explanation/exposition Closed questions	IRE/F IRPRP...E

Lessons observed	Teaching purpose	Discourse	Teacher communicative approach	Teacher intervention style	Pattern of interaction
Reactions of acids: Class 1 Introduction	ideas & developing scientific story & introducing the activity	Non-interactive episodes	NI/A	Elicits Some uptake Overlooks	
Gr 11 Chemistry Reactions of acids: Class 1 Feedback	Capturing learner solutions Checking learner understanding & Developing the scientific story Reviewing	Interactive Interactive & Non-interactive Interactive & Non-interactive	I/D I/A I/D I/A some NI/A	Elicits Open & closed questions Explanation/exposition Closed questions Some thinking questions Foregrounds Evaluates Uptake Elaborates	IRE/F IRE/F IRPRP...E IRE/F
Gr 11 Chemistry Reactions of acids: Class 2	Introducing new topic & exploring learner ideas Developing the scientific story & exploring learner ideas Reviewing	Interactive Non-interactive Interactive & Non-interactive Interactive Non-interactive	I/A I/A I/D NI/A I/A I/D & some NI/A	Elicits & evaluates Closed questions Some Uptake Explanation/exposition Closed questions Foregrounds & evaluates Some Uptake Closed questions Evaluates Explanation/exposition	IRE/F IRPRP...E IRE/F IRPRP...E IRE/F

Appendix 5.02

Description of interactions in Mr Far's lessons

Appendix 5.02

Description of interaction in Mr Far's lessons

Lessons observed	Teaching purpose	Discourse	Teacher communicative approach	Teacher intervention style	Pattern of interaction
Gr 10 Chemistry Properties of compounds	Exploring learner ideas. Prior knowledge of elements, mixtures and compounds	Interactive	I/D I/A	Elicits Open & closed questions Uptake	IRE IRE/F
	Introducing the activity Learner experiment. Demonstration of burning magnesium	Interactive Interactive	I/A IA; I/D	Explanation/exposition Elaborates & Evaluates Elicits Open & closed questions Uptake	IRPRP...E IRE/F
	Introducing new topic & developing scientific story	Non-interactive	NI/A	Explanation/exposition Some thinking questions Elaborates & Evaluates	IRPRP...E IRE/F
	Summary				
Gr 11 Chemistry Chemical systems	Opening for learner ideas of a system Capturing learner solutions from discussions of systems in pairs	Interactive	I/D	Elicits Closed questions Closed questions Explanation/exposition	IRE/F IRPRP...E IRE/F IRPRP...E

Lessons observed	Teaching purpose	Discourse	Teacher communicative approach	Teacher intervention style	Pattern of interaction
Gr 12 Physics Momentum	Developing the scientific story, compiling components of systems	Interactive	ID; I/A	Some thinking questions Evaluates Some thinking questions Foregrounds; maintains Uptake; Elaborates & Evaluates Explanation/exposition	IRE/F IRPRP...E IRF IRPRP...E IRRR...E Unsolicited learner contributions
	Opening for more learners' ideas on "cycle" and "global"	Interactive	ID		
	Capturing learner water cycles Addressing learner misconceptions about water bodies in the water cycle	Interactive	IA; some ID IA	Some thinking questions Elaborates & Evaluates Foregrounds; maintains Uptake	IRF IRPRP...E IRRR...E Unsolicited learner contributions
	Developing the scientific story of water cycles	Interactive	IA; some NIA; some NID	Elaborates & Evaluates Explanation/exposition Some thinking questions Evaluates	IRF IRPRP...E IRRR...E
	Closing down				
Gr 12 Physics Momentum	Reviewing	Interactive	IA; ID	Elicits Open & closed questions	IRE/F
	Exploring learner ideas	Interactive	IA; ID	Elicits Open & closed questions	IRE/F IRPRP...E
	Introducing new	Interactive &	IA; ID	Explanation/exposition	

Lessons observed	Teaching purpose	Discourse	Teacher communicative approach	Teacher intervention style	Pattern of interaction
Gr 12 Chemistry Mining	topic & introducing the activity	Non-interactive	some NIA	Closed questions Some thinking questions	IRE/F IRE/F IRPRP...E
	Capturing learner solutions & developing the scientific story	Interactive& Non-interactive	ID; IA some NIA some NID	Foregrounds Evaluates Uptake Elaborates	IRE/F IRE/F IRPRP...E
	Checking learner understanding & developing the scientific story	Interactive& Non-interactive	IA; NID	Open & closed questions Explanation/exposition Some thinking questions Foregrounds; Evaluates Uptake; Elaborates	
	Summarising	Non-interactive	NIA; NID		
Gr 12 Chemistry Mining	Introducing the activity	Interactive	IA	Exposition	IRE/F IRPRP...E
	Learner presentations	Interactive	ID	Elicits Closed questions Explanation Some uptake Overlooks	
	Checking learner understanding & developing the scientific story	Interactive	IA NID NIA		
	Non-interactive	Non-interactive	NIA; NID		
Gr 12 Organic chemistry Alkanes	Reviewing				IRE/F IRPRP...E
	Introducing new topic & exploring learner ideas	Interactive	IA	Elicits & evaluates Closed questions Some Uptake	

Lessons observed	Teaching purpose	Discourse	Teacher communicative approach	Teacher intervention style	Pattern of interaction
Gr 12 Organic chemistry Alkenes	Developing the scientific story	Interactive & Non-interactive	IA NIA	Explanation/exposition Closed questions Foregrounds & evaluates	IRE/F IRPPRP...E
	Learner small groups on structural formulas	Interactive	ID	Some Uptake	IRE/F
	Exploring learner solutions	Interactive	ID; IA some NIA	Closed questions Evaluates	IRE/F
	Reviewing	Interactive	ID; IA	Explanation/exposition	IRPPRP...E
	Introducing new topic & exploring learner ideas	Non-interactive Interactive	NIA IA	Elicits & evaluates Closed questions Some Uptake	IRE/F IRPPRP...E
	Developing the scientific story	Interactive & Non-interactive	IA	Explanation/exposition Closed questions Foregrounds & evaluates	IRE/F IRPPRP...E
	Learner small groups on structural formulas	Interactive	ID	Some Uptake	IRE/F
	Exploring learner solutions	Interactive	IA; ID NID	Closed questions Evaluates	IRE/F IRPPRP...E
	Reviewing	Non-interactive	NID	Explanation/exposition	IRPPRP...E

Appendix 5.03

Description of interactions in Mrs Nkosi's lessons

Table 5.03 Characterising interaction in each of Mrs Nkosi's lessons

Lessons observed	Teaching purpose	Discourse type	Teacher communicative approach	Teacher intervention style	Pattern of interaction
Grade 11 Respiration: inhalation, exhalation and gaseous exchange	Review of previous lesson Developing scientific story Reviewing	Interactive	I/A; I/D Explanation/exposition Imitation I/A (veiled N/A) Drill 608-614	Explanation/exposition Closed questions Elicitation Uptake Foregrounding Elaboration Evaluation	IRF IRPRP...E
Grade 11 Respiration: Diseases of the respiratory system	Review of previous lesson Developing scientific story Reviewing	Interactive	I/A; I/D; NI/D	Explanation/exposition Closed questions Elicitation Uptake Foregrounding Elaboration Evaluation Thinking questions – few	IRF IRPRP...E
Grade 11 Population dynamics	Review of previous lesson Developing scientific story Reviewing	Interactive	I/A; I/D; NI/D;	Explanation/exposition Closed questions Elicitation Uptake Foregrounding Elaboration Evaluation Thinking questions – few	IRF IRPRP...E
Grade 11 Conservation biology	Review of previous lesson Developing scientific story Reviewing	Interactive	I/A; NI/D; NI/A	Telling/exposition Closed questions Elicitation Uptake Foregrounding Elaboration Evaluation Thinking questions – few	IRF IRPRP...E IRF IRPRP...E IRRR..E

Appendix 6.01

Sample of transcript analysis in ATLAS.ti

(Mrs Thoba's lesson on bond energy)

P 4: Bond energy lesson transcript.rtf

Path: C:\Users\Public\Mother's documen...\Bond energy lesson transcript.rtf
Media: RICHTEXT

Printed: 2012-09-14T12:06:36
By: Super

From HU: RQns hu24Feb2011 Analysis of Groups 1to3
HU-Path: [C:\Users\Public\Mo...\RQns hu24Feb2011 Analysis of Groups 1to3.hpr5]

Codes: 40

Memos: 5

Quotations: 234

Families: <none>

Comment: <none>

- 001 T: Haah?  T Probing
- 002 Ss: ... (inaudible)  S response inaudible
- 003 T: Atoms that bond they share the electrons...what about the ionic bonding? ...what about ionic bonding?  T focuses
 T initiates
 T repeats S response2
- 004 S1: One...one atom will bond (inaudible)...its ion and another one...(inaudible)... One atom...will give its electrons to ...another one...the other one will accept the electrons...and the other one will give its electrons  S response to T
- 005 T: Ok...and it takes place between what type of elements?  T affirms
 T initiates
- 006 S1: metals and no-metals  S response to T
- 007 T: Between no-metals...metals and non-metals ... metals in this regard will...give off their electrons to...  T explains S response
 T focuses
 T repeats S response2
- 008 S?: give away...  S response to T
- 009 T: non-metals  T answers own question
- 010 Ss: non-metals  S chorus answer
- 011 S1: Since the atom...er...since the atom is neutral, Maam it has the same number of protons and...what you call...electrons...so obviously if the electrons (inaudible)...so the number of atoms...the number of protons will be more than the number of electrons  S explains
- 012 T: Positively charged...protons in the nucleus ...will exceed the number of electrons around the nucleus...hence the atom...will be...  T paraphrases2

	positively...charged	
013	Ss: charged	 S chorus answer  ME - 14/04/10 [2]
014	T: Because now the protons...the number of the protons...is no longer the same as the...number of ...electrons	 T explains2
015	Ss: electrons	 S chorus answer
016	T: Ok let us talk about non-metals...they give off...no...they accept...the electrons...and they become...negatively charged	 T new concept
017	Ss: negatively charged	 S chorus answer
018	T: negatively charged...Why?	 T initiates  T repeats S response2
019	S: Because it has accepted the electron from...from the nucleus (inaudible)....so it has (inaudible)	 S response to T
020	T: Because now the number of electrons...exceeds the number of protons in the...nucleus. Ok today...we are going to look at the energy changes during these two types of...bonding. What do you understand by the term energy?...what is energy?	 T initiates  T introduces topic  T new concept  T paraphrases2
021	Ss: (softly) ability to do work	 Ss together a few  ME - 14/04/10 [3]
022	S3: (louder) the ability to do work	 S response to T
023	T: Ability to ...do work	 T repeats S response2
024	Ss: do work	 S chorus answer
025	T: Ok let us talk about energy changes...during covalent bonding...(T writes on board).....Ok what	 T refocusing  ME - 14/04/10 [4]

	do you think...are the types of energy that are going to take place during this bonding?	
026	S4: kinetic energy	✿ S response to T
027	T: Kinetic energy...what is kinetic energy?	✿ T initiates ✿ T repeats S response2
028	S4: (inaudible)	✿ S response inaudible
029	T: The energy of the body by virtue of its movement...Please speak loud...Ne?...ok...What else?...What else?...	✿ T directs~ ✿ T initiates ✿ T repeats S response2
030	S5: I think ionisation energy	✿ S response to T
031	T: Ionisation energy...what is ionisation energy?	✿ T Probing ✿ T repeats S response2
032	S5: Ionisation energy is the energy required to remove an electron...	✿ S response to T
033	T: Energy is the energy required to remove...an electron...remember we are talking about covalent bonding. No electrons are removed in covalent bonding but electrons are...shared. Do we understand each other there?	✿ T checks consensus ✿ T gives cue ✿ T informs ✿ T repeats S response2
034	Ss: Yes	✿ S chorus answer
035	T: So ionisation energy...does not apply to covalent bonding	✿ T focuses ✿ What is this?
036	T: What else?...	✿ T initiates
037	S6: Potential energy	✿ S response to T
038	T: Potential energy...what do you understand by the term potential energy?...Potential energy...What is	✿ T initiates ✿ T Probing ✿ T repeats S response2

	potential energy? Is it for the first time you see this word?	
039	Ss: No	✿ S chorus answer
040	T: Potential energy...Potential energy?	✿ T Probing
041	S1: Energy due to animation...	✿ S response to T
042	T: Due to...?	✿ T asks for clarification
043	S1: Animation (not clear)...	✿ S explains own answer ✿ S response to T
044	T: animation...?	✿ T asks for clarification
045	S1: Yes	✿ S response to T
046	T: What does that mean?	✿ T asks for clarification
047	S?: (inaudible)..er..the position of a body	✿ S explains ✿ S response to T
048	T: energy of a body...?	✿ T asks for clarification
049	S1: (inaudible)	✿ S response to T
050	T: by virtue of its position...we call it the...potential energy...by virtue of its position it has potential energy, the stored energy in it. ok...we are going to explain the energy changes in covalent bonding using the...potential energy graph...ok, the atoms...they have a chemical potential energy. The chemical potential energy...it arises from the positions of the atoms...arises from the positions of the atoms...and secondly from the forces acting on the atoms...That's where potential energy arises...it is from...the positions of the...atoms. Remember we are talking	✿ T new concept ✿ T paraphrases2 ✿ T repeats S response2 ✿ T tells

about...covalent bonding. We going to deal with...two atoms...so the position of the two atoms...they give rise to...potential energy...and the forces acting on the atom...they also give rise to...potential energy. Let us talk about...two hydrogen atoms...they are a far distance apart...Ne? They are a far distance apart. This means that there is no interaction between the atoms...what do you think the potential energy is?...They are a...they are a far distance apart...and if they are at far distance apart that means that...there are no forces acting on them. There is no interaction between them. What do you think their potential energy is?

051 S7: it will be zero Maam

052 T: its zero?...why?

053 S7: Because of there is no attraction...they are not...they are far distant...so they...they are...I cant explain Maam...

054 T: say it in your language its fine

055 S7: Maam in my language its so...ok (Class laughter)
ok... fine Maam let me say it in my language...ok
fine Maam *tinekule* Maam *atihlangananga...ti...*
(inaudible) Maam...but Maam *lokho*
tingahlangananga... tahari... constant ...tahari...net
force yatona...tahari zero...and so lokho tita
atrakthana lokho setitangananga tiya atrakhta ke
yikhona tingataba...tingataba...

✿ S response to T

✿ T Probing

✿ T repeats S response2

✿ S explains own answer

✿ S response to T

✿ T directs~

✿ Code switching

✿ S explains own answer

056 T: The forces will then attract

057 S7: Yes

058 T: Ok what she means is...if they are as far distant apart then it means...their potential energy is zero because there are no forces that act between the...two atoms. Yes...Let us start here (writing into graph - top right quadrant). Therefore this means that the potential energy is zero because there is no interaction between the...atoms. So this gives us the potential energy being zero. Ok now...they move closer...in other words the distance between them decreases...They move closer to one another. If they move closer to one another this means that the distance between them decreases. What do you think is going to happen?

059 S7: er...if they decrease they are now going to be negatively charged...

060 T: Why?

061 S7: they are going to be negative...coz *manje* (now) Maam...

062 T: What is going to be negative? Let us start there.

063 S7: The Hydrogen atoms Maam...they are...er...

064 T: is going to be negative?

065 S7: Yes Maam.

066 T: Why?

Translates S response

S response to T

T Probing

Translates S response

S response to T

T Probing

Code switching

S explains own answer

S response to T

T Probing

S explains own answer

S response to T

T Probing

S response to T

T Probing

- 067 S7: Maam because of ...er...now they are attracting each other *angithi* Maam. *Angithi manje sezahlangana sezifunukuhlangana...*(now they are almost ..they are just about to come together)
- 068 T: If they attract each other the hydrogen becomes negative?
- 069 S7: Yes
- 070 T: What do you think? What do you think of that statement?
- 071 Ss: (inaudible commotion)
- 072 T: She says that...if they come closer the hydrogen is going to become negative because of the attraction force. What do you think about that?
- 073 S8: Er...Maam I much agree...
- 074 T: You agree?
- 075 S8: Yes Maam...
- 076 T: ok
- 077 S8: coz Maam...ok fine...when they bond covalently they are bonding to achieve what the nearest noble gas...
- 078 Ss: Yes
- 079 S8: ok fine then...when they...
- 080 Ss: (Laughter)

- Code switching
- S explains own answer
- S response to T
- T Probing
- S response to T
- T focuses
- S response inaudible
- Ss together
- T initiates
- T repeats S response2
- S response to S
- S response to T
- T Probing
- S response to T
- T Probing
- S explains own answer
- S chorus answer
- S response to T

- 081 S8: soon as they reach the noble the nearest noble gas
both of them what...they share...and then soon as
they are sharing...er...both of these...er...electrons
they become negatively charged...
- 082 T: What becomes negatively charged?
- 083 S7: Those atoms...
- 084 T: The hydrogen?
- 085 S8: Yes Maam
- 086 T: When does a po...when does a negative charge
form? When does an atom become negatively?
- 087 S10: When two atoms collide?
- 088 T: Hah?
- 089 S10: When two atoms collide.
- 090 T: And?...
- 091 S10: it becomes negative charged...they have one
electron
- 092 S7: Eh Maam *manje angithi seziya*
kholay...seziyahlangana angithi...(because now they
are colliding...coming together)
- 093 Ss: (shuffling and whispering)
- 094 S10: That's what we think...
- 095 T: Let me give you a chance
- 096 S11: Madam...I disagree with the statement Maam
- S explains own answer
S response to T
- T Probing
- S response to T
- T Probing
- S response to T
- T Probing
- S response to T
- T Probing
- S repeats own answer
- T Probing
- S explains own answer
- Code switching
S response to S
S response to T
- Ss together
- S response to S
S response to T
- T directs~
- S response to S
S response to T

- coz Maam I think when the two atoms (inaudible)
Maam...the...the...chemical potential energy...will
increase
- 097 **T:** Why...(inaudible)...why do you disagree with the
statement?
- 098 **S11:** Its because Maam...when the...the...the two
atoms Maam interact its impossible for them to be
negatively charged.
- 099 **S7:** Maam didn't you say...
- 100 **T:** Why?
- 101 **S11:** *Azikathintani* (they have not yet touched) Maam.
- 102 **Ss:** Yes...yes
- 103 **S7:** Maam didn't you say when they ...er...when they
get closer to each other when they attract each other
the potential energy it will decrease *angithi* Maam?
- 104 **S11:** Its like this... (holding pen and set square apart
in each hand)
- 105 **S7:** It will decrease...
- 106 **S11:** *Azikathintani* (they have not yet touched) Maam.
- 107 **T:** But you didn't say that...what you said is...
- 108 **S7:** Maam you said... you said the p...yaah...its
because of you didn't say it because you said the
potential energy will decrease...and therefore those
atoms are going to be negative...ly charged

T Probing

S explains own answer
S response to T

S repeats
S response to T

T Probing

Code switching S exp
S response to T

Ss together

S explains own answer

S explains own answer
S illustrates
S response to S
S response to T

S response to S
S response to T

Code switching S exp
S explains own answer

T refocusing

S explains own answer

- 109 T: ok...our statement...the statement is...if the
potential energy decreases then...the hydrogen atoms
are going to be negatively charged. Are they going to
be negatively charged?
- 110 Ss: No...No...Yes...No...
- 111 S7: Let's just say yes Maam...(Class laughter)
- 112 T: When does...when does a negative ion form?
- 113 S7: Er Maam...Maam...I don't know (Class laughter)
- 114 T: That's a problem. Yes? (pointing to another
student)
- 115 S8: Its whereby Maam it gains...er...electrons
- 116 T: Do we have anything about gaining of electrons
here?
- 117 Ss: No
- 118 T: So how can a negative ion form?
- 119 S12: Yes
- 120 T: Yes?
- 121 S13: I don't think of any...er...er...negative charge
forming coz we are dealing with covalent bonding...
(inaudible) we are dealing with covalent bonding the
electrons they share...they share their electrons with
each other...so I think negatively charged electrons
only form when you are dealing with ionic bonding

T Probing
T refocusing

Ss together
ME - 14/04/10

S response to T

T gives cue

S response to T

T affirms
What is this?

S response to T

T focuses

S chorus answer
ME - 14/04/10 [1]

T focuses

S response to T

T directs~

S explains
S response to T

122	Ss: Yes	S chorus answer
123	T: (inaudible)... Yes?	T directs~
124	S14: (inaudible)..	S response inaudible
125	T: They are coming closer	T repeats S response2
126	S?: Yes	S response to T
127	T: They are coming closer. Remember we have a positively charged nucleus we have the negatively charged energy levels...they have electrons which are negatively charged ... What type of forces exist there?	T explains2 T initiates T repeats S response2
128	S?: (inaudible)...magnetic force...	S response to T
129	S8?: <i>Ayikho</i> (never) Maam	Code switching S response to S
130	S?: Potential energy	S response to T
131	S?: Force of attraction	S response to T
132	S8?: Oh force of attraction <i>ushilo</i> (she says). Maam <i>bathi iright</i> (they say its correct) iforce of attraction.	S response to S S res
133	T: Attractiive forces?	T focuses
134	S?: Yes	S response to T
135	T: Yes. We have attractive forces. Can you explain the attractive forces?	T affirms T initiates
136	S?: Explain the attractive forces	
137	S15: When...er...the one atom gets attracted to the other one...and therefore like...to form one atom	S response to T

- 138 **T:** What attracts what? Here we have a nucleus
positively charged we have the electrons around the
nucleus which are negative. So what attracts what?
- 139 **S?:** The electrons
- 140 **T:** Ok let us give her a chance
- 141 **S15:** The electrons Maam
- 142 **T:** They attract?
- 143 **S15:** One another and they collide to form one
electron
- 144 **T:** Electrons attract one another? She said so.
Electrons are...?
- 145 **Ss:** Negatively charged
- 146 **T:** Negatively charged?
- 147 **S15:** Yes
- 148 **T:** How do they attract one another?
- 149 **S15:** Magnetic Maam (Class Laughter)
- 150 **T:** How do they attract one another?
Negative...charges? Two negative charges...do they
attract?
- 151 **Ss:** No
- 152 **S11:** *Yizwa* (look) Maam...*Mina* (I) Maam I think that
the positive nucleus attracts the negative
electron...just like that

✿ T explains2
✿ T initiates

✿ S response to T

✿ T directs~

✿ S response to T

✿ T Probing

✿ S explains own answer
✿ S response to T

✿ T gives cue
✿ T Probing

✿ S chorus answer

✿ T Probing

✿ S response to T

✿ T focuses

✿ S response to T

✿ T focuses

✿ S chorus answer

✿ Code switching ✿ S resp

- 153 T: the positive...nucleus will attract the...  T repeats S response2
- 154 Ss: negative electron  S chorus answer
- 155 T: negative electron of another atom. What
else?...What else?...What else?...And again these
positive will attracts that negative. Shall we talk about
the repulsion forces?  T explains S response
 T initiates
- 156 S?: Yes..Yes... (inaudible learner talk)  S response inaudible
- 157 T: Yes?  T directs~
- 158 S1: Maam a repulsion force...er...is a force which
happens when two charges which are identical
(inaudible) each other and in that way end up...
(moving his hands apart to indicate repulsion)
 S explains
 S response to T
- 159 T: they repel each other  T paraphrases2
- 160 S: Yes  S response to T
- 161 T: Can you give me the repulsion forces in these two
atoms? What will repel what?  T initiates
- 162 S1: The positive nucleus of one hydrogen and the
other...positive nucleus of the other hydrogen...same
to their electrons Maam  S explains own answer
 S response to T
- 163 T: These will...repel  T paraphrases2
- 164 Ss: repel  S chorus answer
- 165 T: And again the electrons will also...repel. When
these forces act on each other...an energy is used.
That is why the potential energy decreases...when the
 T explains2

- atoms come closer and then the potential energy...potential energy will...decrease. This trend will continue until we have the minimum potential energy. They will come closer and closer until we have the...minimum potential energy. And at that time when we have the minimum potential energy...this means that the attractive force is greater than the repulsion...force
- 166 **Ss:** force  S chorus answer
- 167 **T:** Is greater than the...repulsion force. They come closer attracting force is still greater than the...repulsion force.  T summarises
- 168 **Ss:** repulsion force.  S chorus answer
- 169 **T:** There will come a time we have a...minimum potential energy. And thereafter what do you think is going to happen after that stage...when the two atoms come closer after we have reached the minimum potential energy?  T initiates
 T tells
- 170 **S?:** They are going to share their electrons  S response to T
- 171 **T:** They have already shared them... They have come closer until the energy levels overlap. They share the electrons. They come closer. What do you think is going to happen?  T overlook
 T Probing
- 172 **S?:** Maam they'll be held together and H₂ will be formed.  S response to T
- 173 **T:** H₂ is already formed. What do you think is going  T overlook
 T Probing

	to happen? Can you explain this in terms of the attractive force and the repulsion force?	
174	S8?: Eh Maam...I cant explain but	✿ S response to T
175	T: When they come closer...after the minimum potential energy is achieved	✿ T Probing
176	S16: Maam I think repulsion will take....(inaudible)	✿ S response to T
177	T: They take...?	✿ T asks for clarification
178	S16: ... inaudible	✿ S response inaudible
179	T: Yes. When they come closer after this... after this minimum potential energy... attraction force... not attraction... repulsion force is going to be greater than the... attraction force. And...they are going to...repel.	✿ T affirms ✿ T paraphrases2 ✿ T summarises
180	Ss: Repel	✿ S chorus answer
181	T: And when they repel the potential energy rises.	✿ T tells
182	Ss: Rises	✿ S chorus answer
183	T: It increases steeply.	✿ T tells
184	S?: (inaudible)... repulsion force is greater than attraction force.	✿ S idea
185	T: Yes. After this point the repulsion force...becomes...	✿ T affirms ✿ T initiates
186	S?: Greater...than the...	✿ S response to T
187	T: Greater...than the...attraction force_	✿ T tells

- 188 Ss: Attractive force
- 189 T: And... they separate. They dissociate...
- 190 S?: Hmm
- 191 T: If they come... closer... any questions?...So this is our graph... the potential energy graph.
- 192 S11: Maam...is it that always with the...the atoms after they...they have attracted each other Maam...they always have to repel again Maam?
- 193 T: Not necessarily. Remember when we ...when we dissociate the atoms we have to put in energy. Isn't it? Not necessarily that they will... but if they...they they persist on coming closer then the repulsion force is going to take place...its going to take over...and if it takes over the potential energy...rises
- 194 Ss: Rises...
- 195 T: Because they are going to... repel each other. The two nuclei...are going to...repel...
- 196 T: So do you see that the stable molecule has the lowest potential energy? It is negative as you can see in our graph...this side we have positive values of potential energy this side we have ...
- 197 Ss: negative
- 198 T: negative values of potential energy. A stable molecule is having the...lowest potential energy
- S chorus answer
- T tells
- T asks for questions
T returns to idea2
T summarises
- S question
- T explains2
- S chorus answer
- T explains2
- T checks progress so far
T summarises
- S chorus answer
- T summarises

199	Ss: ...lowest potential energy	✿ S chorus answer
200	T: and it is...negative.	✿ T summarises
201	Ss: ... negative	✿ S chorus answer
202	S17: Maam if we have ...(inaudible) different atoms...(inaudible) would the ...(inaudible) take place?	✿ S question
203	S?: No	✿ S response to S
204	T: different...like?	✿ T asks for clarification
205	S17: Maybe hydrogen and helium?	✿ S response to T
206	T: Hydrogen and...?	✿ T Probing
207	S17: Helium	✿ S response to T
208	T Helium! Helium is a...noble gas	✿ T Probing
209	Ss: Noble gas	✿ S chorus answer
210	T: Does it take part in bonding?	✿ T Probing
211	Ss: No	✿ S chorus answer
212	S? & S?: Ok... Maam hydrogen and oxygen (talking at the same time)	✿ S response to S ✿ S response to T
213	T: Why?	✿ T Probing
214	S16: Because it's a noble gas. (Class laughter)	✿ S response to T
215	T: He says because it's a noble gas. Outer energy level is...filled.	✿ T repeats S response2

- 216 Ss: Filled ✿ S chorus answer
- 217 T: So it doesn't take part in...bonding ✿ T Probing
- 218 S?: Ok Maam what....
- 219 T: Ok what happens now if we have hydrogen and chlorine? ✿ T initiates ✿ T Prob
✿ T new concept
- 220 S8: *Angeke ...i-repulsion force i-theyikhe* place (the repulsion force can not take place). ✿ Code switching
✿ S response to T
- 221 T: Is the same thing going to apply? ✿ T Probing
- 222 Ss: No...No... ✿ S chorus answer
- 223 T: Why? ✿ T Probing
- 224 S?: Because...(inaudible) ✿ S response inaudible
- 225 S13: Ah...I don't think so Maam because (inaudible) ✿ S response to T
...ionic bonding (inaudible)..we only use the electron...(inaudible)
- 226 T: He says ionic bonding is going to take place... we talked... last week we talked about electronegativities. What is an electronegativity? ✿ T repeats S response2
✿ T revision
- 227 S?: Yes ✿ S response to T
- 228 S?: An electronegativity... (fades off) ✿ S response to T
- 229 S?: Eh...an electronegativity is the ability of the atom in the molecule... ✿ S response to T

Appendix 6.02

Sample of transcript of interview/discussion with Mrs Nkosi after lesson on indigenous knowledge of owls and conservation

P17: KT Post teaching discussion after Pop

Path: C:\Documents and ...\KT Post teaching discussion after Population.rtf
Media: RICHTEXT

Printed: 2012-09-14T12:08:28
By: Super

From HU: RQns hu24Feb2011 Analysis of Groups 1to3
HU-Path: [C:\Users\Public\Mo...\RQns hu24Feb2011 Analysis of Groups 1to3.hpr5]

Codes: 0

Memos: 0

Quotations: 0

Families: <none>

Comment: <none>

- 01 R: I think we can do just a quick review? You are not rushing are you?
- 02 T: ah ah *ithi ngihlalendaweni yami ngizenze mkhulu* (No let me sit here and make myself important)
- 03 R: *umkhulu vele umkhulu vele* (of course you are important you are important already)
- 04 T: *(to learner)* can you close the door please
- 05 R: thank you very much for allowing me to you class
- 06 T: close the door please papa
- 07 R: *(to learner)* thank you very much for helping me
- 08 Lb: ok Maam
- 09 R: *(to teacher)* thank you very much allowing me to come just a quick debrief as we always do. Ah what is your take of the lesson?
- 10 T: Ah well I would say the learners were actively participating
- 11 R: Hhm
- 12 T: and I tried to involve those you know some of them are quiet
- 13 R: Hhm
- 14 T: they usually don't participate unless you pick up on them so yah I do that
- 15 R: why is it important for all of them to participate?
- 16 T: no its important because you know you may think everyone understands so it actually is a way of taping finding out if they actually understand and they are moving with you as you pursue the lesson.
- 17 R: so its important for them to talk during the lesson?
- 18 T: exactly
- 19 R: How do you get them to talk?
- 20 T: *(laugh)* I think you know learners differ yah there are those you might have noticed who are always talking and some are average but er just pointing at them asking them to say something irrespective of whether the answer is correct or incorrect but at least it gives them you know that confidence that I am recognised as well I am part of the class interaction because sometimes if you just focus on those who are always talking then the others end up inactive and feeling you know that they are not important
- 21 R: Hhm
- 22 T: and a low self esteem as well develops but when you give them that opportunity they actually ... *(inaudible)*
- 23 R: ok and what kind of questions do you find get them talking?

- 24 T: ah maybe its usually if there is a new concept they don't understand then they ask questions they talk but they just ask brief questions then its up to you to elaborate on what they are asking as an educator you know
- 25 R: Hhhm
- 26 T: because its not easy for them to ask lengthy questions but you pick that there is something they want to know they may not even be able to present it as they should
- 27 R: hhm
- 28 T: but then as you elaborate you actually understand
- 29 R: Hhm
- 30 T: that they wanted you answer that question that they actually did not ask
- 31 R: any the questions that you may ask which you find make them talk?
- 32 T: when you start by asking simple questions yah simple questions with a few words you know and then from there as they keep on answering then you can let them explain
- 33 R: Hhm
- 34 T: But it becomes easier if you start with simple questions because once you start with difficult questions then they tend to withdraw and yah not talk at all
- 35 R: HHm what about language issues?
- 36 T: well language is obviously a barrier
- 37 R: Hhm
- 38 T: it is it is a barrier I think it needs a lot of practice. One area you know one area that maybe we have lost you know the issue of debate in high school
- 39 R: hhm
- 40 T: those were the things you know that actually helped us as students. You know not talking mother tongue when you are at school
- 41 R: Hhm
- 42 T: It was the thing during our times you wouldn't speak in Zulu but now ...
- 43 R: Hhhm
- 44 T: Yah and the issue of knowing we used to write summaries you knew that I must write ten summaries I must read ten books in English
- 45 R: HHm
- 46 T: ten books in Afrikaans ten books in Zulu
- 47 R: Hhm

- 48 T: so those I think are the things that developed us
which are no longer done
- 49 R: Hhm
- 50 T: presently but if we can go back there it would help a
lot. So maybe if you let them get into groups yah to
work in groups yah depending on the type of er activity
that you are doing
- 51 R: and so in their groups most likely they will switch
to their language and discuss in their language so how
do you help them to then articulate that?
- 52 T: oh ok when they code switch you let it happen so
that a person can be able to express what she wants to
say and thereafter if she has to present now it has to be
in English
- 53 R: and how well do they do that? The presentation in
English?
- 54 T: well these are a good class actually yah the 11As are
a good class very committed
- 55 R: Hhm
- 56 T: In fact most of them work even harder than our
Grade12
- 57 R: ok
- 58 T: yah so its all about encouraging and motivating
them to do that all the time
- 59 R: hhm ok well thank you very much for allowing me
the time to spent time with your class and to get some
of your ideas. Just one last little question. You
participated in the ICC project
- 60 T: Hhm
- 61 R: how do you feel that is there anything you
benefitted from participating?
- 62 T: oh yes yes yah you benefit a lot because you know
when it comes to your lesson preparation the type of
question that you as learners you know they have to
explain it shouldn't just be one word answers yes or no
but they should be able to explain so it helps in that
you know you are actually you know using the
Bloom's taxonomy type of situation one word answers
you know varying the questions there must be
application there must be synthesis discussion so it
helped a lot
- 63 R: ok so if a similar project was to be run what
improvement do you think should be made?
- 64 T: oh if er were to be run ...
- 65 R: Hhm
- 66 T: I think you know the teaching strategies because

you know once you are experienced you may tend to use a certain type but now with er your involvement you remember that by the way I need to use different types of questions yes different strategies

67 R: ok

68 T: Hhm

69 R: well thank you very much Maam for your time

70 T: hah not to mention Sis Audrey we grow all the time

71 R: we do and we are also learning from you and your students

72 T: Yes

73 *(T and R continue the dialogue as they help each other disconnect the equipment)*

74 R: the girls talk but the boys tend to be a bit quiet.

75 T: hhm its a few boys

76 R: Why? Whay do you think its like that?

77 T: I think its the level. I think one of the issues is that if I don't study but these study and what we have done we have placed them at ... and they get taught Mathematics and Physics on Fridays and Saturdays

78 R: Hhm

79 T: so if those attend there ...

80 R: Do they get selected?

81 T: yes its these three boys and this girl up front

Appendix 8.01: Sample of Physical Sciences teaching and learning materials developed



EdQual

A Research Programme Consortium on
Implementing Education Quality in Low Income Countries

PROPOSED ICC INTERVENTION

PHYSICAL SCIENCES

GRADE 10 - 12

TEACHING STRATEGIES:

Group work

Whole class discussions

Argumentation

Experiments / Investigations



PROPOSED ICC INTERVENTION STRATEGY IN SCIENCE CLASSROOMS

Background

The NCS (FET) introduced at Grade 10 in 2006 requires that teachers use strategies that enhance learner participation. This entails use of teaching and learning strategies that allow learners to a) have a hands-on experience with practical work and research projects, b) construct scientific knowledge through active participation in science lessons and c) formulate links between school science and the various applications of science in every day professional and in the real world.

Rationale for the intervention

This intervention is informed by findings of a baseline study in township science classrooms in Johannesburg. The following observations were made:

1. Teachers find it difficult to get learners to engage in meaningful discussion of science concepts.
2. Many learners are quiet and do not participate in discussions of science concepts.
3. Learners find it easier to discuss their views and opinions of science issues than the issues and concepts themselves.
4. In such classrooms a few learners tend to dominate the discussions.
5. Where teachers succeed in getting more learners talking the discussions tend to get out of hand, becoming chaotic and not focussed on science concepts.
6. Although teachers express the desire to engage learners, classroom interaction is still dominated by teacher talk or question and answer sessions – mainly transmission methods.
7. Teaching and learning is still organised around expectations for the final examinations. This is a source of frustration for teachers since they are not conversant with the new matric examination and cannot use it to guide their planning and execution of the new curriculum as they did previously.

Proposed focus of the intervention

1. Improve teacher questioning techniques – ask more open ended, thought provoking questions.
2. Get learners talking – focus on learner contributions to get them talking about science concepts, asking more & better questions
3. Incorporate argumentation – familiarise teachers with the concept and practice of argumentation, involve learners in focused discussion of science concepts.
4. Inquiry-type experiments – not always conducting experiments according to the teacher's instructions but have learners construct own hypothesis and coming up with own protocols and design own inquiry experiment to resolve the research question, analysing and presenting the results.
5. Formative assessment – one of the requirements for assessment is compilation of a student portfolio. Portfolio tasks can be used as a guideline for formative assessment. This would prove meaningful for both teachers and learners since it forms part of the final assessment (40% of the final grade is based on portfolio tasks).

Workshop

The aim of the workshop is to provide a forum for discussion of the concepts, agree on the content areas, address possible challenges and strategies to deal with them as follows:

1. Getting learners talking
 - introducing teachers to the notion of working with learner contributions
 - talking and listening;
 - use of trigger material, e.g. prompt posters, concept cartoons, puzzles, short research projects {Braund, 2006 #162} strategies that promote talk in science, e.g whole class or small group discussions
2. The nature of scientific arguments (Erduran, Simon, & Osborne, 2004; Rojas-Drummond & Zapata, 2004)
 - knowing the meaning of argument
 - asking students to provide reasons for their claims or relating claims to evidence, base decisions on evidence (constructing arguments)

- evaluating arguments
 - counter-arguing/debating, ability to justify own opinions, willingness to consider alternatives
 - reflecting on the argumentation process.
3. Management of classroom discussions
- how to open and close discussions (Scott & Ametller, 2007)
 - setting ground rules for discussion (Mercer, Wegerif, & Dawes, 1999; Rojas-Drummond & Zapata, 2004; Wegerif, 2002)
 - how to manage emotional situations that may arise during discussions of sensitive issues (IK and ethical issues) – this is likely to vary with context and strategies will come mainly from teachers' discussions.
4. Content areas
- Decisions on appropriate tasks for the contexts
 - timing of various tasks (whole class and small group sessions)
 - where teachers indicate lack of confidence in handling the content areas discussions on the actual content will be conducted.

Development of teaching and learning materials

Transforming pedagogy requires teachers to share the values of an innovation and be prepared to embrace it. This is best achieved through the practice of collaborative reflection between researchers and the teachers. Collaborative studies are a kind of qualitative research done in collaboration with practitioners with the principal aim of generation of knowledge and understanding of practice {Siverman, 2000}. Hatch (2002) argues that collaborative qualitative research brings in both insider (participants) and outsider (researcher) perspectives to the analysis of the phenomena under investigation.

The guiding hypothesis is that with guidance, teachers can initiate and sustain meaningful discussion in their science classrooms by using appropriate teaching and learning material. For example, Scott and Ametller (2007:77) noted that teachers who were able to use both “opening up” (dialogic) and “closing down” (authoritative) communicative approaches could initiate and sustain meaningful discussion in their classrooms.

To this end the NCS FET document's Learning Programmes Guidelines were used to collaboratively develop learning programmes amenable to generation of science discussions in selected topics (Cells, tissues, molecular and genetic studies for Life Sciences and Chemical systems for Physical Sciences).

Teaching and learning materials

Activities that extract learners' ideas and prior knowledge as well as promote Science talk in the classroom have been considered, e.g. group small group discussion, jigsaw activities, experiments, research projects and questionnaires.

Exemplar lessons and/or activities have been developed for selected topics in Physical Sciences.

PHYSICAL SCIENCES

GRADE 10

**LEARNING AREA:
CHEMICAL SYSTEMS**

**TOPIC:
GLOBAL CYCLES**

TEACHING STRATEGY:
Working with Learners' ideas
Group work (argumentation?)
Whole class discussions (argumentation?)

Grade 10

Learning area: Chemical Systems

Topic: Global cycles

Focus: The water cycle

(T = Teacher L(s) = Learner(s))

Learning Outcomes:

- LO2: Knowledge construction
- LO3: Science, society, technology and the environment

Lesson objectives:

- Introduce chemical systems
- Introduce the concept of cycling
- Discuss the water cycle as an example of a global cycle
- Compare MS and IK on water cycling

Teaching and learning activities

Activity 1 – Ls work in pairs

- Identify any system of your choice
- Name the system
- Justify its selection and identification as a system (what makes it a system?)
- From your system identify 3 characteristics of a system

Activity 2 – Whole class discussion

- T captures learners ideas on the board
- T & Ls group ideas into the three characteristics of a system
 - (i) has component parts
 - (ii) parts interdependent / interlinked
 - (iii) involves energy transfer
- T helps Ls define cycling using ideas from (ii) – (iii) above

Activity 3 – Individual work

- Ls apply (i) – (iii) to the water cycle

Activity 4 – Whole class discussion

- T captures Ls ideas about the water cycle
- T & Ls identify the three characteristics of a system in the water cycle
- T guides Ls to define key scientific concepts in the water cycle
 - (i) evaporation / vaporisation
 - (ii) condensation
 - (iii) precipitation

Homework

1. Ls collect IK information on

- rain making beliefs
- rain dissipation beliefs
- sources and uses of water

2. Complete the cross word puzzle and/or label the diagram.

Group work (argumentation?)
Whole class discussions (argumentation?)

PHYSICAL SCIENCES

GRADE 11

LEARNING OUTCOME 1:
SCIENTIFIC INQUIRY
(SAMPLE EXPERIMENTS/ INVESTIGATIONS)

CHEMISTRY

TEACHING STRATEGY:
Laboratory experiments

Small group discussions on reactions of acids and neutralisation reactions.

Learners discuss reactions of acids with other substances:

Group 1:

Reaction 1 Acid + metal = salt + gas

Reaction 4 Acid + base = salt + water

Instructions:

- agree on the products of each of your reactions
- name the salt formed in each of your reactions
- write out and balance the equations
- all members of the group must participate in the discussion

Group 2:

Reaction 2 Acid + metal oxide = salt + water

Reaction 4 Acid + base = salt + water

Instructions to learners:

- agree on the products of each of your reactions
- name the salt formed in each of your reactions
- write out and balance the equations
- all members of the group must participate in the discussion

Group 3:

Reaction 3 Acid + carbonate = salt + water + gas

Reaction 4 Acid + base = salt + water

Instructions to learners:

- agree on the products of each of your reactions
- name the salt formed in each of your reactions
- write out and balance the equations
- all members of the group must participate in the discussion

**Appendix 8.02: Sample of Life Sciences teaching and learning materials
developed**

LIFE SCIENCES

GRADE 10

LEARNING AREA:

CELLS, TISSUES AND MOLECULAR STUDIES

**TEACHING STRATEGY: GROUP AND WHOLE
CLASS DISCUSSIONS
(ARGUMENTATION)**

LESSON EXAMPLE 1

Topic: Cell structure and function

Teaching strategy – Small group and whole class discussion

Learning outcomes and assessment standards covered:

LO1 – Scientific inquiry and problem solving

AS3: Analysing, synthesising, evaluating and communicating findings

LO2 – Construction and application of Life Sciences knowledge

AS2: Interpreting and making meaning of knowledge of Life Sciences

AS3: Showing an understanding of the application of Life Sciences knowledge

Possible instruction to the class for small group discussions:

Cards have been placed on the table facing down.

Every learner should pick a card and check the number printed on it.

The cards have numbers that range from one up to five.

All the learners with cards marked 1 should meet at the table marked 1 and so on with the other numbers.

(Learners are thus divided into groups of five learners each, numbers 1-5. This is a close approximation to random selection - we can avoid having friends work together and learners are not grouped according to their ability)

Each group will be allocated an organelle to find the following information on:

1. Structure
2. Function
3. Biological process/es taking place in the organelle and
4. An argument on whether or not disease may result because of its malfunction.

Time allowed: A week (OR.....days) is allocated for the project and presentation will be done on the

Whole class discussion: You should present your findings in any creative way of your choice to the class.

Resources:

Textbooks, Library, Internet, Encarta, encyclopaedias; visit the clinic or health institutions, etc.

Use the following guidelines to develop your argument:

We think that disease will result (or will not result) when the(name of organelle) malfunctions because:

- 1)
...
- 2)
...
- 3)
...

The following information (evidence) supports our reasoning:

- 1)
.....
- 2)
.....
- 3)
.....

Some of our group members disagreed with our reasoning because they think that

- 1)
.....
- 2)
.....
- 3)
.....

LESSON EXAMPLE 2

Topic: Cell structure and function

Focus: Dysfunctional cells - Cancer

Teaching strategy – Group work and Argumentation

(T = Teacher L(s) = Learner(s))

Learning Outcomes:

- LO2: Knowledge construction
- LO3: Science, society (IK), technology and the environment

Lesson objectives:

- Revise relationship between cell structure and function
- Dysfunctional cells - cancer
- “Facts” about causes and treatment of cancer
- IK on cancer causes and treatment

Teaching and learning activities

Activity 1 – Small groups (5-6 Ls) - Ls ideas and IK concepts on cancer

- Ls discuss among themselves what cancer is and write answers down
- Ls talk about what cancer is regarded as in their cultures

Activity 2 – Small groups - MS concepts on cancer

- Ls get an article on cancer research
- Ls use information from the readings to answer: What is cancer?
 - Relate your answer to cell structure and function
 - Use evidence from the article to justify answers

Activity 3 – Whole class discussion – Groups report back

- T captures Ls IK ideas about what cancer is
- T captures Ls MS ideas about what cancer is

Preparation for next lesson – Given to Ls a week in advance - Group work

LS divided into four groups. Each group must go and prepare an argument for or against the following topics. Arguments must be supported by evidence whether MS or IK:

- Group 1 – Argument for the use of chemotherapy to treat cancer
- Group 2 – Argument against the use of chemotherapy to treat cancer
- Group 3 – Argument for the use of IK methods to treat cancer
- Group 4- Arguments against the use of IK methods to treat cancer

Learning materials: Articles on cancer and chemotherapy (PTO)

CHEMOTHERAPY

<http://cancer.about.com/od/treatmentoptions/a/chemooverview.htm>

Chemotherapy is a treatment option for many cancer patients. Many times, chemotherapy is a combination of drugs referred as "anti-cancer" medications.

How Does Chemotherapy Work

We know that cancer is caused by the out of control multiplication of cells. When these cells break free from the original site, the cancer metastasizes, or spreads. Chemotherapy interrupts the process of the multiplication.

How is Chemotherapy Given?

It is administered intravenously, in a pill form, by injection, or even applied to the skin. The frequency or duration of chemotherapy all depends on the type of cancer you have. It varies from patient to patient and often the treatment schedule is according to successes in trial studies.

Is Chemotherapy Expensive? The cost of chemotherapy can depend on what medication you are prescribed. Some pill form medications cost up to \$16 a pill. This can be costly if you are prescribed frequent dosages. Check with your doctor to see if a medication can be prescribed that your insurance company covers. If not, the hospital social worker can refer you to agencies that may be able to provide assistance or grants.

<http://www.cancerbackup.org.uk/Treatments/Chemotherapy/Generalinformation/Overview>

Chemotherapy is a treatment used for some types of cancer. This section gives information about chemotherapy. We hope that it answers some of the questions you may have about the treatment and helps you to cope with any side effects it may cause. Where cancer is mentioned, this refers to cancer, leukaemia and lymphoma.

Sometimes chemotherapy is used to treat non-cancerous conditions but often the doses are lower and the side effects may be reduced. This section does not cover the use of chemotherapy for conditions other than cancer.

The section is divided into sections about how the treatment works, how it is given and how to deal with some of the more common side effects. You are likely to have questions and concerns about your own treatment that this information does not cover, as there are over 200 different types of cancer and over 50 chemotherapy drugs, which can be given in various ways. It is best to discuss the details of your own treatment with your doctor, who will be familiar with your particular situation and type of cancer.

If you think that this information has helped you, you can show it to any of your family and friends who may find it useful. They too may want to be informed so they can help you cope with any problems you may have.

http://www.curesearch.org/for_parents_and_families/intreatment/medical/article.aspx?Stageld=3&TopicId=70&ArticleId=3126%20

What is chemotherapy?

Chemotherapy is a general term for treatments that use chemical agents (drugs) to kill cancer cells. Many different kinds of drugs are used, either alone or in combination, to treat different cancers. The specific drug or combination used is chosen to best combat the type and extent of cancer present.

Why are chemotherapy drugs given?

Chemotherapy drugs are given for several reasons:

- To treat cancers that respond well to chemotherapy
- To decrease the size of tumors for easier and safer removal by surgery
- To enhance the cancer-killing effectiveness of other treatments, such as radiation therapy
- In higher dosages, to overcome the resistance of cancer cells
- To control the cancer and enhance the patient's quality of life

How does chemotherapy work?

Healthy normal cells in the body grow and divide in an orderly manner to replace old or damaged cells. Cancer cells have lost that capacity and divide out of control. Chemotherapy drugs work by interfering with the ability of cancer cells to divide and reproduce themselves. Chemotherapy can be delivered by the bloodstream to reach cancer cells all over the body, or it can be administered directly to specific cancer sites.

Each class of chemotherapy drugs damage cells in different ways:

- Prevent the copying of cellular components needed to divide
- Replace or eliminate essential enzymes or nutrients the cells needed to survive
- Trigger cells to self-destruct

Each chemotherapy drug works in a different way to prevent cells from growing. Often a combination of drugs will be used, with each drug attacking the cancer cells in a different way. This decreases the possibility that cancer cells will survive, become resistant and continue to grow.

How are chemotherapy drugs given?

Chemotherapy is given in different ways depending on the cancer type and the drugs used.

Methods of giving chemotherapy drugs include:

- Intravenously (IV) – injected into a vein

- Intrathecally (IT) – injected into the spinal canal during a lumbar puncture
- Intramuscular (IM) – injected into a muscle
- Intraperitoneal (IP) – injected into the abdominal cavity
- Intracavitary (IC) – injected into a body cavity
- Subcutaneous (sub.q.) – injected just under the skin
- Oral (PO) – as a pill or a liquid to be swallowed

How are chemotherapy drugs chosen for treatment?

For some types of cancer, the treatment plan is well established, through many years of research and experience. For other cancers, clinical research is in progress to find the most effective treatment. Many children are treated according to Children's Oncology Group clinical trial protocols. Each protocol is based on the best available treatment (Standard of Care) with minor differences that are believed to reduce side effects or improve success. A protocol may study two or more different treatment plans, each believed to be effective, but no one knows which treatment will prove to be more effective.

Learn more about clinical trials

Factors influencing treatment plan design:

- Maximum destruction of cancer cells while limiting side effects to healthy cells.
- Dosages of the drugs are based on the child's weight or body surface area.
- The length of treatment depends upon the cancer type and how responsive it is to the chemotherapy.
- The treatment duration has been determined through previous experience. It takes into account the optimal cure with the least side effects. Each cancer type and extent of disease has a different treatment duration.
- Chemotherapy drugs may be discontinued if the drug no longer proves to be effective, or if the child experiences a serious side effect.
- Certain drugs are known to cause permanent side effects after a cumulative dose. Those agents are monitored very closely, and when the risks of continuing outweigh the benefits, they are discontinued.

Why are there side effects from chemotherapy drugs?

Chemotherapy drugs target rapidly dividing cells, including normal ones. When normal cells are damaged, it can cause side effects. But normal cells can repair the damage or be replaced by other healthy cells, which is why side effects are usually temporary.

Factors influencing side effects include:

- The specific chemotherapy drug
- The dose of the drug

- The health of the patient

Despite monitoring the effects of chemotherapy very closely, some long-term effects can occur, sometimes years after therapy is completed. Therefore, it is important that every patient be followed throughout his or her life by a physician who is aware of the late effects of treatment. *Sharon Friedrich, RN, MS, CPNP, University of Wisconsin Children's Hospital*

USING LEARNERS' PRECONCEPTIONS TO PLAN A LESSON ON CELLS

The following questionnaire can be used to extract learners' ideas about the cell and therefore to assess their prior knowledge and help in lesson planning.

This can be combined with any of the other exercises to address both the content and the prior ideas.

Questionnaire

Indicate your knowledge about cells; place an X in the space you think best suits your knowledge. Be honest as much as you can.

1. The cell is known as a basic unit of life.

Agree		Disagree		Not sure	

2. Cells can be compared to bricks; they are what organisms are made from.

Agree		Disagree		Not sure	

3. Cells contain many distinct structures or organelles that perform different functions.

Agree		Disagree		Not sure	

4. Cell division is important for growth, reproduction and renewal of organisms damaged tissues.

Agree		Disagree		Not sure	

5. Plants and animals are the only living organisms in the universe.

Agree		Disagree		Not sure	

6. Only animals are made up of cells.

Agree		Disagree		Not sure	

7. Where are chromosomes found? Give them an option to choose from.

Agree		Disagree		Not sure	

8. Chromosomes carry the heredity of the cells. Did you mean “Chromosomes carry the structures for heredity in the cells”?

Agree		Disagree		Not sure	

9. Cloning is a process where one cell is used to reproduce a new organisms.

Agree		Disagree		Not sure	

10. Cloning and mitosis are the same.

Agree		Disagree		Not sure	

11. During mitosis the daughter cell have identical chromosomes from the mother cell.

Agree		Disagree		Not sure	

12. Meiosis produces gametes that contain half of all the chromosomes of an organism.

Agree		Disagree		Not sure	

13. Energy in the form of ATP is produced in the mitochondrion during cellular respiration.

Agree		Disagree		Not sure	

14. Plant cells use carbon dioxide, sunlight, chlorophyll and water to manufacture organic food.

Agree		Disagree		Not sure	

15. Diseases caused by viruses attack the cell.

Agree		Disagree		Not sure	

LIFE SCIENCES

GRADE 12

TEACHING STRATEGIES:

GROUP DISCUSSIONS

ARGUMENTATION

GRADE 12 LIFE SCIENCES

Teaching strategy – Small group discussion and argumentation

Learning outcomes and assessment standards covered:

LO1 – Scientific inquiry and problem solving

AS3: Analysing, synthesising, evaluating and communicating findings

LO2 – Construction and application of Life Sciences knowledge

AS2: Interpreting and making meaning of knowledge of Life Sciences

AS3: Showing an understanding of the application of Life Sciences knowledge in every day life

LO3 – AS3: Comparing the influence of different beliefs, attitudes and value on scientific knowledge

Possible instruction to the class for small group discussions:

Learners divided into groups of five (or break into previously organized groups).

Each group is assigned a name/number and instructions for the activities corresponding to their group number, e.g. group 1 will do Activity 1, etc.

You are provided with a copy of the cartoon with the child who wants a word with her parents. Study the cartoon and carry out the activities assigned to your group. Assume that the child learnt about human reproduction and inheritance at school today. You are also provided with notes from a Genetics expert Prof John Alsobrook.

Carry out the following activities and decide who will present your findings to the whole class.

Group 1

The child cannot roll her tongue and her teacher said that this can only happen if both her father and mother cannot roll their tongues. However, the child knows that her mother can roll her tongue (her father cannot). Using evidence (data/information) from Prof John Alsobrook's notes on what biology textbooks say, explain to the girl why she cannot roll her tongue.

Group 2

The child cannot roll her tongue and her teacher said that this can only happen if both her father and mother cannot roll their tongues. However, the child knows that her mother can roll her tongue (her father cannot). Using evidence (data/information) from Prof John Alsobrook's notes on what scientific literature says based on analyses of what's really going on, explain to the child whether or not she can ever expect to be able to roll her tongue in future.

Group 3

In the parents' culture it is believed that a child must look exactly like her parents, if she does not then she is not theirs. This is a problem especially for the men in that culture since they have no other way of proving that the child is theirs (the mother carries the baby so she knows it's hers). Both this girl's father and mother are tall. How would you convince this father that this girl is his child although she seems to be much shorter than others of her age (she is going to be short as an adult)?

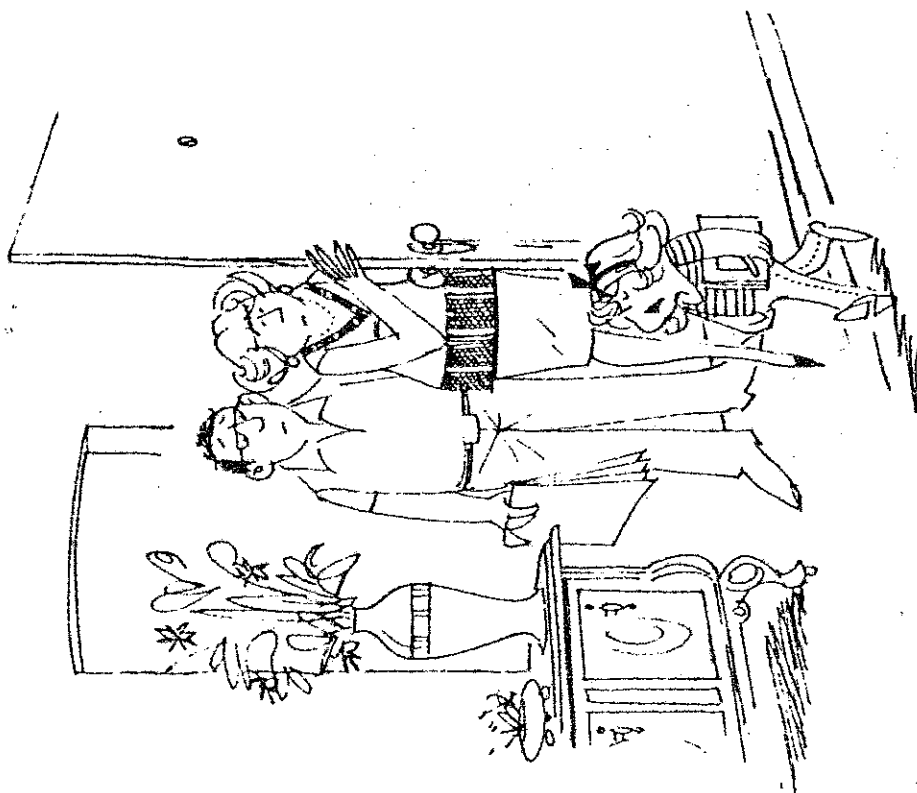
Group 4

Discuss what people believe in the different cultures of your group members about

1. Why children look like their parents?
2. Albinos
3. Twins
4. The sixth finger

Resources:

Handouts – cartoon and Prof John Alsobrook's notes.



"I learnt at school today
where I came from,
and I'd like to have a word with you."

LO LINKERT

<http://en.allexperts.com/q/Genetics-1795/Genetics-5.htm>

Explanation of tongue rolling by an expert: Prof John Alsobrook

Subject: Genetics

Question

If two parents are unable to curl their tongues, is it possible that their biological child can curl his?

Answer

First, I'll answer your question. No and Yes. You probably didn't expect this to be such a controversial issue, did you?

Now I'll give you the explanations: No is what your biology textbook probably says, and that's what is generally taught in secondary schools in the U.S. Yes is what the scientific literature says, and is based on analyses of what's really going on. I'm not sure when the introductory textbooks first got it wrong, but I'm guessing it was probably back in the 1950's or 1960's.

In many U.S. elementary and secondary school biology texts, tongue rolling is taught to be autosomal dominant. Here's what that means. "Autosomal" means the gene that determines this trait is on one of the 22 pairs of chromosomes that do NOT determine gender; in humans, the 23rd pair of chromosomes are the X or Y, the sex chromosomes. We each have two copies of every chromosome (and therefore every gene - that's important in the next paragraph!). If we have 2 X versions, then we are female or XX. If we have an X version and a Y version of the sex chromosomes, then we are male or XY. The YY combination is a 'lethal', and does not allow a viable fetus to develop. So autosomal means tongue rolling doesn't have anything to do with your genetic gender (and that seems to be true).

The "dominant" part means that you only need 1 copy of the 'Tongue Roller' version of the gene to have the Tongue Rolling ability. If 'T' represents the rolling version of the gene, and 't' represents the non-rolling version of the gene, then you can be either TT or Tt and still be able to roll your tongue (that's where having two copies of each gene comes in). If you're tt, you don't have the roller gene and you can't do it.

So if both of the parents can't tongue roll, they must both be tt, and they can only have 1 kind of child when it comes to tongue rolling: tt. Remember we inherit 1 copy of each chromosome from each parent. So if the child is tt, then both copies of the gene are non-rolling, and they can't roll their tongue! Any other combination of parents (Tt and tt, Tt and Tt, Tt and TT, TT and tt, or TT and TT) could produce a tongue-rolling child.

That's the reason for answering your question with a NO. But really, the actual observed data in published studies is that tongue rolling is probably NOT due to a single gene, and is NOT an autosomal dominant. It seems to be more complicated. And that's the reason that the answer to your question is really YES. The situation you propose is seen to occur, but no one has a perfect genetic model for explaining it yet; it appears that the simple interpretation given in secondary schools is an oversimplification. One reason no one says much about this might be that you need a few counter examples to the autosomal dominant model within the same classroom; an easy one would be two non-tongue rolling parents who have a tongue-rolling child (as in your question!). That's where I'll bet a lot of teenagers taking introductory biology don't test their parents and grandparents, so they don't have the data to show that the model doesn't fit.

Here's a web site that summarizes why tongue rolling isn't really autosomal dominant:

<http://www.discovery.com/area/skinnyon/skinnyon970226/skinny1.html>

Here's a web site that provides more details of studies and cites the journals that published those studies (it's also good for looking up info on any and all genetic traits in human beings):

<http://www.ncbi.nlm.nih.gov/entrez/dispomim.cgi?id=189300>

Myths of Human Genetics: Tongue Rolling

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<http://udel.edu/~mcdonald/myhtongueroll.html>

The myth

Some people can roll their tongue into a tube, and some people can't. The proportion of people who can roll their tongue ranges from 65 to 81 percent, with a slightly higher proportion of tongue-rollers in females than in males (Sturtevant 1940, Urbanowski and Wilson 1947, Liu and Hsu 1949, Komai 1951, Lee 1955).

Tongue rolling is one of the human traits most commonly used to demonstrate simple Mendelian genetics. It is said to be a simple two-allele character, with the allele for rolling (usually given the symbol T or R) being dominant over the allele for non-rolling (t or r). Here are a few examples of the many web pages that perpetuate this myth:

- [Science Connection-Hereditry and Genetics](#)
 - [Variation and Mendel's Laws](#)
 - [Genetics Traits Activity: Scoring Tips](#)
 - [Chromosomes, Genes and Inheritance](#)
 - [Evolution--MSN Encarta](#)
 - [Life Science: Why are my eyes brown?](#)
 - [Wearing My Genes: Basic Principles of Heredity](#)
 - [Class Traits Lab](#)
-

The reality

Tongue rolling as a character

Most people, when first asked, either can easily roll their tongue (here called "R"), or cannot roll it at all ("NR"). However, some people, especially children, cannot roll their tongue when first asked but later learn to do so (Sturtevant 1940). Komai (1951) found that the proportion of tongue-rollers among Japanese schoolchildren increased from 54 percent at ages 6-7 to 76 percent at age 12, suggesting that over 20 percent of the population learns to tongue-roll during that age range. There are also some people

who can only slightly roll the edges of their tongue and cannot easily be classified as rollers or non-rollers (Reedy et al. 1971).

Anar Badalov, of the Metal Hearts, can roll his tongue.

Family studies

Sturtevant (1940) compared parents and offspring, with the following results:

Parents	R offspring	NR offspring
R x R	28	5
R x NR	33	22
NR x NR	4	9

He concluded that tongue rolling was at least partially genetic, with rolling dominant to non-rolling, despite the four R offspring of NR x NR parents.

Komai (1951) performed a similar study with much larger sample sizes, and found similar results:

Parents	R offspring	NR offspring
R x R	928	104
R x NR	468	217
NR x NR	48	92

In both family studies, individuals with tongue-rolling parents are much more likely to be tongue-rollers than individuals with non-rolling parents. It is difficult to imagine how the common family environment could influence tongue-rolling, so this resemblance between relatives suggests that there is a large genetic influence on tongue-rolling. However, the large number of tongue-rolling individuals with two non-rolling parents is inconsistent with the myth that this is a simple one-gene, two-allele genetic character, with rolling completely dominant to non-rolling. The discrepancy could be due to more complicated genetics, involving multiple alleles or multiple genes, or some kind of environmental influence.

Twin studies

Matlock (1952) found that out of 33 pairs of monozygotic (identical) twins, 7 pairs consisted of one R and one NR twin. This clearly establishes that there are important non-genetic influences on tongue rolling, and it convinced Sturtevant (1965) that his initial interpretation was incorrect. Reedy et al. (1971) and Martin (1975) also found numerous pairs of monozygotic twins who differed in tongue rolling. Dizygotic twins were twice as likely to differ in tongue-rolling ability as monozygotic twins (Reedy et al. 1971), which is additional evidence that there is some genetic influence on this trait.

	Matlock (1952)	Reedy et al. (1971)	Martin (1975)	Reedy et al. (1971) DZ twins
Both twins R	18	43	15	81
Both twins NR	8	11	5	21
One R, one NR twin	7	7	8	30

Conclusion

Family studies clearly demonstrate that tongue rolling is not a simple genetic character, and twin studies demonstrate that it is influenced by both genetics and the environment. Despite this, tongue rolling is probably the most commonly used classroom example of a simple genetic trait in humans. Sturtevant (1965) said he was "embarrassed to see it listed in some current works as an established Mendelian case." Tongue rolling is unsuitable for classroom use as an illustration of simple Mendelian genetics.

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OMIM entry

Example of biology activity - small group discussions on indigenous knowledge of owls and conservation.

Teacher's instructions: Have learners in groups and either assign different tasks to different groups or the same task to all groups depending on lesson objectives.

Blurb for distribution to all groups: Owls are useful, harmless birds that occupy an important position on the food chain/web and therefore all members of the community must find ways to introduce owls to environments where they are not already present or to preserve their populations where they already occur.

Possible Task 1 Discuss the statement above.

(The teacher's strategy with this task: provide no information; elicit students' ideas, knowledge, opinions; expose misconceptions; identify beliefs, attitudes)

Possible Task 2 Discuss the statement above considering

- Your personal opinion on owls; Some cultural beliefs about owls
- The local communities' feelings and attitudes towards owls
- What the owl feeds on - the owl's prey
- The owl's position on the food web as both a predator and prey for other organisms
- How the presence or absence of owls may affect the food web (use examples)

(The teacher's strategy with this task: to provoke thinking about conflicting situations; may also expose student ideas, beliefs, attitudes, misconceptions)

Owl indigenous knowledge and conservation

Role play of a notice from the local administrative council

New notice from the council offices

**“IN THE INTEREST OF ENSURING ANIMAL DIVERSITY
AND SPECIES CONSERVATION, GOVERNMENT NOW
REQUIRES ALL RESIDENTS TO KEEP AT LEAST ONE
OWL IN THEIR BACKYARD”**

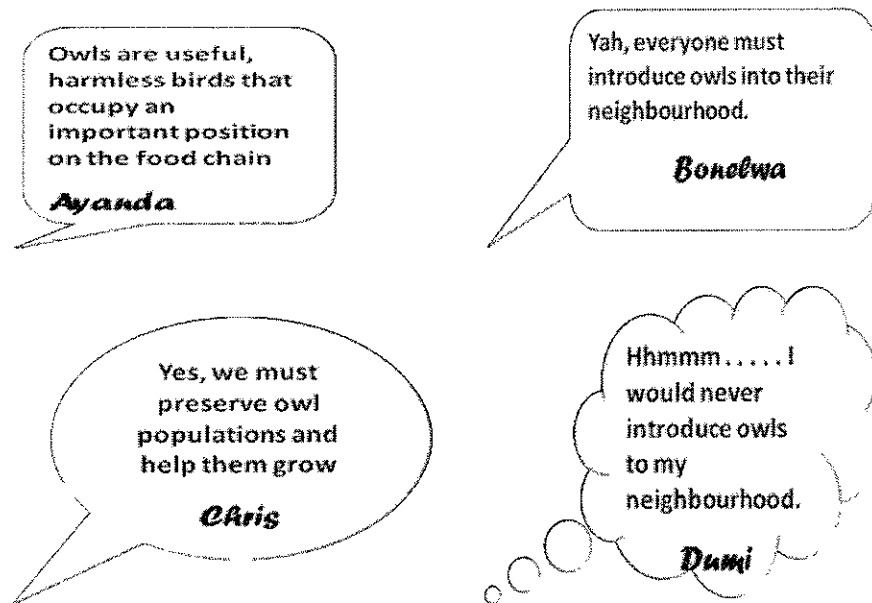
Discuss the new notice

Remember that everyone's idea is important, so

- Everyone must participate
- Everyone must say what they think
- You must listen to what others have to say
- You must always give reasons for what you say

Concept cartoons on learner IK on owls and biodiversity conservation

Task 1:

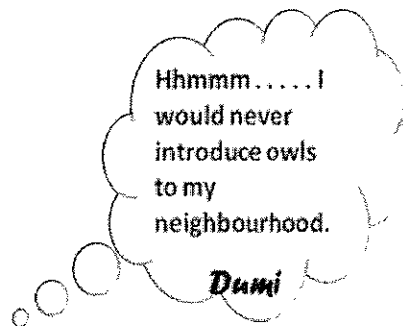
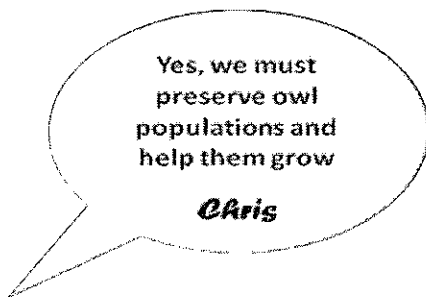
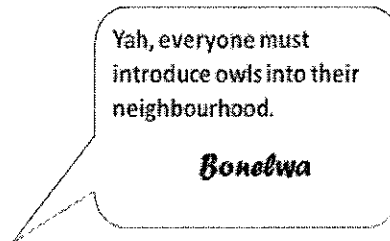
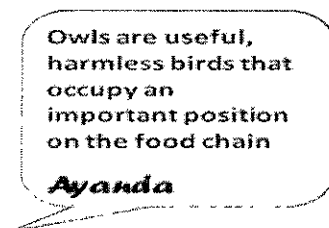


Discuss the following:

Who do you agree with? Why do you agree with them?

Concept cartoons on learner IK on owls and biodiversity conservation

Task 2:



Discuss the following:

Who do you disagree with? Why do you disagree with them?