SCAFFOLDING SCIENCE:
A PEDAGOGY FOR MARGINALISED STUDENTS

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Thesis declaration

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Abstract

At a time when scientific literacy is recognised as essential for participatory Australian citizenship, science education has struggled to find a pedagogy that engages educationally marginalised students while at the same time assisting them to them becoming scientifically literate. The study reported here, titled *Scaffolding science: a pedagogy for marginalised students*, investigates an alternative pedagogic paradigm, scaffolding pedagogy, based on socio-cultural, language-focused principles. It draws on three complementary theories: Vygotsky's sociocultural activity theory, Halliday's systemic functional linguistics, and Bernstein's theory of pedagogic discourse.

The methodology is a classroom discourse analysis of a series of lessons around energy transformation with 7-8 year-old students in a suburban disadvantaged early primary classroom. Its focus is two-fold: firstly it provides a pre- and post-topic analysis of the oral and written performance of a number of case study students to ascertain changes in their language use. Secondly, it provides a discourse analysis of classroom interactions in the seven lessons in the topic. It identifies the changing nature of teacher scaffolding techniques across time as students gradually appropriate scientific language, as well as identifying the issues encountered by the teacher as she endeavoured to develop a principled scaffolding pedagogy in the teaching of science.

The study argues that student use of scientific language is fundamental to the ongoing learning of scientific knowledge. It supports the development of summary texts, called *focus texts*, to assist the teacher in a consistent use of scientific language, increasing the opportunities for its appropriation by marginalised students.

The study identifies the paradox of 'hands-on' science which brings about high student engagement, but neglects the development of the required language because of its situated nature. It proposes pedagogic strategies that may help to ameliorate the current situation in primary school science education.

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CHAPTER 1

Science education and educationally marginalised students

1.1 The place of science in the 21st century

1.1.1 Citizenship and employment

Science education in Australia in the 21st century is imbued with a sense of urgency. Strongly influenced by the emerging impact of climate change on our world, scientific literacy has now become a fundamental asset for contemporary citizenship in Australian society (Fensham, P.J. 2008:6-7; Fensham, P.J. & Cross, R.T. 2000; Harlen, W. 2008). Not only must future citizens be able to make critical judgments about the quality and relevance of climate change information presented in various media, but to participate as global citizens, require a consciousness of the impact of their own actions on climate change, and a willingness to change personal behaviours (Rodríguez, M. *et al* 2011). The current Australian science curriculum regards scientific literacy as part of a futures-oriented education which prepares students as *citizens in a global world, who need to make personal decisions on the basis of a scientific view of the world* (ACARA 2009:4).

Participatory citizenship is not the only required outcome of science education. If science is to help solve the problems of climate change and not simply raise awareness, science education has a second, more challenging purpose: preparing students for potential employment in the fields of science and technology. The science curriculum continues:

> *As well as preparing students to use science for life and active citizenship, school science should…open up a wide range of careers in engineering, technology, medical and health professions, as well as careers in science and education (ACARA 2009:5).*

For the educationally marginalised students who are the focus of this study, whether or not they develop scientific literacy has a significant impact on their futures as participating Australian citizens. Therefore the providers of science education have an increased onus of responsibility to ensure that science education is effective for all learners in developing scientific literacy.

1.1.2 Scientific literacy and scientific knowledge

The identification of scientific literacy as the goal of science education, rather than simply scientific knowledge, is a relatively new phenomenon (Brown, B.A., Reveles, J.M. & Kelly, G.J. 2005). PISA describes scientific literacy as the ability not only to know about science but also to apply that knowledge in real life contexts. It emphasises the ability to draw on scientific knowledge, to think scientifically, and to engage with the world through a scientific lens *(*ACER 2009:202-3).

The elements of scientific literacy - knowing about science, applying that knowledge and seeing life through a scientific lens - require, from a language perspective, that students have the ability to engage with scientifically valued texts of many types. Indeed, the field of systemic functional linguistics argues that learning scientific language and learning the principles, knowledge and values of science cannot be regarded separately, but are one and the same thing (Christie, F. 1998a; Fang, Z. 2005; Halliday, M.A.K. & Martin, J.R. 1993; Martin, J.R. & Veel, R. 1998; Schleppegrell, M.J. 2004). Fang summarises the position of these linguists:

> *To become scientifically literate, students must ultimately learn to cope with the specialized language of science. For example, students must be able to read and comprehend texts where scientific knowledge and ideas are typically presented in school. They must also be able to employ appropriate linguistic resources to communicate what they have learned from empirical activities and from what they have read. … Students who do not appreciate and understand the specialized language of science will be severely handicapped in their learning of scientific principles, knowledge, and values* (Fang, Z. 2005:345).

The Literacy Capability of the Australian Curriculum (ACARA 2013) is strongly aligned with the position of the systemic functional linguists, and spells out in detail the language and literacy demands of learning science. The Capability makes it clear that teachers are responsible for teaching the language and literacy of science and need a *clear understanding of the literacy demands and opportunities of their learning area* (ibid: 1-2). These demands include the ability to comprehend and compose oral, written, visual and multi-modal texts, as well as an understanding of the increasing complexity of text, grammar, word and visual knowledge (ibid: 6-7). The specific academic language demands of scientific literacy present a particular struggle for educationally marginalised students who are already grappling with literacy in general (ACARA 2012).

1.1.3 The importance of science education for marginalised students

At the same time that the increasingly close interrelationship between scientific literacy and citizenship was being acknowledged, concerns about student engagement and the teacher's role in science education appeared (Jenkins, E.W. & Nelson, N.W. 2005; Sjoberg, S. & Schreiner, C. 2005; Tytler, R. 2007). School systems within the western world were, and still are facing significant issues in the teaching and learning of the subject science. In the last decade, three major Australian reports echoing international concerns have been published on the status of science education: *The status and quality of teaching and learning of science in Australian schools* (Goodrum, D., Rennie, L.J. & Hackling, M.W. 2000); *Re-imagining science Education* (Tytler, R. 2007); and *Opening up pathways: Engagement in STEM across the Primary-Secondary school transition* (Tytler, R. *et al* 2008). They identified the sad state of science education in primary schools, where little science was being taught at all, and teachers lacked confidence about their capacity to teach science effectively (Goodrum, D. *et al* 2000).

Of particular interest to this study, Tytler et al identified two groups of students: Indigenous and those with low socio-economic status, as unlikely to pursue post-compulsory science education (2008:104). Along with refugees, Indigenous and low socio-economic students are identified as educationally marginalised groups (MCEETYA 2009), and have traditionally not been served well by science education. This fact is supported by the results from the Program for International Student Assessment (PISA), an assessment program which assesses scientific literacy (OECD 2007). The PISA results show that 'socio-economic background and performance are closely related – students from wealthier families do better' (OECD 2009a:32).

Indigenous students have performed well below average in the PISA scientific literacy assessments, consistently averaging more than one proficiency level below non-Indigenous students (De Bortoli, L. & Thomson, S. 2009:1). Although the number of Indigenous students enrolled in the final stages of high school in South Australia has tripled over the past decade, the percentage of those students taking post-compulsory science subjects has diminished. The percentage of Indigenous students completing Biology, for example, has dropped from 40% in 2001 to 9% in 2011 (SACE 2012).

Refugees are a third group of educationally marginalised students to struggle with scientific literacy (MCEETYA 2009). An increase in refugee intake into Australia over recent years has created a small but highly disadvantaged sub-group of migrants, characterized by little or no prior formal schooling, or interrupted schooling prior to arrival in Australia. Moreover, families in this group may continue to suffer the ongoing effects of severe trauma in their home countries or in refugee camps, trauma which continues to impact on children born in Australia (Miller, J. 2009).

The study of science for marginalised students is not a continuation of the world view that they already bring from home: it requires them to take on a new, often conflicting orientation to how and why the natural world functions. Importantly, science requires a significant expansion of their language repertoire, a new and sophisticated language with which to represent that world view (Brown, B.A. 2004; Brown, B.A. *et al* 2005; Fleer, M. 2008).

The juxtaposition of marginalised students' science outcomes with the increasing expectation of scientific literacy for all Australian citizens creates a bleak picture for the future of marginalised students. The reports, together with the imperatives proposed by the Australian science curriculum, suggest that, unless these students can become engaged with science, their future active participation in Australian society may be severely compromised. From a social justice perspective, the mandate is clear. If marginalised students are to be given the chance to participate fully in Australian society and have the opportunities for science-oriented employment, there is a clear imperative to improve science education in their schools. Yet current programs and policies continue to fail to deliver the desired outcomes.

To this point, the chapter has described the scientific literacy which is now an important goal of science education, as well as providing a motivation for improving science education for marginalised students. The question then becomes how this goal is to be achieved. What pedagogy is likely to be most effective in supporting marginalised students?

1.2 The way forward: finding an effective pedagogy

1.2.1 Progressivist or transmission education

The Australian reports listed in Section 1.1, p1, identified features of science education that needed to change if students were to engage. The reports highlighted issues in pedagogy as a major reason for concern. They advocated for new pedagogic processes in an effort to re-engage students in learning science (Goodrum, D. *et al* 2000:viii). In doing this, two pedagogic paradigms evident in contemporary science classrooms were juxtaposed: firstly the discredited low challenge, chalk-and-talk teaching; and secondly the favoured student-centred, activity-based science education.

These two pedagogic paradigms identified in the Australian reports align with the categories of transmission and progressivist education, two polarized and oft-debated approaches (e.g. Chall, J. 2000).

The stereotype of transmission pedagogy locates the teacher at the front of the class where s/he imparts content; a teacher-centred focus on abstract and objective learning (Daniels, H. 2001:42; Maton, K. 2011:9). It has been described as one-dimensional, conveyor-belt pedagogy, the empty vessel approach to teaching and learning. (Mehan, H. 1998:254). Transmission pedagogy

overlooks the importance of student agency in the process of appropriation of new knowledge, requiring instead student passivity and compliance.

In contrast, progressivist pedagogy valorises holistic and authentic student activity and voice, and subjective perspectives on everyday experience (ibid: 10). The notion of child-centred, constructivist progressivist pedagogy began with Dewey (e.g.1940; 1929), and gradually gained credence in western education systems across the 20th century. Dewey's preference for *learning through experience* rather than *learning from texts and teachers* (Dewey, J. 1938:7-8) is echoed seventy years later in Tytler's report which called for a new role for science teachers, moving from that of 'knowledgeable expert' to giving more agency to students, opening up the possibility of 'new knowledges' rather than 'rehearsals of well-known knowledge elements' (Tytler, R. 2007:57).

There is no doubt that the authors of the reports are strong advocates for progressivist pedagogy. Their stance is exemplified by the dichotomous comparisons of 'teacher centred' versus 'child centred', and 'cookbook practical sessions' versus 'genuine scientific investigations' (Goodrum, D. *et al* 2000; Tytler, R. 2007).

The influence of Goodrum and Tytler in advocating for discovery learning in science at the beginning of the 21st century is evident in the National Science Curriculum Framing Paper:

> *(t)o achieve the stated aims of the Australian science curriculum it is proposed that there needs to be less emphasis on a transmission model of pedagogy and more emphasis on a model of student engagement and inquiry (NCB 2009a:13).*

The new direction of inquiry science foreshadowed in the Shaping Paper is in accord with the prevailing philosophical orientation at the beginning of the 21st century. Transmission pedagogies have been dismissed by critics as socially unsuited for contemporary society. Progressivist pedagogies are generally upheld as the favoured approach across western industrial societies. This much is clear. However, what is in doubt is whether they are any more effective for already marginalised low socio-economic and disenfranchised groups. Their 'fit' with disadvantaged students has been challenged by a number of academics in the field of education (Chall, J. 2000; Delpit, L. 1995, 1993; Hirsch, E.D.J. 2006; Ogbu, J.U. 1987; Ravitch, D. 2000; Taber, K. 2006). Ravitch's work, for example, tracked the development of the roots of progressivism with Dewey to the educational outcomes in the USA in the 1990's, where the emphasis on *personal experiences, activities, and spontaneity* led to significant differentiation in the curriculum and further disadvantage:

> *The children most harmed by such practices were those who could not count on the protection of educated parents. The attacks on the academic tradition, by restricting its availability to*

> *those who were already advantaged, and diminishing access to knowledge, undermined the democratic promise of public education* (Ravitch, D. 2000:460).

One of the salient concerns with progressivist approaches is the disavowal of explicit teaching as it is perceived as running counter to processes of student discovery and student experiential learning. An important role for the teacher in the progressivist classroom is to support students in learning *how* to learn. A good progressivist teacher creates classroom situations in which students are challenged to become autonomous learners, developing generic learning processes. These processes are regarded as more important than the acquisition of specific knowledge (Black, P. *et al* 2006; Pedder, D. 2006; Winch, C. 2008). Philosophically this approach runs counter to those who regard the development of discipline-appropriate language and literacy as central to the achievement of scientific literacy, and who view the teacher as the figure responsible for explicitly providing this knowledge to classroom learners. Concerns about progressivism's lack of explicit teaching of important disciplinary knowledge, and particularly its lack of attention to language, are shared within the field of socio-linguistics (Christie, F. 2005b; Christie, F. 1991a; Christie, F. & Martin, J.R. 2007; Halliday, M.A.K. 1988, 1975, 1993).

Some educational sociologists have also been critical of progressivist education (Bernstein, B. 1972, 2000; Bourne, J. 2004, 2003; Maton, K. 2000; Maton, K. 2004; Moore, R. & Young, M. 2001). Bernstein, for example, argues that progressivist pedagogy masks the assumed social and academic rules with which students are expected to comply, including control over culturally-valued knowledge. While teachers must assess against these rules, the invisibility of progressivist pedagogy means that marginalised students are left to discover for themselves how these unclear or hidden rules work (Bernstein, B. 2000:13-14).

More recently, concerns about discovery and inquiry learning as an effective method for teaching novices have been voiced in cognitive psychology and neuroscience (Kirschner, P.A., Sweller, J. & Clark, R.E. 2006; Mayer, R.E. 2004; Novak, J., D. 1977; Siegel, M. 2008; Willingham, D.T. 2009):

> *Although unguided or minimally guided instructional approaches are very popular and intuitively appealing, the point is made that these approaches ignore both the structures that constitute human cognitive architecture and evidence from empirical studies over the past half-century that consistently indicate that minimally guided instruction is less effective and less efficient than instructional approaches that place a strong emphasis on guidance of the student learning process. The advantage of guidance begins to recede only when learners have sufficiently high prior knowledge to provide "internal" guidance* (Kirschner, P.A. *et al* 2006:75)

One conclusion then, is that whilst progressivism has replaced transmission as the preferred pedagogy in contemporary Australian schooling, both progressivist and transmission pedagogies have been found wanting in supporting marginalised students.

Given that neither of these approaches appear to best support disadvantaged learners the question arises as to whether there is there an alternative which enables student agency in science education without sidelining the role of the teacher in guiding learning, and which will better serve the needs of marginalised learners in becoming scientifically literate. This study addresses this question. It investigates one classroom-based effort to describe, implement and evaluate an alternative pedagogic approach to teaching science which specifically aims to support disadvantaged learners, with close attention to scientific language development. This alternative approach, labeled as a negotiated or scaffolded pedagogy is offered as one example of a third way.

1.2.2 New directions in research: scaffolded pedagogy

Three intersecting theoretical fields converge to suggest a coherent new pedagogic paradigm that unsettles the differences between progressivism and transmission pedagogy, and points to a pedagogy which better serves the needs of disadvantaged learners.

Firstly Vygotsky's socio-historical theory of social activity and his theory of child development help us to understand the social nature of learning and the role of pedagogy in developing the child. Secondly Bernstein's educational sociology helps us to understand the political nature of education and the differential effects of particular pedagogic choices on marginalised students. Finally Halliday and the field of systemic functional linguistics provide an analysis of the language systems with which schooling engages, both within the classroom, and within the discipline of science, helping us to understand the centrality of language in negotiating teaching and learning.

Both progressivist and transmission pedagogy perceive learning as an autonomous venture by the child (Bernstein, B. 1990:xx). In contrast, scaffolded pedagogy is a socially embedded process negotiated between student and teacher (Vygotsky, L.S. 1978). Rather than presenting child-centred and teacher-centred pedagogy as a dichotomy, socio-cultural theory recognises pedagogy as *obuchenie*, where teaching and learning are regarded as two sides of the one coin (Daniels, H. 2001:10). It is process of flexible dialogue between teacher and learner (Bruner, J.S. 1978) which, rather than being an aimless conversation, is intentionally concerned with the negotiation of teaching and learning. The metaphor of scaffolding has been proposed for this process (Wood, D.J. 1989). Because student learning depends on its quality, the process of negotiation or scaffolding in the classroom becomes an important focus of study when trying to

identify effective ways of interacting that lead to positive student outcomes in science (Christie, F. 2002).

Scaffolded pedagogy is influenced by Vygotskian activity theory. Variously described as sociocultural (Wertsch, J., Alvarez, A. & Río, P. 1995) or cultural-historical (Roth, W. & Lee, Y. 2010), activity theory recognises that students engaging with the discipline of science are being apprenticed into a new and discretely bounded cultural system, with its own subjects, objects, means, community, division of labour and outcomes (Engestrom, Y. 1987). Whether students are engaged in a 'cook-book' practical lesson or 'authentic real world contexts', activity theory highlights the importance of student engagement leading to an awareness of, and control over the intent, goals, values, and means of the scientific community (Wertsch, J.V. 1993). The process of science education is one of apprenticeship into new ways of thinking, talking, ways which are gradually aligned with the scientific community (Rogoff, B. 1990).

Scaffolded pedagogy has been labelled as 'radical' (Bourne, J. 2004:63) and 'subversive' (Martin, J.R. 2011:39). Its political nature and purpose is highlighted by the work of the British educational sociologist Basil Bernstein. Across the second half of the 20th century, Bernstein identified the political and social consequences of particular pedagogic choices and contributed significantly to the critique of progressivist education and the inequities it produces for marginalised students (Bernstein, B. 2000). Whereas Vygotskian theory explains the pedagogic processes, end goals and requirements of child development, Bernstein's educational sociology provides a clear explanation of how pedagogic systems and their outcomes have the potential to perpetuate or ameliorate inequity:

> *What we are asking… is how the distribution of power and the principles of control are transformed, at the level of the subject, into different, invidiously related, organizing principles, in such a way as both to position subjects and to create the possibility of change in such positioning. The broad answer given by this thesis is that class relations generate, distribute, reproduce, and legitimate distinctive forms of communication, which transmit dominant and dominated codes, and that subjects are differentially positioned by these codes in the process of acquiring them* (Bernstein, B. 1990:13).

The importance of marginalised students controlling the language demands of scientific literacy has already been proposed (Section 1.1.3, p3). Both transmission and progressivist pedagogies fail in taking responsibility for students' developing ability to comprehend and produce this language. For this reason, the contribution of a third theoretical field becomes even more important. The work of linguists in the tradition of Systemic Functional Linguistics (SFL) argues for conscious awareness and explicit teaching of the language resources needed to communicate scientifically and provides significant detail about what this entails (Halliday,

M.A.K. & Martin, J.R. 1993). The development of science-specific texts across the years of schooling and the increasingly technical and abstract language within those texts has been painstakingly analysed and documented to assist educators in explicitly teaching these important cultural resources (Christie, F. & Derewianka, B. 2008; Halliday, M.A.K. & Martin, J.R. 1993; Korner, H., McInnes, D. & Rose, D. 2007; Martin, J.R. & Veel, R. 1998).

Together, Vygotskian socio-historic psychology, Bernsteinian educational sociology and Hallidayan linguistics provide a broad foundation on which to build a pedagogy focused on providing access to scientific literacy for all students, but particularly those who are educationally marginalised. Central to this study, each of the three perspectives recognises the essential and inseparable relationship between language and meaning, and language and learning. The role of language in making meaning and in child development will be discussed at length in Chapter 2. In addition, Vygotsky accounts for the important role of the adult in children's development, and explains the sensitivity and nuanced scaffolding required for gradual handover of learning. Bernstein alerts us to the political and social consequences of pedagogic choices, with their potential to exacerbate disadvantage. Halliday provides complex detail on the language demands of science so that teachers can consciously teach forms of language which support students in becoming scientifically literate.

Together these theories help to shape a language-centred, scaffolded pedagogy. Whilst they provide a strongly theorised basis, they do so at the broad philosophical level. Attempts to apply these transdisciplinary ideas within the field of education create their own challenges.

1.2.3 Challenges with scaffolded pedagogy

The three meta-theories of Vygotsky, Bernstein and Halliday have been adopted and adapted by educators in a range of ways, particularly in the final decades of the last century and into the new one. However, it is not an easy path to synthesise these complementary but abstract theories into a pedagogic approach that is both understandable and manageable for classroom practitioners.

Scaffolded pedagogy creates its own dilemmas and potential issues. Rather than the simplistic 'sage on the stage' of transmission pedagogy, or 'guide on the side' of progressivist pedagogy (Ravitch, D. 2007:187), scaffolded pedagogy requires a sophisticated and nuanced shift back and forth from sage to guide. Central to effective scaffolding is the notion of contingency, meaning that the teacher provides just the right scaffold at the right time to move the student forward, and senses when the scaffold might be inappropriate and need to be modified (Wood, D. & Wood, H. 1996). The ability to modify levels of support for different students at any point in a lesson requires a high level of sensitivity and sophisticated control of language on the part of the teacher.

Despite the demands and challenges, a number of initiatives have been made in this direction, with Australia leading the way. For example, the work of the Sydney School, using Hallidayan linguistics in educational contexts under the umbrella term of genre pedagogy (Martin, J.R. 1999); Dr Brian Gray with Concentrated Language Encounters, subsequently developed as 'Scaffolded Literacy' and further renamed 'Accelerated Literacy' (Gray, B. 2006a; Gray, B. & Cazden, C.B. 1992), and Rose in 'Reading to Learn' (Rose, D. 2005) have incorporated these theories, in different ways, into systematic pedagogies. Their contributions will be discussed in Chapter 2. This study, *Scaffolding Science*, engages with the three meta-theories and with the Australian developments of the past three decades which have attempted to describe a viable pedagogy for marginalised students. It uses these resources to confront the unchallenged practices of progressivist pedagogy that are so prevalent in the primary school science classroom and to replace them with contingent strategies from the new paradigm of scaffolded pedagogy.

1.3 Introduction to the study

The aim of the study was to develop, implement and evaluate a scaffolded pedagogy in a systematic way in an early primary science classroom with a group of marginalised students. Working from the premise that learning the language of science is central to learning about science, the study has two aligned interests: firstly the pedagogically purposed language choices of the teacher across time as she worked to scaffold her students to successful learning outcomes; and secondly the development of language by the learners in the class, before during and after the unit of work.

The study involved one Year 2-3 class in a multicultural low socio-economic classroom in Adelaide. The school was recognised as a 'Climate Change' school, committed to reducing its carbon footprint. Students in the school were active recyclers and gardeners, turned off lights and made compost. Those activities were part of the school culture. The challenge for this study was to reorient their socially-motivated activity to an understanding of the science behind the activities. The teacher's aim was to link individual action at a daily and micro level to the global issue of climate change. Specifically she wanted the students in this class to understand that the energy chain culminating in the eating an apple for recess and then composting the core used less of the earth's energy than the energy chain involved in the eating a packet of chips and disposing of the wrapper. Such a goal required these young students to develop an understanding of the abstract concept of energy and energy transformation. This requirement would put significant additional demands on their language resources as they developed an understanding and then came to demonstrate their learning.

This was the context in which the research project was developed. The research team was one participant teacher in one classroom and the researcher. Together we co-planned a topic on Energy Transformation in the subject of science, applying scaffolding principles to the teaching and learning. The teacher implemented the topic and the study documented and analysed the total process. The key research questions were:

1. Student performance: what changes in student language use are evident from the beginning to the end of the study?
2. Enabling processes: which teaching processes enable the scaffolding of effective teaching and learning negotiation with marginalised learners within the subject of science?
3. Issues: what presumptions and issues underlying current teaching practice are confronted as the teacher incorporates scaffolding principles into her science education repertoire with marginalised learners?

The study proposes that teacher control over, and student development of scientific language is core to the development of scientific literacy. Consequently the language use in the classroom is a key focus of study. To look at the relationship between the teacher's pedagogy and student language development, the study uses classroom discourse analysis to examine both the scaffolding choices made by the teacher across a series of science lessons and the take-up of new scientific language by the students as the topic unfolds. The effect of the pedagogy is evaluated through a language analysis of the oral and written texts of a number of individual case-study students, pre- and post-topic.

The following chapter, Chapter 2, expands on the theoretical underpinnings of scaffolded pedagogy employed in this study, drawing principally from the fields of Vygotsky's socio-historical theory, Halliday's systemic functional linguistics and Bernstein's educational sociology. The chapter demonstrates how these exotropic theories (Hasan, R. 2005), in dialogue with each other, intersect to establish a solid theoretical foundation.

From the literature, a tailored set of pedagogic principles and practices was established and refined for this project. These principles, the methodology and methods of analysis employed in the study are outlined in Chapter 3. Chapter 4 begins by summarising the change in student language from the beginning to the end of the topic as an indication of the effectiveness of the topic in developing student language. The chapter then examines the macro- and micro-scaffolding strategies; from planning and staging the topic, to classroom interactions. It describes and explains the changing scaffolding techniques used by the teacher, and identifies issues evident as the teacher moved into a new paradigm of scaffolded pedagogy. Finally, Chapter 5 summarises the learning and proposes areas for further study.

CHAPTER 2

Pedagogic foundations

2.1 Pedagogy: the curriculum, the learner and the teacher

Chapter 1 outlined the motivations and purpose of this study. The importance of producing scientifically literate citizens and problem solvers to face the issues of climate change was juxtaposed with the current struggle to keep students engaged in science education in Australia. In particular, the science education of marginalised students was shown to be failing in this endeavour.

Based on the premise that the teaching and learning of scientific language was an integral part of students engaging in science and understanding its orientation to the world, and that neither progressivist nor transmission education was likely to be adequate to this challenge, an alternative paradigm of scaffolded pedagogy was proposed. The works of Vygotsky, Halliday and Bernstein were identified as contributing to an understanding of scaffolded pedagogy, providing a robust 'meta-theoretical' foundation on which to build classroom practice.

Chapter 2 continues to elaborate on the contributions made to scaffolded pedagogy from the work of Vygotsky, Bernstein and Halliday. In addition, recent work from related fields such as cognitive psychology and neuroscience provide affirming corroborating insights, and the three theories are supplemented with these complementary perspectives where relevant.

The current study is preceded over the past two decades by a number of classroom and research programs which have endeavoured to enact these theories and highlights their contributions. The chapter concludes with a sample of these, including Australian initiatives.

Firstly, in order to do this work, a careful definition of the term 'pedagogy' is required. Sometimes loosely described as 'the art and science of teaching' (e.g. OCC 2008; Wikipedia 2013b), pedagogy derives from the Greek, meaning 'leading the child' (Roth, W. & Lee, Y. 2010). The definition used to guide the study is Bernstein's:

> *Pedagogy is a sustained process whereby somebody(s) acquires new forms or develops existing forms of conduct, knowledge, practice and criteria, from somebody(s) or something deemed to be an appropriate provider and*

> *evaluator. Appropriate either from the point of view of the acquirer or by some other body(s) or both* (Bernstein, B. 1999:259).

In other words, three interacting elements together create a pedagogic triad: the learner; identified by Bernstein in the quotation above as 'the acquiring somebody'; the curriculum; or 'new forms of knowledge'; and the teacher; 'the appropriate provider and evaluator'. Teasing out the three intersecting elements of the curriculum, the learner and the teacher creates a useful framework, making it possible to isolate to some extent the contributions of the three theories to each element. Each element is addressed in turn in the following sections. Section 2.2 introduces pedagogic element 1, the curriculum. Section 2.3 addresses pedagogic element 2, the learner. Section 2.4 outlines pedagogic element 3, the teacher. Within each section, the contributions of Vygotsky, Bernstein and Halliday and their followers are outlined in sequence.

2.2 Pedagogic element 1: the curriculum

The science curriculum is part of the '*Official Knowledge*'... *which the state constructs and distributes in educational institutions* (Bernstein, B.B. 2000:65). To echo Bernstein, the current Australian Science Curriculum embodies the 'forms of conduct, knowledge, practice and criteria' deemed to be important for students learning in the 21st century. To this end, it has embraced the goal of scientific literacy, and identified two alternative end points: a minimum goal of participatory citizenship, and a higher level goal for some of the scientific professions. The curriculum addresses these goals through three inter-related strands; Science Understanding, Science Inquiry Skills and finally Science as a Human Endeavour (ACARA 2011:4). These strands represent in general terms scientific knowledge, scientific processes, and a contextualizing of science as social practice.

The third strand, Science as Human Endeavour, aims to provide a social and cultural context within which the other two strands are embedded. It attempts to make explicit for students the relationship between scientific activity in the classroom and its wider social and historical purpose.

The goal of making science education socially relevant activity resonates strongly with the approach of activity theory. Activity theory, first proposed by Vygotsky, and further developed by his followers, provides a systematic structure for understanding cultural activity systems and their characteristics. It provides a cultural perspective on the world of science and science education. Furthermore, activity theory explicates what is required for membership of any cultural group, including the world of science. It helps to show the relationship between the strands of the Australian Curriculum Science, and importantly

how they need to work together for students to develop as members of the scientific community, whether as scientifically oriented citizens, or as scientists.

2.2.1 Vygotsky, activity systems and the goals of science education

Lev Vygotsky was a psychologist conducting his research in Russia in the 1920's and 1930's. A contemporary of Piaget and Montessori, Vygotsky's works were not translated into English until the 1960's, resulting in a delayed influence on Western education. Vygotsky's socio-historical activity theory provides a frame for understanding cultural and historical contexts and their relationship with child development. In other words, activity theory describes the structure and processes of cultural *systems* and the nature of child development in leading to cultural membership.

In turn, an understanding of the requisites of cultural membership helps to explain why disadvantaged students are so often marginalised through the process of schooling. Science education and the world of science are both activity systems, operating at different levels in society. To understand how this might be, activity theory is now introduced in more detail.

Activity theory was originally developed by Vygotsky, along with his students Davydov and Luria (Davydov, V.V. & Radsikhovskii, L.A. 1985; Lee, B. 1985; Luria, A.R. 1981; Vygotsky, L.S. 1978). The theory was further developed by Burke, Wertsch, Cole and others within the field of socio-cognitive psychology (Burke, K. 1969; Cole, M. & Wertsch, J.V. 1996; Roth, W. & Lee, Y. 2007a; Wertsch, J.V. 1991, 1985a; Wertsch, J.V., Alvarez, A. & Río, P. 1995). More recently third generation activity theory has developed as Cultural Historical Activity Theory (CHAT) (Daniels, H. 2007; Engeström, Y. 1987; Roth, W. 2010; Williams, J., Davis, P. & Black, L. 2007) .

Activity theory makes sense of the relationship between human development and the social, cultural and political context, using human activity as the unit of analysis. All human activity has three attributes. It is social, cultural, and historical: social because activity derives from and is influenced by relationships within and between social groups, both local and institutional; cultural because it is concerned with the cultural development of humans within these social settings; and historical because these phenomena are always historically situated and evolving (Vygotsky, L.S. 1978:3; Wertsch, J.V. 1998:Ch 1). The three overlapping terms; sociocultural, cultural-historical and socio-historical, variously preferred by different generations of activity theory, foreground particular attributes of human activity to distinguish between their specific foci.

All human activities are collectively part of activity systems. An activity system is:

> *…an evolving, complex structure of mediated and collective human agency. Thus, farming, commerce, dance, architecture, and, as a more recent form, mass schooling all are historical activities with objects and motives that contribute to maintaining human societies and, therefore, to maintaining individuals (Roth, W. & Lee, Y. 2007a: 198).*

In other words, activity theory explains group actions: what we do, with whom we do it, how we do it, why we do it and the significance of what we've done. The orientation to activity theory taken in this chapter is from second generation activity, particularly the work of Wertsch. Although the model of activity has been further developed by the third generation of activity theory, cultural historical activity theory (CHAT), the more recent model is also more complex (e.g. Haynes, A. 2010), and for the purposes of this study, the earlier model suffices.

The activity system of science carries the purpose of describing and explaining the natural world, generalizing phenomena and objects through taxonomies, and using this knowledge to turn nature into 'arenas of action'(Wartofsky, M. 1979:203). This activity system needs and is supported by the activity system of science *education* which carries a pedagogic intent: its goal is to reproduce those scientific purposes through apprenticing students into the larger activity system of science. In this way it develops a new generation of members to describe, explain and solve problems from a scientific perspective and to continue the work of the activity system. Western education has developed an extensive activity system of schooling to do this pedagogic work (Engeström, Y. 1987).

Cultural mediation is central to activity theory. Almost all individual actions, whether physical, verbal or mental, are mediated through a cultural lens, influenced by shared purpose and selecting from available cultural resources. Human agency is not attributable solely to any one person and their personal preferences, but is accounted for by the actions of that person together with the cultural purpose for the activity and the selection made by that person from culturally available resources; that is the 'agent-acting-with-mediational-means' (Wertsch, J.V. 1998:17-22). Wertsch described these resources interchangeably as 'cultural tools' or 'mediational means' (ibid: 17).

Drawing on Burke's pentad of activity (1969:xv) and Leont'ev (1981), Wertsch expanded on the nature of activity by proposing six elements of human cultural activity: the action, the agent, the mediational means the agent employs, the setting, motivation, and goals (Wertsch, J.V. 1998:32). Members of any activity system share understandings about each of these elements: what behaviours and tools are recognisable as appropriate and fitting according to shared intentions, and what are not.

The mutuality of understanding of intentionality, beliefs, goals, and tools or mediating means is the salient point here. Mutual understanding means that members share attention to the same features in their context, those that are relevant to their shared goals. They share significant *common ground* , that is *mutual, common, or joint knowledge, beliefs and suppositions* (Clark, H.H. 1996:93). Groups of people with these same perceptions can, with reasonable safety, based on assumed shared knowledge, make certain assumptions, that *not only do I know, but you know, and I know that you know, and you know that I know that you know*….(Sperber, D. & Wilson, D. 1986:18). Cultural communities, or activity systems, are groups of people with sufficient common ground to participate in authentically joint actions together. Developmental psychologist Tomasello explains:

> *Human beings, and only human beings, are biologically adapted for participating in collaborative activities involving shared goals and socially coordinated action plans (joint intentions). Interactions of this type require not only an understanding of the goals, intentions and perceptions of other persons, but also …a motivation to share these things in interaction with others – and perhaps special forms of dialogic cognitive representation for doing so.*(Tomasello, M. *et al* 2005:676).

Successful communication between members of an activity system presumes intersubjectivity, or *the degree to which interlocutors in a communicative situation share a perspective (Wertsch, J.V. 1998:111).*A high degree of intersubjectivity between activity system members is characterised by Trevarthen as *both recognition and control of cooperative intentions and joint patterns of awareness* (1979b:530). Translating those characteristics into Wertsch's elements of activity, activity system members would demonstrate a high degree of intersubjectivity by having a similar perspective on all elements; the setting, the goals and motivations, and what counts as both appropriate activity and appropriate mediational means with which to carry out the activity.

Importantly, members of an activity system share intentionality. That is they understand that they can draw someone's attention to something and in doing that, common meanings will be shared (Tomasello, M. 2006a:5). According to cognitive psychologists Sperber and Wilson, shared intentionality is fundamental to participants' ability to infer meanings from other participant actions, including spoken and written discourse within that cultural community (Clark, H.H. 1996:111; Sperber, D. & Wilson, D. 1986:38). Particularly poignant for teachers who struggle to find ways of improving inferential comprehension with their marginalised students is their claim that participant ability to make inferences about other participant behaviour is dependent on whether those people share intentionality in their behaviours and communication. In other words, they must be members of the same

activity system. Such an idea unsettles the notion that student comprehension of text might be taught through apparently simple strategies such as finding the main idea or self-questioning (e.g. Duke, N.K. & Pearson, P.D. 2008).

Viewing the science curriculum through the lens of activity theory confirms that the goal of students becoming scientifically literate includes far more than their ability to interact with scientific objects and observe those objects interacting in a particular physical setting. The goal of science education is for students to engage in activity in specific scientifically recognisable ways. To do this, their perspectives need to change, thereby *transforming their points of view as they adopt recognizable [scientific] perspectives, visibly trustworthy to other participants* (Bazerman, K. 2012:266).

When beginning science instruction, the teacher cannot assume high levels of intersubjectivity with and amongst her/his students. The teacher needs to expect that shared perspectives and intentionality will need to be built through science activity in the classroom. Teaching and learning *is* the process of developing intersubjectivity within the activity system of the classroom, and simultaneously within the activity system of each subject or discipline. As Rogoff explains, when working with novices, there is likely to be disjuncture in perspectives, and modifications in the perspectives of each participant are necessary to build alignment:

> *If we focus on the modifications of a novice's perspective, they can be seen as the basis for development: as the novice adjusts to better understand and communicate, the new perspective amounts to greater understanding itself and is the basis for further growth (Isaacs, E.A. & Clark, H.H. 1987; Wertsch, J.V. 1984). As such, bridging from the known to the new necessarily involves both initial differences in perspective and attempts to reach common ground for communication* (Rogoff, B. 1990:72).

This process of bridging from the familiar perspective to the new to build intersubjectivity is particularly apparent and urgent with novices who are also marginalised students who may bring quite different cultural orientations and perspectives to the classroom. In fact, educationally marginalised students could be re-defined as 'those students for whom schooling perpetually fails in establishing intersubjectivity within target activity systems'.

In summary, the goal of science education is to develop intersubjectivity between teacher and students about why scientists care about the phenomenon being observed (motivations), how a scientist should behave in engaging with the phenomenon (agency), what to do (action), what the purpose and goal of engagement is (goals and intent), how to engage in the physical processes and routines (physical means), and how to engage in

communicating about the phenomenon, both comprehending and producing scientifically recognisable texts (language means).

It goes without saying that teachers themselves need to have developed intersubjectivity with the world of science, sharing some level of intentionality with scientists, as well as having a clear understanding of scientific content and processes. Without this, their ability to effectively apprentice students into science is severely compromised. Sadly, the Australian Science reports indicate that this necessary alignment is often not the case, particularly in primary schools (Goodrum, D. *et al* 2000:104).

For the generalist science teacher in Australia, scientific values must be gleaned from the expressed aims of the Australian Science Curriculum (ACARA 2011:3). However, the information is not straightforward but requires significant inference from the reader.

The Australian Science Curriculum has the potential to develop the necessary intersubjectivity with the support of an aware teacher. Students are apprenticed into all six elements of the activity system of science through its three strands. Science as Human Endeavour addresses setting, motivation, and intent. Science Understanding continues to address motivation and intent, and extends to actions and mediational means. Science Processes continues with the 'how', teaching action and mediational means, both physical and language.

Language skills are arguably the most important 'mediational means', enabling students to make meaning with other members of the science community and to become scientifically literate. This includes both comprehending oral, visual and written texts produced by scientists and educators, and producing authoritative text themselves. The Literacy Capability in the Australian Curriculum makes these language demands explicit (ACARA 2013).

As a post-script to this section, the parallel between the notion of an activity system and the work of sociolinguist James Gee on discourses will be evident here to those who are familiar with Gee's work (Gee, J.P. 1994). Gee's attributes of discourses are clearly aligned with Wertsch's elements of activity systems:

> *…discourses are ways of coordinating and integrating words, signs, acts, values, thoughts, beliefs, attitudes, social identities, as well as gestures, glances, body positions, objects and settings. A discourse is a sort of 'identity kit' which comes complete with the appropriate costume and instructions on how to act, talk and often, write in order to take on a particular social role that others will recognise (Gee, J.P. 1996:6).*

The descriptors in Gee's notion of discourse; words, signs, acts, values and so on correlate well with Wertsch's six elements which constitute an activity system; action, agent, means, setting, goal and motivation. The approximate equivalence is demonstrated in Table 1:

Table 1. Comparison of Gee's Discourse markers and Wertsch's activity system elements

Wertsch's elements	Gee's descriptors
action	acts
agent	social identities, take on role that others will recognise
means	words, gestures, glances, body positions, thoughts, costume
setting	setting
goal	
motivation	beliefs, attitudes

Although 'discourse' and 'activity system' could arguably be used interchangeably, the substitution of 'discourse' for activity system is problematic in this study because of other uses of the term. Whereas Gee's use of 'discourse' is closely aligned with 'activity system', 'discourse' in Systemic Functional Linguistics and Bernstein's educational sociology refers specifically to a corpus of language operating at the level of text in a social context (Martin, J. R. & Rose, David 2007). Therefore, in this discussion, 'activity system' is used to refer to the broader cultural system, and 'discourse' refers to language.

This section outlined the complexity of activity system membership, and showed the relationship of the science curriculum to activity system membership. It argued that building alignment towards high levels of intersubjectivity between student, teacher and the target activity systems was the goal of science education.

For marginalised students, the disjuncture between the language of home activity systems and that of school is a significant reason for their marginalisation.. Bernstein, the British sociologist, sheds further light on why the activity system of science and its embedded language or discourse is so unfamiliar to marginalised students. In the next section, the work of Bernstein is drawn on to explain the gap between student home discourses and those encountered at school.

2.2.2 Bernstein and the structure of knowledge and discourses

Educational sociologist Basil Bernstein distinguished between 'everyday, commonsense, local' knowledge, and 'schooled, academic, official' knowledge (Bernstein, B. 2000:156). Each is realised as a different discourse. The former, everyday knowledge, is realised as horizontally organised discourse, while the latter, academic knowledge, is realised as vertically organised discourse. Horizontal discourse is *likely to be oral, local, context*

dependent and specific, tacit, multi-layered and contradictory across but not within contexts. Its purpose is to *maximize encounters with persons and habitats* (ibid:157). Crucially, horizontal discourse is segmentally, rather than hierarchically ordered, so that the sequencing and acquisition of knowledge in one area of everyday life may have little bearing, and certainly not be dependent on learning in another area. Bernstein continues: *they are contextually specific and context dependent, embedded in on-going practices, usually with strong affective loading, and directed towards specific, immediate goals* (ibid:159). In other words, horizontal discourses have a social orientation. Horizontal discourses are the experience and cultural resource of all children in their everyday lives. These discourses express community-oriented, local activity systems.

However, horizontal discourses are not an homogenous classification. Bernstein's earlier work explained how the mediating tools of language, which he terms 'modes' are differentially distributed across social groups and within local horizontal discourses. Despite drawing strong criticism, one of the outcomes of his work on restricted and elaborated codes was to show differences in language use and purpose between low socio-economic and middle class home discourses (Bernstein, B. 1971). As explained by Wells:

> *…although all had access to the same language, adults of different social classes tended to adopt characteristically different ways of using language – different 'orientations to meaning' – according to their involvement in material and symbolic production, either as laborers, directors, or creators; these differences would then carry over to the ways in which they talked with their children, thereby differentially preparing the children for the ways in which they would be expected to use language in the context of formal education* (Wells, G. 2007:257).

Building on Bernstein's work, these 'mode' differences were further exemplified by Hasan and Williams, in their analyses of child-parent talk, and also around book reading (Hasan, R. 1988; Williams, G. 1998). Their work highlights contrasting ways that middle-class and low socio-economic parents mediate the development of language and the reading of stories in the home. Whereas the middle-class interactions show similar patterns of interactions as those used in school settings, the low socio-economic parents develop an orientation to text which is less congruent with school practices. Earlier work by Heath in the USA identified the same issue. She compared home language practices of three contrasting communities and highlighted how *the differences in language use are linked to the systemic relations between education and production for members of the three groups* (Heath, S.B. 1983).

In summary, although all children bring language resources from their home horizontal discourses to school, some local horizontal discourses provide children with a cultural orientation and ways of using language that are more congruent with school uses than others.

In contrast to horizontal discourses, formal academic knowledge is realised in vertical discourses: *coherent, explicit and systematically principled structure(s), hierarchically organized… or with specialized modes… for the production and circulation of texts* (Bernstein, B. 2000:160). Vertical discourses do not consist of separate segments, but of specialized symbolic structures of explicit knowledge. Their processes are linked hierarchically, not segmentally, to other processes within the discourse. Importantly, their settings, roles, activities and tools are marked not by specific physical contexts, but through specific ways of decontextualising. If horizontal discourses are involved with commonsense, the 'thinkable', then vertical discourses are involved with the uncommonsense, the 'unthinkable', that is abstract ideas which can be distanced from present reality. These discourses express discipline-oriented activity systems. The contexts of vertical discourse are *specialised knowledge of the natural and social sciences [and] their technologies* (Bernstein, B.B. & Solomon, J. 1999:273).

The nature of vertical discourses presents many challenges for marginalised students whose horizontal home discourses have little in common with academic discourses. The vertical discourse and abstract perspective of science brings with it new and unfamiliar purposes, goals, and mediational means, a different orientation and new foci of attention. While familiar horizontal discourses attend to social interactions, the vertical discourse of science attends to the systems of the natural world.

Bernstein draws attention to two further aspects of vertical discourses which are significant when thinking about pedagogy. The first is the nature of the knowledge structures of vertical discourses, and the second is the nature of their boundaries.

From Bernstein's perspective, the knowledge structures of science are hierarchical (2000). Scientific concepts move towards higher levels of generalisations, finding patterns at increasingly abstract levels. One concept builds on another. In hierarchical knowledge structures, gaps in constructing earlier knowledge matter because later concepts are dependent on this understanding. Effective science education must ensure that each level of learning is solid, that abstract concepts have solid foundations.

Another variable to consider when understanding the nature of discourses is their relationship with each other. The distinction between discourses is marked by a boundary or classification, which may *vary in its explicitness, its visibility, its potential and in the*

manner of its transmission and acquisition (Bernstein 1990: 206). Boundaries mark the specialisation of a discourse by insulating what matters from what does not matter, what is aligned with the discourse and what stands in opposition to the discourse. The discourse of science as realised in the aims of the new Australian Science curriculum has a strong boundary with membership criteria clearly stated and, for the first time, the language expectations laid out in the Literacy Capability. For Bernstein, a strong boundary is important to the learner. It *opens the possibility of futures* (ibid), and marks the shift from the commonsense to the uncommonsense, from the known to the unknown.

Visibility is not the only important consideration for boundaries. To be accessible to all, boundaries have not only to be visible but also permeable. Science education has not only to mark the boundary but provide a way to cross over, a bridge:

> *(s)ocial class relations through distributive regulations, distribute unequally, discursive, material and social resources which in turn create categories of the included and excluded, makes crucial boundaries permeable to some and impermeable to others, and specialises and positions oppositional identities* (ibid: 207).

Traditionally, transmission pedagogy, valuing knowledge over the knower has a strong boundary. At the same time, transmission pedagogy limits the permeability of the boundary of science; it excludes those who don't come with the required membership criteria and language for engagement. Progressivist education, valuing the knower over knowledge, has a weak and permeable boundary (Maton, K. & Moore, R. 2010). It invites all as members, but overlooks the important membership criteria which give students a legitimate voice in the new discourse:

> *…the progressivist primary classroom… can be seen to operate with a weak classification of subject disciplines through its integrated, 'child-centred' curriculum* (Bourne, J. 2003:498).

Successful boundary crossing into a vertical discourse such as science requires a boundary that is both visible and permeable. Only with these two criteria met will all students fulfill their democratic right to enhancement, inclusion and participation (Bernstein, B. 2000:xx). Scaffolded pedagogy, respecting both knower and knowledge, has to control and modify both criteria for effective teaching and learning. It begins with a slightly weaker, but never invisible boundary, to build a bridge for marginalised students and help ensure permeability. As learning progresses and intersubjectivity is established, the boundary becomes stronger and more visible, and the teaching and learning conversations continue within the vertical discourse.

In summary, Bernstein identifies some important issues facing marginalised students in achieving the goals of science education. They have to shift from their familiar and personal horizontal discourses to an unfamiliar abstract vertical discourse. This new discourse presents a different orientation to the world, attending to phenomena rather than people. Its knowledge structure is hierarchical, rather than segmented, creating difficulties if each layer of knowledge is not solidly constructed. The purposes for, and ways of using language are unfamiliar. Neither transmission nor progressivist pedagogies provide the optimum conditions for successful boundary crossing. Scaffolded pedagogy has the potential means to achieve this, with the challenge of marking a clear but permeable boundary to this unfamiliar world.

A significant part of this challenge for the teacher is to understand and be able to make explicit the language required for membership of the scientific community. The field of systemic functional linguistics provides a great deal of support in this area. An outline of its contribution follows.

2.2.3 Systemic functional linguistics and the language of science

> *As teachers of science, . . . our primary skills lie not in our ability to do science, or showing children how to do science, but in our ability to interpret and convey a complex and fascinating subject. We are, primarily, raconteurs of science, knowledge intermediaries between the scientific canon and its new acolytes. Such an emphasis means that we must give prominence to the means and modes of representing scientific ideas, and explicitly to the teaching of how to read, how to write and how to talk science* (Wellington, J.J. & Osborne, J. 2001:138).

The combined perspectives of Vygotsky's activity theory and Bernstein's work on discourse demonstrate that access to, and control over the language of vertical discourse is central to membership of the activity system of science. Linguists from the field of systemic functional linguistics have contributed significantly in explaining the function, text types and lexico-grammatical choices which reflect and realise the purposes of scientific endeavour and which are necessary goals of student appropriation. By using new language, students' orientation shifts from the everyday, horizontal discourse to the knowledge focused, vertical discourse of science.

To begin with, Halliday has clearly defined the salient purposes and processes of texts used by scientists to go about their business, engaging with concrete objects, observable phenomena and abstract concepts:

> *Such that they can jointly engage with the values, purposes and processes of science; describing, classifying, hypothesizing, explaining and arguing about the natural world, students must appropriate new ways of using language* (Halliday, M.A.K. & Martin, J.R. 1993:186-96).

Each of these processes is realised as scientific activity, and to express the activities, particular text types or genres are called on, each with predictable and purposeful structures (Halliday, M.A.K. & Martin, J.R. 1993; Korner, H. *et al* 2007; Lemke, J.L. 1993; Martin, J.R. & Veel, R. 1998; Unsworth, L. 2001). As learning in science progresses, the genres become increasingly complex and abstract. Macro-genres, addressing several purposes in the one text, are frequent in the secondary science curriculum.

It is apparent that the ability to use these texts impacts on student life trajectories. Rose and Korner's analysis of scientific texts produced in the workplace identified a developmental continuum of genres and grammatical patterns associated with the work of scientists at growing levels of abstractness from everyday spoken English (Level 1) to research scientist level (Level 8). Rose argued that students' failure to gain control over the more abstract genres such as complex explanations and the macrogenres is likely to restrict access for students to the higher level goal of science education, namely skills sufficient for employment in the scientific professions. Unless science education gives marginalised students control of these more specialised text types as they move through schooling, employment possibilities are restricted to the maximum level of 'skilled operator', thus reducing the chance of higher levels of employment such as technician, applied scientist or research scientist (Korner, H. *et al* 2007:143; Rose, D. 1998).

The importance of scientific language is not restricted to the level of text type or genres. Within the genres, lexico-grammatical choices are also important. From a systemic perspective, language choices represent three meaning systems which are concurrently realised in any communication situation: Field (topic or focus), Tenor (relationships), and Mode (situatedness) (Eggins, S. 1994). Together these systems form the variables of 'Register'. These three Register considerations have significant and predictable impacts on language use in creating and understanding texts (ibid: 9).

Language users in any language event make Register choices along a continuum from situated or most spoken-like language to decontextualised or most written-like language (Polias, J. 2011:27).

Table 2. Language Register continuum representing situated to decontextualised language

Field continuum

Everyday	Specialised	Highly technical and abstract
Typically concrete and specific	Combination of specific and non-specific,technical and non-technical, abstract and concrete	Typically technical generalisations and abstractions

Tenor continuum

Informal	Increasing formality	Formal
Familiar people, greatest contact. Novice. Greatest subjectivity	Decreasing contact, neutral status, more informed	Unfamiliar people, least contact, expert, greatest objectivity

Mode continuum

Most spoken	Spoken texts written down, and written texts spoken aloud	Most written
Language accompanying action. Close, here and now, shared	Language as recounting and reporting	Language as reflection. Distant, not shared.
Face-to-face, dialogic, spontaneous. Concrete and specific to the context.	Unshared experiences, recounting, generalising, debating, formal oral presentation	Monologic and reflective. Precise, planned, edited, organised.

The language of horizontal, every day discourses fits typically at the situated or 'most spoken' end of the continuum. The highest level of academic writing, a goal for the higher end of secondary or tertiary education belongs at the decontextualised or 'written-like' end of the continuum. The shift along the continuum from oral to written is not a personal style preference but represents a different way of seeing the world. Halliday argues that the differences in forms between oral and written language create different realities where *writing creates a world of things; talking creates a world of happening* (Halliday, M.A.K. 1985:93). He continues:

> *Each is a metaphor for a different dimension of experience. Spoken language happens… Written language exists… Spoken language favours the clause, where processes take place, whereas written language favours the nominal group, the locus of the constitution of things* (Halliday, M.A.K. 1985:98-99).

To become scientifically literate, students must develop scientifically recognisable and useful language through a shift, orally and in written form, along the Mode continuum from more situated to more decontextualised language, from concrete to abstract, from language favouring the clause to language favouring the nominal group, and from informal to formal. These language forms are summarised by Martin as power words, power grammar and power composition (Martin, J.R. 2013a). Control over these language forms enables a shift from language accompanying action to language as reflection, a transition which is essential for the shift from specific instances of concrete action to scientific generalisations. Importantly, the capacity to use language in more sophisticated ways means that students are not bound to 'hands-on' activity, but can use language to reflect on prior activity, both their own and that of others (Eggins, S. 1994:54).

The distinct features of scientific texts have been described by a number of linguists, including Halliday (1990), Rose (Rose, D. 1998), Korner et al (Korner, H. *et al* 2007) Martin (1993) and Fang (2005). They describe language features at text level (genres and their purpose), stage level (how the text is structured), clause level (clause structure and relationship between clauses), and word level. A summary of the most important scientific genres and their language features, as described by the linguists above follows as Table 3 (Eggins, S. 1994; Fang, Z. 2005; Halliday, M.A.K. & Martin, J.R. 1993; Korner, H. *et al* 2007).

Table 3. Summary of scientific genres and language features

Purpose	Genres / macrogenres	Language features typical of this genre (e.g.s from http://en.wikipedia.org/wiki/Snake#Moulting)
Taxonomising the world Describing things Classifying things	Information reports: Compositional report (part-whole) Classification report (class-members)	Relational processes (e.g. Snakes **are** elongate, legless, carnivorous reptiles of the suborder Serpentes) Expanded nominal groups (e.g. Snakes are **elongate, legless, carnivorous reptiles of the suborder Serpentes**) Non-finite clauses of purpose (e.g.**To accommodate their narrow bodies**, snakes' paired organs appear one in front of the other.) Careful modality to make statements true (e.g. Like **all** squamates…, **Many** species of snakes…, **Some** species retain…
Describing activity Explaining bservable phenomena Explaining abstract theories	Explanations: Sequential Causal Theoretical Factorial Consequential	Material processes (e.g. Before a molt, the snake **stops eating** and often **hides** or **moves** to a safe place.) Conjunctions (temporal, causal) (e.g.Just **before** shedding, the skin becomes dull and dry looking.) Flow of information (e.g. **The inner surface of the old skin liquefies**. **This** causes the old skin to separate from the new skin beneath it.) Foregrounding of clauses and circumstances of time, place (e.g. **Before a molt**, the snake stops eating and often hides or moves to a safe place.) Non-finite clauses of purpose e.g.(Cobras, vipers, and closely related species use venom **to immobilize or kill their prey**.)
Instructing	Procedures	Material processes, using commands, in Theme position, numbered (e.g. 1. **Place** the powder in a beaker.) Sometimes clause or circumstance of condition or time in Theme position (eg. **If the mixture is too stiff**, add a little water.) Circumstances of place, time, means, and condition (eg. **In the beaker, when ready, with the spatula, at 60 degrees)** Can be elaborated with figures or flow chart Expanded nominal groups (eg. large brown glass or plastic bottle (not metal)
Hypothesis/procedure /explanation /argument	Laboratory report	Each section reflects one of the genres above, and retains the language features of that genre.
Arguing / explaining	Argument	If written for scientific audience, establishes authority through use of technical language, lexical density, nominalisation, and uses scientific explanations as evidence to support argument. Use of passive voice (e.g. it is expected that…) Non-human participants (e.g. Research shows…)
Language features typical of all written, scientific genres Endophoric, i.e. logic is contained within the text Technical language (e.g. ectothermic, amniote vertebrates) Lexically dense through nominalisation and simple grammar		Grammatically simple; complexity comes from expansions within the clause Non-human participants Use of passive voice to mask agency and organise logical chains (e.g. Living snakes **are found** on almost every continent.) Use of grammatical metaphor (nominalisations)

The genres and lexico-grammatical choices outlined on the previous page are essential cultural tools of science. Students' ability to reconstrue the world using this new language enables them to expand their identity and become discourse apprentices. Acquisition of these new language resources does not guarantee that students have developed deep understandings of scientific content, but importantly it gives students the resources for further negotiation of meaning as novice members of the activity system of science. This important point of the relationship between concept development and language will be discussed further in the chapter.

2.2.4 Activity theory and the primary science curriculum

The exploration of the curriculum began with an outline of activity theory and the criteria required for membership of the activity system of science. Developing a high level of intersubjectivity with the scientific community through building common perspectives, values, and mediational means was identified as the ongoing work of science education. The challenge of this work with marginalised students is clear, with the demanding shift from social, horizontal discourses to vertical knowledge discourse of science. In particular, the gradual development of scientific language across the years of schooling was highlighted as central work of science education so that marginalised students have greater choice over their life trajectories.

The principles of activity theory outlined here demonstrate that, if young apprentices are to develop that high level of intersubjectivity, superficial and novel engagement with 'hands-on' science activities will not be sufficient. It is what happens around activity that matters. Students need to be describing, classifying, explaining, hypothesizing and arguing, and using scientifically valued language for these purposes. They need to be shown how to interact scientifically with material objects. They have to appropriate material, cognitive and verbal means such that they can be recognised as novice members of the scientific community.

This is not a simple question of whether science lessons should be 'hands-on' or 'hands-free'. Regardless of whether the lesson involves material (hands-on) or linguistic (hands-free) tools, all science activities need to be goal-oriented, that is have a culturally useful purpose linked to scientifically valued skills, knowledge, understanding and dispositions. The role of language in the development of intersubjectivity is clear. For this reason, the goals of science have to include close attention to the development of not simply scientifically useful written genres, but also the lexico-grammatical choices which demonstrate the logical relationship between ideas, and enable the use of language as a tool for reflection and planning. The new Australian Curriculum science has made efforts to meet this aim particularly through Literacy as a General Capability which outlines relevant genres, grammatical features and word knowledge to be developed in science as students move through the years of schooling.

Now that the cultural goals of science education have been established, it is time to think about the second element in the pedagogic triad: the role of the learner, or in Bernstein's terms the 'acquiring someone', in engaging with those goals. This will be addressed in the next section.

2.3 Pedagogic element 2: the learner

The second pedagogic element is the acquirer of knowledge; that is the student. The curriculum element foregrounded the goals of schooling as a product of the cultural and social context. This section foregrounds the active role of the learner in socially embedded psychological and linguistic processes.

The section begins by outlining the work of Vygotsky and his followers on the processes of social mediation and internalisation in children's learning and development; that is how the linguistic becomes the psychological. It continues by explaining how intersubjectivity between participants grows through these developmental processes, calling on the detailed work of developmental psychologists Trevarthen (1998; 1979a; 1979b) and Tomasello (1999, 2006a; 2005)

The perspectives of Vygotsky, Trevarthen and Tomasello build an understanding of socially and culturally saturated child development that stands in challenging contrast to the work of Piaget, a contemporary of Vygotsky's. Piaget's theories of child development, and in particular the stages of development, have gained significant traction in western education and underpin progressivist pedagogy (Cole, M. & Wertsch, J.V. 1996; Piaget, J. 1953, 1950). Because the pedagogic processes available to the student are strongly influenced by the developmental perspective taken by the teacher, it is important to identify the points of contradiction and their effect on pedagogy.

Bernstein too contributes to understandings about child development. Like Vygotsky, he sees child development as a process of social mediation. Bernstein explains how the Piagetian construction of the developing child built in progressivist pedagogy normalises inequality by restricting the role of the teacher and limiting the chances for students to appropriate important cultural resources.

The final contribution to child development comes from the perspective of systemic functional linguistics, specifically their work on child language development in relation to learning. As Bernstein has argued, children's language development may follow different directions depending on the orientations to meaning made available in their social contexts. The work of Halliday and Matthiessen describes this process of making meaning in social contexts and foregrounds one important developmental trajectory; the process of generalisation and abstraction necessary for successful participation in the language of vertical discourses.

2.3.1 The relationship between learning and development

First we return to Vygotsky's most familiar contribution to education: his thesis on learning and development as a socially mediated process (Daniels, H. 2001; Vygotsky, L.S. 1978, 1986; Wertsch, J.V. 1985a). This section, Section 2.3.1, serves three purposes: firstly it outlines the important principles of development from a Vygotskian perspective; secondly, when relevant it draws in corroborating research from other theorists. Finally, it contrasts the perspectives of sociocultural theory on learning and development with those of psychologist Piaget, whose account of child development has so strongly influenced progressivist education and whose work is frequently called on to support a pedagogy where children *construct their own knowledge through their own discoveries* (Ravitch, D. 2001:441).

-Learning is socially constructed: from the collective to the individual

Fundamental to Vygotsky's view of development is the social nature of learning: to understand the development of the individual, one must first understand the social relations in which the individual exists (Wertsch, J.V. 1985a:58). Rather than attempt to look at internal psychological processes to understand behaviour, Vygotsky argued that the reverse order was necessary:

> *Formerly, psychologists tried to derive social behaviour from individual behaviour. They investigated individual responses observed in the laboratory and then studied them in the collective… genetically speaking, [posing the question] deals with the second level in behavioural development. The first problem is to show how the individual response emerges from the forms of collective life (Vygotsky, L.S. 1981:164-5; cited in Wertsch, J.V. 1985a:59)* .

While Piaget's theory of development, stage theory, does not ignore the role of the social context, it does not play a primary role in development:

> *Piaget's stage theory of development tacitly reflects the ideology of individualism. The stage theory is based on an interactionist metaphor in which the relation between the person and the social world is conceived as an individual standing apart from and interacting with the social environment* (Bidell, T.R. 1992:307; cited in Daniels, H. 2001:37).

Piaget regarded the autonomous child as standing apart from society and interacting with it as a separate identity, whereas Vygotsky regarded the child as immersed in social activity with development emanating from his or her participation within society (Vygotsky, L.S. 1978). While Piaget acknowledged the role of experience and social transmission in development, it was only pertinent if the child was 'ready', that is already in a state to accept the information (Piaget, J. 1964:180). Piaget's unit of analysis was the individual, with social influence overlaid once the child was able to take another's perspective. In contrast, Vygotsky regarded cultural

mediation, particularly language, as having primacy in child development, and consequently his unit of analysis was social activity within which the individual child develops.

From a Vygotskian perspective, learning and development are fundamentally cultural. The child's learning cannot be separated from the context within which it occurs. This position is reflected in the work of the Vygotskian-influenced educational psychologist Bruner:

> *I have come increasingly to recognize that most learning in most settings is a communal activity, a sharing of the culture. It is not just that the child must make his knowledge his own, but that he must make it his own in a community of those who share his sense of belonging to a culture. It is this that leads me to emphasize not only discovery and invention but the importance of negotiating and sharing - in a word, of joint culture creating as an object of schooling and as an appropriate step en route to becoming a member of the adult society in which one lives out one's life* (Bruner, J. 1986:127).

-Intersubjectivity as the goal of learning and child development

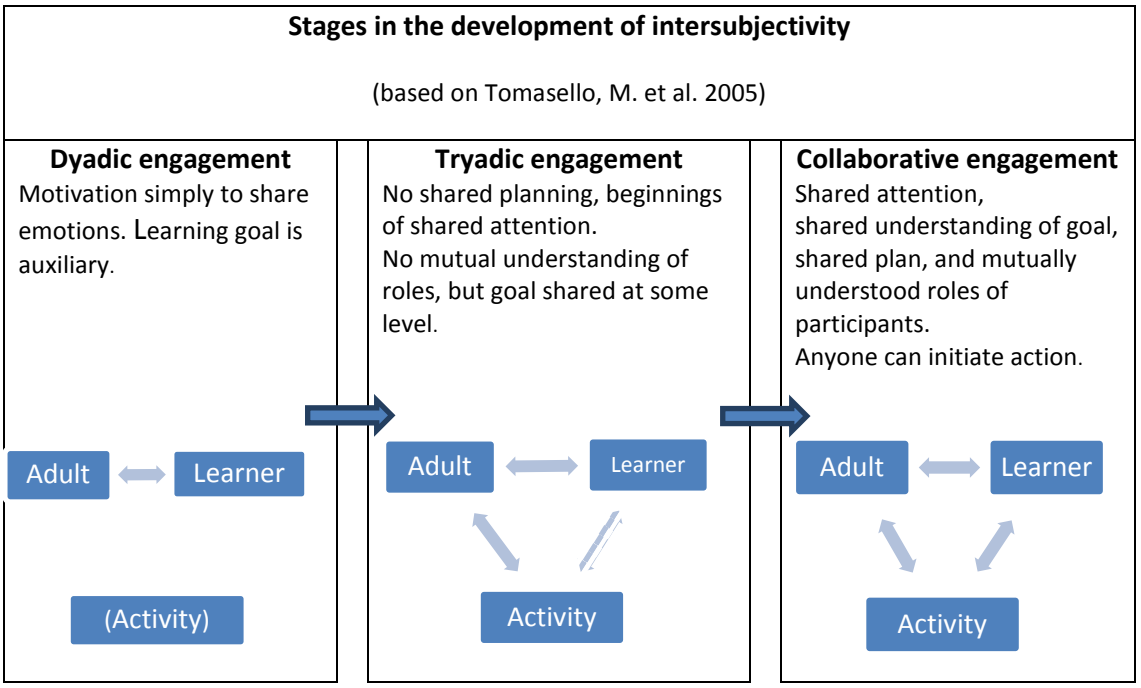
Whether the most important goal of learning and development is personal fulfillment or participatory citizenship depends on the understanding of human subjectivity. Piaget saw the child from what von Wright would call a *punctual* perspective, a discrete and singular human being, in other words *homo clausus,… a cognitively autonomous subject* (Von Wright, M. 2006:160). In contrast, the socio-historical perspective is *relational*; it sees children as *homines aperti*, open selves, *intersubjectively and socially constituted* (ibid). Choosing between these perspectives has a significant influence on understanding the goals of child learning and development. Piaget's interest was in change and transformation of the child. While he acknowledged that the environment was an influence, he saw development as essentially a natural, biological process which continued regardless of cultural influences (Campbell, R.L. 2006:8). Vygotsky acknowledged the influence of biology, but regarded culture as directing the development of higher systems of thinking (Vygotsky, L.S. 1978) From a socio-historical perspective, the goal of development is personal fulfillment embedded in and dependent on membership of valued activity systems, in other words, the goal is cultural intersubjectivity.

To recall Wertsch's list of activity system elements (ref Section 2.2.1, p16), a high level of intersubjectivity includes shared understanding about who can be an agent, and about agency, that is the means available to the agent. It requires shared perception of settings and shared purpose or intent. Then question then arises: how does intersubjectivity develop between established members of an activity system and would-be novices or apprentices?

The process of developing intersubjectivity is described by child psychologist Trevarthen as moving from the primary, pre-linguistic intersubjectivity of babies, to secondary, socially-based

intersubjectivity where the ability to read the intentions of others is essential (Trevarthen, C. 1998; Trevarthen, C. 1979a; Trevarthen, C. & Hubley, P. 1978). This notion is further developed by developmental psychologist Michael Tomasello as a process of changing states of engagement. He refers to three levels of intersubjectivity: the first is dyadic engagement, the second is triadic engagement which leads to a third and final stage of collaboration (Tomasello, M. *et al* 2005).

Figure 1. Stages in development of intersubjectivity (extrapolated from Tomasello, M. *et al* 2005)



For Tomasello, the process of developing intersubjectivity begins with strong dyadic engagement; that is a strong emotionally positive relationship between infant and adult. At this stage, it is essentially emotions that are shared. For the child, the relationship is the focus of attention and may well be the prime initial motivation for student engagement and induction into new cultural activity. Tomasello's perspective is echoed by Wood, the psychologist who developed the concept of scaffolding:

> *The child's entry into these activities, whose rewards are distant and often ill-defined, rests in the first instance on a social contract – a trust in and desire to please or to emulate another. It is just such a social contract which appears to underlie adult intervention and the growth of intersubjectivity. But it is an intersubjectivity managed mostly from the adult's side* (Wood, D.J. 1980:283).

The importance of strong emotional attachment for healthy child development and the issues that arise from lack of attunement between child and caregiver have been long recognised in the field of clinical psychology (Stolorow, R. 1994). Stolorow points out that when caregivers do not attend effectively to a child's affective state, the response becomes one of defense and

resistance (ibid: 6). Thus emotional attachment is a necessary precursor for deeper engagement in new activity.

More recently, these claims have gained support through the work of neuroscience on the development of mirror neurons. Mirror neurons develop in humans through positive interactions with significant others, and through imitation, lead to the development of empathy and social identification at an important but unconscious level:

> *The role of mirror neurons in intersubjectivity, then, may be… described as allowing interdependence… through mirror neurons, we can understand the intentions of others* (Iacoboni, M. 2009:265).

Strong positive dyadic engagement, therefore, is not simply feel-good ideology, but an important neurological foundation for the development of intersubjectivity. The effect of the absence of a strong positive relationship between teacher and student cannot be underestimated when the experiences of so many marginalised students in classrooms are so excluding. Dyadic engagement is the essential foundation of intersubjectivity but not sufficient in itself. It must move on if intersubjectivity is to extend beyond this social contract.

Engagement, argues Tomasello, continues to the triadic stage as the child's attention is drawn to the shared activity, as the child develops a mutually shared understanding of the goal of activity, and the child is able to participate with shared intention.

In the triadic stage of intersubjective development, goals are shared, and the adult supports with the cultural tools available until the child is ready to and capable of taking over. Gradually, the meaning of all aspects of an activity becomes common knowledge, mediated in most cases, through language. As meaning is established, participants begin to share roles and language, underpinned by shared intent. This process leads to the final stage of collaborative engagement, where all participants share goals, can plan together, and can comfortably assume shared knowledge about the purpose, motivation, roles and means.

The gradual shift in engagement from dyadic to collaborative engagement described by Tomasello resonates with Wertsch's observations about child regulation. He too recognises three stages in engagement in activity, shifting from 'other-regulation' when the goal of activity is not shared by adult and child, gradually shifting to 'self-regulation', when the goals and means relevant to the activity have been internalised by the child such that the child no longer needs the adult to complete the activity (Wertsch, J.V. 1979).

While Tomasello's description of intersubjective development begins at infancy, there is a strong case for extrapolating this process to the classroom. Two important principles can be taken from this theory for teaching science in the early years of schooling: firstly that dyadic

intersubjectivity or strong positive emotional attachment between teacher and students is an essential foundation for learning and must be sustained for learning to occur. Secondly, that dyadic engagement is just the beginning: student engagement must become seriously immersed in the activity system of science, building to triadic engagement in shared goals and means, including language, if students are to ever become members of the scientific community.

Dyadic and triadic engagement can be reconceptualised in the classroom as focusing on *affective* and *academic* intersubjectivity respectively. These terms will be used throughout this study. The two stages are not mutually exclusive. In both stages, students are engaged with activity. Dyadic or affective engagement focuses primarily on the establishment and maintenance of goodwill, trust and positive relationships. Triadic or academic intersubjectivity does not ignore these aspects; rather it builds on them. It supports the appropriation of cultural meanings attached to the activity mediated through language, enabling the student to shift from 'other-regulation' to 'self-regulation' (Wertsch, J.V. 1979).

The development of intersubjectivity to the level of collaborative engagement within science is likely to be a slow process, from the early years of schooling to tertiary level. However, in the early years of primary school, the achievement of triadic engagement; that is academic intersubjectivity between student, teacher and scientific activity is arguably a reasonable interim goal.

-Learning moves from the intermental to the intramental

Vygotsky was concerned with the interpsychological processes through which child internalised learning from others in the social context. He formulated the 'general genetic law of cultural development' to explain the process of internalisation:

> *Every function in the child's cultural development appears twice: first, on the social level, and later, on the individual level; first between people (interpsychological), and then inside the child (intrapsychological). This applies equally to voluntary attention, to logical memory, and to the formation of concepts. All the higher functions originate as actual relations between human individuals* (Vygotsky, L.S. 1978:57).

In the process of internalisation the learner is not passive, but an agent who influences the direction of development. To avoid the inference of passivity from the term 'internalisation', subsequent theorists have adopted the alternative term proposed by Leontev and Bakhtin of 'appropriation' (Cazden, C.B. 2001:76). This alternative term also avoided the perception of a duality between internal and external processes (Newman, D., Griffin, P. & Cole, M. 1989; Rogoff, B. 1990; Rogoff, B. *et al* 2003; Wertsch, J. & Stone, C.A. 1985):

> *If…the individuals are seen as appropriating some aspects of activity in which they are already engaged as participants and active observers, with the interpersonal aspects of their functioning integral to the individual aspects, then what is practiced in social interaction is never on the outside of a barrier, and there is no need for a separate process of internalization (Rogoff, B. 1990:195).*

The notion of appropriation is a useful one in the classroom. It not only highlights the agency of the child as active participant in the teaching-learning negotiation, but it also recognises the complexity of internalisation, as the child selects from new information made available, reconciling new learning with prior knowledge to form new knowledge.

-Learning precedes development and occurs within the zone of proximal development

One of the most important differences between the Piagetian and Vygotskian theories of child development is the relationship between learning and development. Piaget's stage theory stressed biologically supported, universal stages of development (John-Steiner, V. & Souberman, E. 1978:123; Piaget, J. 1964). For Piaget, instruction is ineffective until children reach the appropriate stage of development. Until this stage is reached, new learning is not possible:

> *Each time one prematurely teaches a child something he could have discovered himself, the child is kept from inventing it and consequently from understanding it completely* (Piaget, J. 1970:715).

Vygotsky's understanding of learning and development places the concepts in reverse order. He regarded learning in socially constructed settings with culturally informed 'others' as the pathway to child development. This idea led to the one of the most familiar of Vygotsky's concepts, the zone of proximal development (ZPD), also translated as the 'zone of potential development' (Luria, A.R. 1961:5), the 'zone of next development' (Sutton, A. 1988) and interpreted as the 'construction' zone (Newman, D. *et al* 1989) . The ZPD is defined by Vygotsky 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, L.S. 1978:86).

Two important aspects of the ZPD are often misinterpreted: firstly it is not an attribute of the child, but a socially constructed zone, the extent of which is determined partly by the child's already established developmental level, as well as internal cognitive functions that are

'embryonic' (ibid) and partly by the capacity of the adult to support the learning in a contingent manner. The capacity of the ZPD is influenced by contingency:

> *Contingency is defined as instruction that is paced by moment-to-moment signs of success and failure by the child. So, where a child shows signs of success, any ensuing instruction should offer more scope for child control and greater degrees of freedom for potential failure. Following on failure, more help should be given immediately; control should be increased and degrees of freedom for error reduced* (Wood, D.J. 1989:70).

Secondly, the zone of children's proximal development is often viewed as being 'slightly beyond their competence' (Rogoff, B. 1990:14). The suggestion of 'just beyond' is not Vygotsky's. Rather, instruction in the ZPD should not be close to the point of independent functioning, but rather that *the most effective learning occurs when the adult draws the child out to the jointly constructed 'potential' level of performance* (Gray, B. 1998:97). Indeed, Vygotsky argued that the tendency to teach low performing children at the 'lower boundary' of the ZPD underestimates what they might achieve (Brown, A.L. & Ferrara, R.A. 1985).

-Language is the central most important semiotic mediational tool in child development

Of all the material and psychological cultural tools employed within an activity system, Vygotsky regards language as playing a central, social role in child development. Language mediates in the zone of proximal development, orienting and leading the child towards cultural goals. Control of language releases learners from being bound in situated concrete activity to being able to plan and review activity:

> *The specifically human capacity for language enables children to provide for auxiliary tools in the solution of difficult tasks, to overcome impulsive action, to plan a solution to a problem prior to its execution, and to master their own behaviour (Vygotsky, L.S. 1978:28).*

Language frees students from the need for perpetual 'hands-on' engagement. It provides a sophisticated tool for planning, reflection, and self-regulation. Hasan interprets Vygotsky's position:

> *…of all the semiotic modalities only language at once defies time, is capable of being reflexive, classifies reality, construes communicable human experience, and articulates the many voices of a culture with equal facility, which is not to say that it ensures their social privilege, or that other modalities make no contribution. These qualities of language are relevant to its capacity for acting as an effective abstract tool, and nowhere is this more evident than in the formation of the growing child's*

> *consciousness. It is here that the social nature of the semiotic tool assumes great importance* (Hasan, R. 2005:6).

When language development is such an important tool for developing abstract thought, the progressivist emphasis on 'hands-on' science activity for its own sake must be questioned. What matters in such activity is how language is called on to perform important scientific functions, embedded in the activity system of science. Appropriation of scientific language moves students beyond concrete activity to generalising and reflecting on activity such that they build capacity within the vertical discourse of science.

However, learners do not simply appropriate discrete and well-established scientific concepts. The process of generalisation and concept development takes time and significant mediation from informed others. The next section outlines the process of conceptual development from a Vygotskian perspective.

-The process of conceptual development: everyday and scientific concepts; concepts to complexes

An important question when discussing child development within a vertical discourse like science is how students develop the abstract concepts which are so prevalent. Vygotsky's research demonstrated three levels of conceptual development in young children. Children begin by classifying concrete objects into what he called 'unorganised heaps', for example 'things I like' or 'familiar objects'. The criteria for selection are subjective, and often not easily apparent. The second level is that of 'complexes': *the generalizations created with the help of this mode of thinking are complexes of various concrete objects or things that are… related on the basis of objective connections that actually exist among the objects* (Vygotsky, L.S. 1986:121). Significantly, they are tied to the concrete context in which the subject carries out the task and are influenced by the physical features of the objects themselves. Examples of complexes are 'wooden objects' or 'gardening tools'.

The final level of conceptual development is when genuine concepts appear. Vygotsky proposed that educational activity in particular supports the development of real concepts, because within formal education the concepts are present as part of an interrelated system of complex linguistic relationships.

Importantly for this study, Vygotsky identified a transitional construct between complexes and concepts, that of 'pseudo-concepts'. When operating with pseudo-concepts, the child uses language appropriated from others to refer to the concept. However, the criteria used by the child to identify and understand the concept are still influenced by the concrete environment in which the activity occurs. The use of pseudo-concepts is an interim step that indicates that the process of conceptual development is in train, but that the end point has not yet been reached:

> *The pseudoconcept serves as a connecting link between thinking in complexes and thinking in concepts. It is dual in nature: a complex already carrying the germinating seed of a concept. Verbal communication with adults thus becomes a powerful factor in the development of the child's concepts* (Vygotsky, L.S. 1986:123)

In other words, dialogue with 'informed others' acts as a bridge between pseudoconcepts and conceptual development. Whereas Piaget believed that a child's thinking goes though certain stages of development regardless of instruction, that instruction 'hobbles' behind development (Vygotsky, L.S. 1962:175-76), Vygotsky argued that instruction is a powerful factor in the conceptual development of children, and is central in the negotiation of meaning that shifts children from pseudo- to real concepts (ibid: 123).

In the early stages of abstract thought, newly acquired concepts are unreliable, and easily dissolve. This notion is an important consideration in understanding the nascent development of scientific concepts in the primary years of schooling:

> *As long as complex thinking predominates, the abstracted trait is unstable, has no privileged position, and easily yields its temporary dominance to other traits* (Vygotsky, L.S. 1986:139).

The instability of conceptual understanding is not an argument against the teaching of concepts, but is a warning against expecting that concepts will be solidly appropriated once and for all in the short term.

Finally, the development of 'scientific' or academic concepts is bi-directional. The use of abstract terms gradually becomes realised in concrete actions, while at the same time interactions with concrete objects are gradually generalised and abstracted. A relationship is established with the everyday concepts in which:

> *the scientific concept grows downward through the everyday concept and the everyday concept moves upward through the scientific… In this process [everyday]concepts… are restructured in accordance with the structures prepared by the scientific concept (Vygotsky, L.S. 1986:220).*

This notion suggests that the mediation provided by the informed other in teaching also has to move in two directions: from the concept to its practical realisations, and from the concrete to the abstract. How this should be enacted in the classroom became one of the challenges of the study.

If the child's first naming of a concept may not represent a stable understanding, the question arises of how to describe the relationship between linguistic and conceptual development.

Wertsch argued that language acquisition and the learning of new words is the beginning of conceptual development, rather than the end point:

> *Although it is tempting to attribute a complete understanding of word meaning to children when they begin to use new forms in what seem to be appropriate ways, the appearance of new words marks the beginning rather than the end point in the development of meaning* (Wertsch, J.V. 1985a:99).

In other words, the appropriation of new language becomes a tool for further negotiation of meanings in dialogue with other cultural members as conceptual understandings become established and more stable (Wertsch, J.V. 1998:132).

The relationship between language and cognition, that is 'thought', including abstract concepts, is a point of polarising debate conducted in academic fields such as psychology, anthropology, linguistics and cognitive neuroscience (e.g. Bruner, J.S. *et al* 1966; Cole, M. & Griffin, P. ; Gomila, A. 2012; Langer, J. 2001). The next section positions the study within this debate.

-The relationship between the development of language and cognition

The academic stances taken to this topic sit on a continuum. At one end are the communicativists who contend that thought is separate from and precedes language, and for whom language simply makes thought explicit. At the other end are the constitutivists for whom language is conceptually essential for thought. The former see language as a lens for viewing thought, the latter see language as a tool for creating thought (Gomila, A. 2012). Finding a position along this continuum is critical for this study because it influences the trajectory and goals of student scientific development. Is it possible for students to have scientific concepts without the language to express them? Or conversely, is the fact that they can use scientific language proof that students are thinking scientifically?

Cognitive neuroscientists can be found at the communicative end of the debate, where language is regarded is secondary, and useful, but separate from cognition. For example, Langer (2001) regards language as a subset of cognitively generated knowledge. Cognition proceeds regardless, but language is useful to accelerate the process: it is *a powerful heuristic medi[um] that multiplies new phenomena upon which cognition may operate* (ibid: 2001:36). Because language lags behind in infancy, he argues that it is less likely that it influences cognition; rather the converse is likely, that cognition influences language.

Although Vygotsky is situated closely towards the constitutivist end of the language-cognition continuum, he recognised a pre-linguistic cognitive state: he argued that cognition (thought) and speech have different roots in infancy. He identified a pre-intellectual stage in speech development, and a pre-linguistic stage in thought development and asserted that for a brief time, the two operated independently, following their own directions. However, at a certain

point in infancy the two directions meet, whereupon thought becomes verbal, and speech rational (Vygotsky, L.S. 1962:83). From this meeting point, verbal thought is not an innate, natural form of behaviour, but is determined by a historical-cultural process. It has specific properties and laws that cannot be found in the natural forms of thought and speech (Vygotsky, L.S. 1962:94). For Vygotsky, after the early months of life, human cognition and language become part of the same social process of development.

Similarly, development psychologist Tomasello regards cognition and language as coming from different sources. His position is that children develop from two separate lines of cognition: the general primate line that sees others as animate and goal directed; and a second purely human strand of cognition which carries a species-unique motivation to share emotions, experience, and activities with other persons (Tomasello, M. *et al* 2005:675). The outcome of the convergence of these two pathways is firstly culture, and secondarily a child's ability to construct 'dialogic cognitive representations' (ibid). For Tomasello, language is not fundamental; it is a secondary artefact arising from these primary and unique human motivations to engage in joint intentional activity with others:

> *Language is not basic; it is derived. It rests on the same underlying cognitive and social skills that lead infants to point to things and show things to other people declaratively and informatively, in a way that other primates do not do, and that lead them to engage in collaborative and joint attentional activities with others of a kind that are also unique among primates. The general question is What is language if not a set of coordination devices for directing the attention of others? What could it mean to say that language is responsible for understanding and sharing intentions, when in fact the idea of linguistic communication without these underlying skills is incoherent? And so, while it is true that language represents a major difference between humans and other primates, we believe that it actually derives from the uniquely human abilities to read and share intentions with other people – which also underwrite other uniquely human skills that emerge along with language such as declarative gestures, collaboration, pretence, and imitative learning* (Tomasello, M. *et al* 2005:690).

Despite Tomasello's positioning of language as the secondary consequence of shared intentionality, he places the role of language as central in developing intersubjectivity, as cultures form and work to maintain and develop themselves.

At the far end of the cognition-language continuum is the position of systemic functional linguistics. Systemicists refer not to cognition and thought but 'meaning making', and argue that without language, there is no meaning:

> *Language is not a domain of human knowledge;… language is the essential condition of knowing, the process by which experience becomes knowledge (Halliday, M.A.K. 1993:94).*

For Halliday, the logical relations of a social group are realised and construed through language. Meaning (i.e. thought) is accessed and realised in grammar:

> *Cognition "is" not thinking but meaning: the "mental" map is in fact a semiotic map, and "cognition" is just a way of talking about language. In modelling knowledge as meaning, we are treating it as a linguistic construct: hence, a something that is construed in the lexicogrammar* (Halliday, M.A.K. & Matthiessen, C. 1999:xxx).

From this perspective, the cultural 'forms of rationality' produced as thought (Olson, D.R. 1994:20), are created by, and reflected in the logical relationships realised through the grammar. This is true of all generalisations from experience which are not natural but culturally bound, but particularly apparent in the development of abstract concepts such as scientific taxonomies which can only be accessed by examining and making meaning from scientific language (Halliday, M.A.K. & Matthiessen, C. 1999:3).

If cultural meanings, and importantly in this instance scientific meaning, are accessed through and realised as language, it is imperative that control of scientific language becomes an important goal of science education. However, does this mean that a child's cautious initial use of new abstract linguistic terms demonstrates their control of new concepts and their understanding of the relationship between those concepts? The work of Vygotsky previously mentioned would suggest not. As previously explained (this section, p37), Vygotsky identified the gradual movement from heaps to complexes to pseudo-concepts and finally to concepts which developed from the use of language. The initial appropriation of language is but a step in development, a stage of imitation which is crucial, but not the end point.

For Halliday, children who are learning to mean construe and consolidate their semiotic resources through dialogue (Halliday, M.A.K. & Matthiessen, C. 1999:614). They first appropriate language, and then use that language as a resource for further development of meaning.

In this study, the development of learners' scientific language is an essential goal of science education, but it is not the end goal. The early introduction and development of consistent scientific language enables language to serve as an essential mediational tool through which meaning can grow and strengthen. Discrete and complete scientific meanings do not arrive as a package with language use, but develop through continued dialogue with this language. Students and teacher sharing a common scientific language enables further negotiation and development of scientific abstractions across the years of schooling.

The first stage of language appropriation is the stage of imitation, a process which is often regarded as anathema by western educators because of its connotations of mindless rote learning (Willingham, D.T. 2009:72). Nevertheless, its role in development is crucial.

-The role of imitation in learning

Vygotsky identified the important role that imitation plays in children's learning within the zone of proximal development. Imitation is not simply a rote mechanical activity. Rather, it is an active process that can only be achieved within a person's developmental level:

> *In learning to speak, as in school subjects, imitation is indispensable. What the child can do in cooperation today he can do alone tomorrow* (Vygotsky, L.S. 1986:188).

He argued that a child's imitation of adults is a sign of the process of development underway. Active imitation requires an understanding by the learner of the purpose of the task, and allows the child to borrow the culturally mediated means from the knowledgeable others around them:

> *Understanding the nature of the goal and the intentionalities held and operated upon by participants in an activity allows the imitation process to move beyond 'rote' performance* (Gray, B. 2007:35).

Intentional imitation is a sign that the process of development is underway, but not complete. Imitation is the first level of appropriation, where the young learner tries out new ways of talking and behaving, borrowing language and gestures from other discourse members. Cazden refers to the early stages of appropriation as 'performance before competence' (Cazden, C. 1981), while Wertsch describes these early attempts at taking on new language as 'mouthing' (Wertsch, J.V. 1998:133) or ventriloquation, after Bakhtin: *the process whereby one voice speaks through another voice… the word in language is half someone else's* (Wertsch, J.V. 1991:59). Neuroscientific research suggests that the development of mirror neurons is linked to 'goal-oriented imitation' in social contexts, and has an important function in developing language (Iacoboni, M. 2009:66).

Eventually, learning must move beyond imitation as meanings develop through dialogue and application in new contexts, supporting learners to take control of the three aspects of Register: the topic, the relationship they wish to express, and the manner in which to communicate their intent. Nevertheless, imitation is the first step in this process.

-The dialogic nature of 'voice'

As children move beyond imitation, the process of language appropriation continues as they develop agency within their various activity systems. Agency, from a socio-historical perspective, is not atomistic, that is, it does not just belong to the individual. Rather it is the

outcome of the agent-acting-with-mediational means, or 'mediated agency' (Wertsch, J.V. 1996:342). Neither agent nor socially developed mediational means operates separately:

> *…humans' psychological nature represents the aggregate of internalized social relations that have become functions for the individual and form the individual's structure (Vygotsky, L.S. 1981; cited in Wertsch, J.V. 1996:340)* .

Such a position has implications for the development of 'voice', that is the conscious stance taken by individuals when communicating in social contexts. Their choice of 'voice' in turn impacts on their agency in that context. (There is a clear alignment here between 'voice' and Halliday's notion of 'Register' choices (Halliday, M.A.K. & Matthiessen, C. 1999, 2004).)

Voice, according to Wertsch, is *a speaking subject's perspective, conceptual horizon, intention and world view* (Wertsch, J.V. 1991:51). Individuals do not possess one voice, but select their voice depending on their perspective, intentions and available language choices. Wertsch's position is influenced by Bakhtin's view on the dialogic nature of voice (Bakhtin, M.M. 1981; 2004). Voice, the speaking consciousness, is dialogic in two directions. When deciding what to say or write, we look back, carrying in our heads dialogue with those who have used the 'patterns of discourse' before us:

> *Any utterance involves at least two voices: that of the speaker producing the concrete utterance and that if another speaker or other speakers who have used the same words, or more generally, patterns of discourse* (Wertsch, J.V. 1996:345) .

At the same time as looking back, we also look forward, anticipating the response of an intended audience:

> *Writers for example anticipate audience response and mould their writing in an attempt to coordinate with and even shape the responses of particular audiences both individual and collective. In this sense we can say that they are in fact in dialogue with the voices of the audience… That is, they are continually reading the minds (ie. intentionalities) of the various voices arrayed within and around the text* (Gray, B. 2006b:7).

Dialogicality is of course not just a function of composing texts, but also of comprehending other people's texts:

> *To understand another person's utterance means to orient oneself with respect to it, to find the proper place for it in the corresponding context. For each word of the utterance that we are in the process of understanding, we, as it were, lay down a set of answering words. The greater their number and weight, the deeper and more substantial our understanding will be*

> (Voloshinov, V.N., Matejka, L. & Titunik, I.R. 1973: cited in Wertsch, J.V. 1991: 54*).*

That is to say, taking on a voice is the process of *intentionally* taking a stance, of selecting language from the speaker's language repertoire that is appropriate to meet communication goals in the social context while anticipating the expected stance of the imagined or intended audience. In effective communication, the audience is not an afterthought; word choices must consciously take into account the intended audience as if in dialogue.

The socio-historical stance on voice has implications for the popular notion of 'student voice', a concept which has gained traction in progressivist education over recent years. It is aligned with values of democracy, of student autonomy, and with the entitlement of students to provide opinions and be heard in influencing their learning (VDE 2007:4):

> *At its simplest level, student voice can consist of young people sharing their opinions of school problems with administrators and faculty. More extensive student voice initiatives include collaboration between young people and adults to address problems in the school, with rare cases even allowing students to assume leadership roles in change efforts* (Mitra, D.L. & Serriere, S.C. 2012:744).

Student voice in the sense defined here is equated with agency and power in the activity system of schooling. The stance reacts to perceptions of traditional schooling, where student opinion had less legitimacy, and students were compliant and unconsulted in their participation in learning activities (VDE 2007:2). Supporters of student voice talk of the importance of making schooling relevant to student motivations and interests in an effort to better engage them in learning (Toshalis, E. & Nakkula, M.J. 2012).

When seen through the lens of activity theory, the student voice movement is restricted largely to student membership and agency inside the activity system of schooling: the setting is school, the activity is knowledge production, and the advocates of student voice call for an active student role in negotiating the mediational means employed, for example curriculum structures, subject choice, preferred ways of learning, as well as school uniform and homework policy (e.g. CommonAction 2006).

The invitation to students to provide opinions and collaborate comes from the horizontal, socially oriented discourse of schooling: a negotiation of power and of the ways in which social roles in the school community are to be played out. Through the largesse of teachers, students' personal opinions and home language may be sufficient to be accepted as legitimate in this context. However, students are misled if student voice is limited to the right to give a personal opinion without consciously looking back at what language choices are available, and without looking forward to take into consideration the intended audience and the most strategic stance.

Unfortunately the current position on student voice neglects the central criterion that creates legitimate agency within any activity system, that is the mediational means with which agency is enacted, specifically language. The stance taken in the student voice literature does not sufficiently take into account the specific demands of the socially constructed contexts within which students learn to create a 'voice' and trivialises the challenges of students developing a powerful dialogic voice beyond the sympathetic confines of the school.

Rather than seeing student voice as an entitlement to have their opinion heard, a socio-historical perspective regards student voice as a developing role. Teachers can play an important part in assisting students in the development of voice in a broadening array of contexts. This includes those which require more abstract and generalised world views. Teachers can help students to develop a language repertoire which gives them choice, and helps them to understand the dialogic nature of communication, consciously taking a stance which takes into account the intended audience and the students' strategic intent.

If the current focus on student voice is on the horizontal discourse of schooling, what of student voice in the activity system of science with its vertical structure? For student voice to be recognised as legitimate in the context of the science classroom, students need to communicate intentionally and be able to speak and write with some authority for less familiar purposes. Their opinion in science must be backed up with scientific knowledge and explanations. To this end, finding the right voice requires students to expand their repertoire of language to include authoritative scientific genres, grammar and language resources that enable them to make considered communicative choices.

The contrast of contemporary notions of voice with those of socio-historical theorists leads us back to Bernstein. Bernstein was concerned with the differential resources made available to learners for them to appropriate, and of the effect of different pedagogic choices on students' developmental trajectories. He was concerned about the limitations of student voice resulting from the acceptance and valorizing of horizontal discourses in the official curriculum for the 'less able' students …

> *in the name of empowering or unsilencing voices to combat the elitism and alleged authoritarianism of Vertical discourse. Here students are offered an official context in which to speak as they are thought to be: Spon-Tex (the sound bite of 'spontaneous text')* (Bernstein, B. 2000:170).

Bernstein's criticism of positioning the learner as the 'thought to be' comes from his stance on the social nature of child development and the potential futures created by pedagogic choices. The next section outlines his position.

2.3.2 Bernstein and the sociology of child development

As a sociologist, Bernstein's contribution to an understanding of child development is his analysis of the roles, the 'pedagogic identities' enabled by the Piagetian and Vygotskian perceptions of the child (Bernstein, B. 2000: Ch 4).

The perception strongly influenced by the work of Piaget and playing a strong role in Western primary education is the role of the child as autonomous and self-regulating, making his/her own choices about what and how to learn in a democratic classroom where each child has a voice. In this model, the goals of learning and development are not foregrounded. Bernstein calls this the model of 'competence' (ibid: 42). Children have more *apparent* control of their learning, but the control does not guarantee success. While students are free to 'discover' for themselves, their outcomes inevitably need to be evaluated through classroom or system-wide assessments against some external norms, namely official curriculum goals. Often it is the same teacher who has left the child to his/her own devices who then has to judge the learning outcomes. Because the student's efforts are regarded as autonomous, the quality of learning success becomes 'biologised', perceived not as a result of the degree of access to, and control of important cultural resources, but as some innate quality of the child (Bourne, J. 2003:64-65).

From the Piagetian perspective, development is benign and not advanced by formal instruction; the child is self-regulating. The competency model of the child regards creativity and virtuous self-regulation as 'built-in' to the child, as personal attributes. Learning is perceived as democratic because all children possess common processes and the potential to learn (Bernstein, B. 2000:43).

A contrasting pedagogic perception of the child draws on socio-psychological theories of learning. In this view, the child is not autonomous, but involved in social endeavour with other cultural members. The model is not one of competence but of performance. A performance model places emphasis on *a specific output of the acquirer, upon a particular text the acquirer is expected to construct and upon the specialised skills necessary to the production of this specific output* (Bernstein, B. 2000:44). Knowledge is jointly constructed:

> *Competitive concepts of innate individual 'ability' and 'talent' are replaced by the concept of collective access to and participation in academically valued social practices and the discourses by which they are constituted. It situates learning within the social and political context in which learners are themselves socially positioned. Thus it foregrounds learning as a collective endeavour rather than a neutral and individual attainment* (Bourne, J. 2003:66).

For Bernstein, the goal of child development is in part personal fulfillment, but also *the right to participate in the construction, maintenance and transformation of order* (Bernstein, B.

2000:xxi). He argued that personal enhancement is attained through the experience of boundaries between familiar and new discourses which provide *the right to the means of critical understanding and to new possibilities* (ibid: xx). Development requires the tension of interaction with boundaries and new discourses to provide a broader perspective. The tension is not always comfortable. The chance of students realising their 'right to new possibilities' is strongly influenced by which of these two contrasting constructions of the developing learner influences teacher practice: the autonomous child interacting at will with social practice, or the socially-constructed child immersed in communities of practice and gradually appropriating from available resources. The pedagogic implications of the contrasting perceptions of the learner will be discussed further in Section 2.4.

2.3.3 Systemic functional linguistics and the development of language in the child

Previous sections have demonstrated that language is an integral part of building cultural knowledge and making social meanings. The development of language is unequivocally essential to the goals of education and child development. Indeed, the field of systemic functional linguistics takes the view that there is no knowledge without language, that they are one and the same:

> *When we talk of 'construing experience' as the metafunctional realm of the ideational base, we are referring to the shared experience of the group, the culture and the species; it is by means of dialogue that children gain access to this shared experience and are enabled to construe their own experience with reference to it. And the dialogic nature of discourse serves the child also as a metaphor, as the semiotic manifestation of the social conditions of human existence* (Halliday, M.A.K. & Matthiessen, C. 1999:614).

Halliday and Matthiessen characterise the process of meaning construal; that is knowledge construction, within children's language development in the following ways (ibid p82):

a. Initially the child makes meanings from phenomena that they can physically see. Once initial meanings are established and constituted as language, the child shares, validates and continues to negotiate those meanings collaboratively with other members of his/her 'meaning group'.

b. Once the process of meaning making (construal) has been established, experiences begin to be generalised through language, in the form of classes (categories) available in the semantic system of the social group.

c. These processes of generalisation are further developed vicariously through discourse (i.e. the object no longer needs to be present), and eventually lead to abstract categories. These are the beginnings of decontextualisation and generalisation.

d. Once systems of meanings have been built up, new categories can be constructed, and rearrangements of categories can take place.

Halliday and Matthiessen proposed that a dynamic of "generalization – abstractness – metaphor" is observable in children's language development (ibid: 618). This dynamic can be regarded as a more refined interpretation of that observed by Vygotsky as the move from heaps to complexes to concepts. The first important facet of language development is the move in the early years from the specific to the abstract, from 'proper' to 'common' (ibid: 615). Halliday noted that this process is necessary to build up forms of knowledge that are systematically organised and explicit. However, language development does not stop at this age. Further transformation is required in the reconstrual of technical knowledge, according to the disciplines in primary to middle years. The control of technical language includes a final and most difficult reconstrual in the form of grammatical metaphor. In this final transformation…

> *processes and qualities [are] metaphorically reconstrued to become participants. When our adolescents' ideation base comes to accommodate a meaning potential of this technicalized kind, we consider that they have reached semiotic maturity (ibid: p617-8).*

Language development extends children's capacity from reliance on 'talk-accompanying-action' to 'talk-as-action'. Language becomes a cultural tool which enables reflection, evaluation and future planning (Halliday, M.A.K. & Martin, J.R. 1993). The process of language development continues throughout childhood and through all the years of schooling.

The early development of language has been the focus of study for a number of systemic functional linguists. Hasan and Cloran mapped the language development of children according to social class, comparing children from families with breadwinners in lower (LAP) and higher autonomy professions (HAP) (1990). They were able to identify the differentiation in language use resulting from different interactions with parents, with the HAP children demonstrating early language use congruent with that required at school, including a greater likelihood of asking *how/why* questions, and elaborate in their answers (ibid: 89). Importantly for this study, Hasan plotted the different forms of reasoning developed by children as a result of their home socialisation: working class children tend to develop a *social* basis for their reasoning, while middle class children tend to develop a *logical*, or more extended and generalised foundation for reasoning (Hasan, R. 1991). According to Hasan, drawing on Bernstein, the reasoning of both working class and middle class groups are responses to their social and political contexts (ibid:

299). When logical reasoning and argument is so essential in the field of science, this early learning of different ways of reasoning helps to explicate the marginalisation of many students when they reach school.

Painter's work documents more closely the processes through which a middle class child is prepared for school through their home language development (Painter, C. 1998). She identifies how language interactions in the middle class home support the child's ability to decontextualise at an early age, providing the foundation for abstract grammatical metaphor that is essential later for deep engagement in science (ibid: 73).

2.3.4 Implications of these perspectives on child development for science education: entitlement to resources

When the developing child is viewed from the perspectives introduced above of socio-historical activity theory, sociology and systemic linguistics, certain expectations of the role of the child in learning science are established.

To begin learning, children need to develop positive attachment to the teacher through dyadic engagement. A strong interpersonal relationship and trust between students and teacher is essential for marginalised students embarking on the risky transition from familiar, socially oriented horizontal discourses to the foreign, vertical discourse of science, calling for a re-orientation to the world. However, for effective apprenticeship into the new discourse, that dyadic, or affective engagement must move to triadic, or academic engagement, as the teacher and students together build meaning through activity, including importantly language to taxonomise, reflect, plan and explain, within the world of science.

For the shift from affective engagement to academic engagement to take place within science, students need to recognise the boundary between the everyday and science, and then be assisted to cross that boundary as the teacher mediates activity to make the boundary permeable. Crossing boundaries is often uncomfortable, and a strong relationship and mutual trust will support that crossing. For children to develop scientific knowledge and language, the teacher must lead them beyond what they already know, and keep them company on the journey, working always towards the development of intersubjectivity in science. So many factors in developing the child require the active and conscious involvement of the teacher: the importance of dialogue, of goal-oriented imitation, of developing language as a tool for creating abstract meanings. To hope that children will discover scientific meaning and intent for themselves through hands-on involvement with scientific artefacts is a high-risk pedagogic strategy. To expect them to glean from their inquiry lessons the language forms they need to powerfully represent the processes of science is at best naïve.

The most important mediational tool for teacher and students is language, so for effective teaching and learning in science, close attention must be paid to students taking up important language resources that enable them to move beyond engagement with material objects to operate in the abstract. The development of scientific language provides common ground for further negotiation of meaning as learners move from imitation to appropriation, engaging in and explaining scientific activity.

Students are active agents in appropriating scientific knowledge and are entitled to accrue mediational means that enable them to develop powerful voices within the community of scientists. Development within science education means, with the assistance of informed others, developing the mediational means such that their agency is aligned with valid roles within the scientific community.

2.4 Pedagogic element 3: the teacher

So far, this chapter has situated the role of science education as pedagogically motivated cultural activity, with the goal of building a high level of intersubjectivity within the activity system of science. A Vygotskian language-focused position on socially situated child development has been laid out, with the developmental trajectory leading to cultural intersubjectivities.

Now the focus shifts to the third element of the pedagogic triad, namely the role of the teacher, whose job it is to facilitate affective and academic engagement in the classroom, leading to intersubjectivity within science. Chapter 1 argued that neither transmission nor progressivist pedagogy has been shown to provide the conditions for effective learning for marginalised students. This section will demonstrate how scaffolded pedagogy carries the potential to achieve socially just outcomes if teachers are skilled in its use.

Section 2.4.1 begins this focus on socio-historically oriented pedagogy. It describes from the literature elements of scaffolding that distinguish it from other types of pedagogic support. Section 2.4.1.2 takes a closer look at one often debated aspect of classroom talk which requires particular attention here in the light of socio-historic theory, namely the ubiquitous Initiation-Response-Evaluation (I-R-E) sequence.

Section 2.4.2 introduces Basil Bernstein's notion of the 'pedagogic device' (Bernstein, B. 2000). His analysis of broad pedagogic structures, and close analysis of the moment-by-moment choices made within it helps us to understand the potential outcomes of particular choices at many levels.

The focus on teacher pedagogic choices concludes by looking at the contribution of systemic functional linguistics, particularly the work of Martin and Christie (Section 2.4.3).

2.4.1 Socio-historic theory and pedagogy

2.4.1.1 Negotiating learning: the role of scaffolding

Vygotsky's work on the zone of proximal development as the zone of effective learning emphasised the role of 'more knowledgeable others' (Wood, D.J. 1989:59) in leading the child to the next level of development. While Vygotsky's work was cut short by illness, many other researchers influenced by Vygotsky have investigated the process of drawing a child from independence to the next level of development through the ZPD. The notion of 'scaffolding', that is a negotiated, two-way pedagogy, was introduced by Wood, Bruner and Ross in the study of adult-child dyads (Wood, D., Bruner, J. & Ross, G. 1976). Bruner described the process of scaffolding:

> *In general, what the tutor did was what the child could not do. For the rest, she made things such that the child could do with her what he plainly could not do without her. And as the tutoring proceeded, the child took over from her parts of the task that he was not able to do at first, but, with mastery, became consciously able to do under his own control. And she gladly handed those over.*(Bruner, J.S. 1986:76).

Some important features distinguish scaffolding from other provision of help to children. The features of scaffolded pedagogy, taken from a number of sources, can be summarised thus:

-The 'knowledgeable other' serves as a 'vicarious consciousness' for the learner (Bruner, J.S. 1986:76). From a socio-historical perspective, cognition is not individually possessed, but distributed; that is shared amongst discourse members (Salomon, G. 1993 cited in Daniels, H. 2001) . Until the novice has internalised or appropriated the cognitive resources available, the adult lends cognition through their language in order to achieve the goal using culturally available means.

-The process of scaffolding is not a simple act of will on the part of the adult, but a negotiable transaction (Wood, D.J. 1989:59).

-For scaffolding to be successful, *comprehension of the solution must precede production.* In other words, even though there may be many elements of the task that are out of the novice's reach, there must be a shared understanding between adult and child of the end goal (Wood, D. *et al* 1976:90)

-The adult doesn't necessarily begin with the child's current interest: if there is some cultural imperative for completing the activity now, the adult recruits the child's interest in the activity (ibid: p98).

-During the activity, the adult draws the child's attention to what is important, and maintains their 'gaze' on the important features of the task (ibid).

-The adult demonstrates or models parts of the task that the child cannot do independently in a way that supports the child to imitate the adult's actions for successful completion (ibid).

-Contingency is one of the most important properties of successful scaffolding (Wells, G.A. 1999:12; Wood, D.J. 1989:70). Contingent scaffolding is characterised by:

> *…how well the teacher is able to judge the need and quality of assistance required by the learner, and related to the way in which help is paced on the basis of students' developing understandings… The sensitivity and skill involved in responding contingently to students is sometimes seen as the defining quality of teaching* (Hammond, J. 2001:5).

Contingent scaffolding requires the adult to monitor and respond to moment-by-moment signs of success and failure by the child. As Wood explained, when the child shows signs of success, the adult hands over more control and greater degrees of freedom. If failure ensues, the adult provides more help, increases control and reduces the degrees of freedom for error (Wood, D.J. 1989:70). Wood pointed out that maximal contingency is not nearly as easy as it might sound, even for adult-child dyads. The challenge of contingency in a classroom setting is exponentially greater.

-The process of appropriation of cultural resources supported by scaffolding requires a transfer of control from adult to child as he/she appropriates resources. Bruner called this transfer 'handover'(Bruner, J.S. & Watson, R. 1983:60). The transfer is recognised in the 'gradual release of responsibility' pedagogic model first described by Pearson and in common use in South Australian schools (DECD 2012b):

Figure 2. Gradual release of responsibility (Pearson, P.D. & Gallagher, M.C. 1983:337)

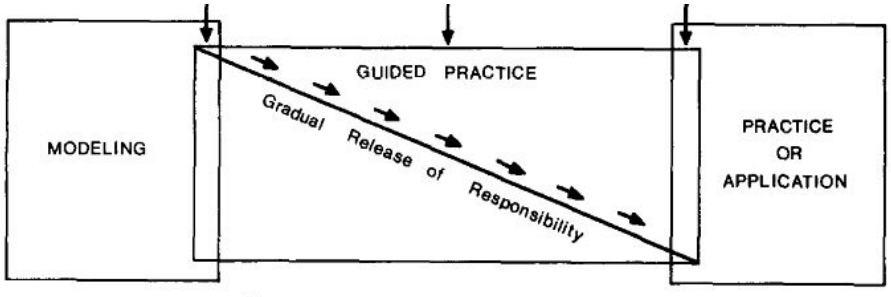


FIG. 1. A model of explicit instruction.

Handover, that is the gradual release, is not a neat trajectory as it is represented in Pearson's diagram; more like a pedagogic dance. Contingency requires that the adult is always prepared to shift the balance of responsibility, taking it back or handing it over whenever the child needs it.

-Scaffolding requires at the very least a common goal understood by all participants. If the goal is established, then other aspects of cultural knowledge come behind (Wood, D.J. 1989:72). In general terms, the goal of scaffolding is the building of intersubjectivity between adult and child around the goal. The adult shares 'perceptions, conceptions, feelings, and intentions' (Wood, D.J. 1980:282), in the form of language and behaviours which enable the child to take over the role of the adult.

-Because scaffolding is ends-oriented, it involves a re-orientation of the child's established representations, including new ways of talking. This is progressed through the reframing by the adult of children's talk, requiring the adult to introduce and model new forms of language through their responses. This process has been given many labels: Bernstein calls this 'recontextualisation' (2000:60-61), Sharpe calls it 'recasting' (2006:218), Gray calls it 'reconceptualisation' (1998:252), Mercer calls it 'redefining' (1994:99) and Rose calls it 'elaboration' (2005:155).

-Vygotsky argued that the development of scientific concepts in the classroom moves in both directions: it draws the child upwards towards abstraction and generalisations, and at the same time the abstract moves to the concrete, readjusting the child's conceptual understandings in everyday activity (Vygotsky, L.S. 1986:157). This up-and-down process implies that scaffolding in the classroom must shunt back and forth from the thinkable to the unthinkable, from the familiar to the new, from the concrete and context-specific to abstract decontextualised meanings, building bridges between what children already know and the new learning goal.

-While the term scaffolding was originally developed by Wood and Bruner in 1976 to refer to the specific meaning negotiation between an adult-child dyad in context, through language, the concept within the classroom has broadened in intervening years. It is often used to refer to the scope and sequencing of a topic over a series of lessons, the logic of which provides a predictable and logical format. Such planning is sometimes termed a 'macro-scaffold' in contrast to the moment-by-moment interactions which are termed the 'micro-scaffold':

> *Scaffolding needs to be thought of in relation to the development of overall programs and curricula, as well as to selection and sequencing of tasks and to the specific classroom interactions that are part of those tasks. Here we are extending the notion of scaffolding beyond the moment-by-moment interactions between teacher and student to include also the nature and design of the classroom program* (Hammond, J. 2001:6).

-Power sharing in the process of scaffolding is by definition mostly unequal. It begins with a high level of control by the adult. As knowledge and language are appropriated, the learner takes an increasing amount of control. By the time the child has internalised and can use and apply new learning independently, scaffolding is no longer necessary, and the adult is a minor

player in the context. As Edwards and Mercer argued, the only time power is equally shared is at an arbitrary point some way through the scaffolding process, when the adult has partially handed over what the child has partially appropriated. Maintaining equally shared power is not a goal of the educational context:

> *But education is concerned with introducing children and adults into pre-existing culture of thought and language. However active the students are, we cannot assume that they can reinvent that culture through their own activity and experience. It is a social process, and inherently includes an asymmetry of roles between teacher and learner. If the educational process is not to be completely compromised by the asymmetry of teacher and learner, then we need to develop an understanding of the process which recognizes and encourages that asymmetry in a manner that fosters rather than hinders learning* (Edwards, D. & Mercer, N. 1987:157-8).

-While scaffolding is negotiated, and child and adult each have roles to play, it is not democratic. The teacher is responsible and accountable for successful learning by the child, for providing the contingent scaffolds which establish and hand over share meanings.

The potential for group work to provide valuable learning cannot be taken for granted. Working in the zone of proximal development requires the presence of a knowledgeable other to lend language and cognition at this unstable time. What then, is the effect of group work when students are not able to function on a task at independent, or near independent level, but are still working within the ZPD? If the teacher has divided the class into several groups, and is strenuously circulating, managing behaviour and keeping students on task, what chance is there of contingent scaffolding, of the teacher being able to lend consciousness whenever it is needed? Peers may be able to help other students (Rogoff, B. 1990:Ch 8), but they cannot be relied on for contingent, point of need scaffolds. The person who takes conscious responsibility for that is the teacher. This perspective would suggest that group work is a high risk strategy for students working in the ZPD, when the likelihood of contingent scaffolding is exchanged for unpredictable acts of help by well-meaning peers (ibid).

-Not all support qualifies as scaffolding. Mentoring, coaching and tutoring may all include scaffolding, but a less productive type of support is often observed in low socio-economic schools. This ‘dependent’ support can be seen when adults withdraw students from the class, or sit beside the student in the class and coax them through a task. The adult may be under time pressure to get through a task, or want to maintain positive affect at the expense of learning, or be responding to habitual helplessness on the part of the student. This type of support requires a different metaphor from scaffolding. It has been described as ‘shepherding’ by Sugrue (1997:Ch 8), when the adult *pays attention to (student) social and personal needs in ways that adequately*

safeguard and shepherd their social development, self-confidence and self-esteem; a strategy he perceives to be in tension with *upholding standards* (ibid: 178). Lundgren calls the approach 'piloting' whereby *the teacher avoids problems by simplifying them so that the students are able to solve them by answering a simple chain of questions* (1981:200). In contrast to scaffolding, the goals of shepherding or piloting are short-term: to get the task done, and to relieve the pressure in the classroom situation rather than to develop intersubjectivity. They are often mistaken for scaffolding, but are not likely to achieve the goal of independence.

In summary, scaffolding is contingent, goal-oriented support provided by a culturally knowledgeable other to novices with the intention of willingly supporting the gradual handover, that is appropriation of knowledge by the learner. In the process, the scaffolder builds a bridge between the known and the unknown, gradually moving the learner towards new meanings and forms of language which express those meanings. Within the classroom, scaffolding is used to refer to the macro-structures of the scope and sequencing of learning, as well as the micro-scaffolds of language used in negotiating within lessons.

2.4.1.2 The role of the Initiation-Response-Evaluation (I-R-E) sequence in pedagogy

The I-R-E sequence, or triadic dialogue, has attracted a deal of attention over the years (Cazden, C.B. 2001; Edwards, D. & Mercer, N. 1987; Freebody, P., Ludwig, C. & Gunn, S. 1995; Macbeth, D. 2003; Mehan, H. 1979; Sinclair, J.M. & Coulthard, R.M. 1975; Wells, G. 1999a). Sinclair and Coulthard first described the phenomenon, acknowledging it as the default strategy of teachers (Sinclair, J.M. & Coulthard, R.M. 1975).

A number of these academics have written in support of this pedagogic strategy: Mercer and Edwards described triadic dialogue as part of the 'discursive weaponry' available to teachers for controlling topics of conversation, directing pupils' thought and action, and establishing the extent of shared attention, joint activity and common knowledge (Edwards, D. & Mercer, N. 1987:46). Cole also claimed that triadic dialogue was 'quite nicely designed' to achieve the goals of education (Newman, D. *et al* 1989). Macbeth argued that the I-R-E sequence provides an opportunity for students to display what they know, regardless of how partial:

> *The power and utility of the three-turn sequence lies in how it writes filaments of understanding into public, witnessable organizations of interactional regularity and coherence* (Macbeth, D. 2011:446).

In other words, it is an effective means of monitoring student knowledge and marking significant knowledge. Macbeth regarded partially correct answers and bids by the students to

pass (e.g. 'I don't know'), as unproblematic, because all turns provide launching points for the next steps in learning, and to take a turn is evidence of understanding (ibid: 440).

However, there has also been significant criticism of the sequence. Mehan argued that it could 'deaden discussion and induce passivity in students' (1998:249). Lemke argued that its overuse stems from a mistaken belief that it encourages maximum student participation. (Lemke, J.L. 1993:168). Edwards and Mercer proposed that this cultural phenomenon, part of the 'educational ground rules' in the classroom, creates many problems for students unfamiliar with this way of operating. The rules are not explicitly taught but are nevertheless required for social participation (Mercer, N. & Edwards, A.D. 1981). Gray made a similar observation when investigating the participation of Aboriginal students in classroom teaching and learning negotiation:

> *..to respond to questions in the manner teachers expect, children must already share with teachers, considerable inter-subjectivity concerning how questions function in academic/literate discourses.*
>
> *…the traditional teacher-directed pedagogy of largely closed questions that generally have a preordained answer or child-centred pedagogies that concentrate on more inductive, open-ended questions… essentially seek information from the student and expect the students will display their knowledge and thinking processes. Both assume that the students share the intentionalities of the teacher (Gray, B. 2007:37)* .

The lack of congruence between teacher and student about the intent and required knowledge implicit in questions was identified as a cause for breakdown in the teaching and learning negotiation by Freebody et al's significant Australian study (Freebody, P. *et al* 1995):

> *…the less explication there is in the question about the form of the preferred answer, the more the teacher is relying upon the cultural congruence between herself/himself and the students. In the case of students at 'disadvantaged' schools, therefore, the more knowledge is pre-supposed the more difficult it may be for those students to interact productively with mainstream school teachers* (ibid:299).

This chapter has previously established the importance of sharing motivations and intent to mark discourse membership and therefore high levels of intersubjectivity, termed by Freebody above as cultural congruence. The lack of explicit orientation for the student about the purpose of the teacher's question and what sort of answer is an acceptable one, means that marginalised students are left 'guessing what's in the teacher's head' and the breakdown of communication leads to 'interactive trouble'(ibid:199).

While the criticisms of the I-R-E sequence focus largely on their lack of productivity and effectiveness, less attention has been paid to the emotional impact for marginalised students of their involvement in frequent interactive trouble. Students know very quickly how their responses have been evaluated by the teacher. The evaluation can be a direct rejection, but it can also be more subtly implied through a hesitation, a qualified answer 'good try…', by rephrasing the question or by redirecting the question to another student (Freebody, P. *et al* 1995:197).

For marginalised students, interaction breakdown can be frequent and damaging to self-esteem. Malcolm describes the outcome of such breakdowns between teacher and Aboriginal students as an issue of losing face:

> *When a person's positive impression upon others seems to be sustained, he is said to "save face", and when it is not sustained, he is said to "lose face". The latter may result for the individual in a sense of insecurity, confusion and shame* (Malcolm, I. 1991:10).

From Malcolm's experience, acceptance of Aboriginal students' bids for turns, and for affirmation of both the content and form of their responses is essential for their ongoing participation in classroom learning (ibid).

When positive affect, or strong dyadic engagement, is now shown to be so significant in children's learning through the work of Trevarthen, Tomasello, and more recently the work of neuroscience (Section 2.3.1, p31ff), questions must be raised about the uncritical use of the I-R-E sequence as a pedagogic strategy for monitoring of knowledge or to launch the next steps in learning. If teachers call for a display of student knowledge at an early point in the teaching and learning negotiation when intersubjectivity is low, the risk of interactive trouble between teacher and marginalised students is high. Once the question has been posed by the teacher, several choices are possible in seeking a response: the teacher can nominate randomly without waiting for a bid, thereby potentially putting a marginalised student on the spot and causing them to lose face. If the teacher selects a student whose response is incorrect, or partially correct, she/he is faced with the dilemma of how to respond in a way that doesn't cause further 'face loss'. Alternatively the teacher can more safely nominate a culturally congruent student who is likely to provide the right answer, which means the lesson can progress, even if others do not understand the significance of the answer.

Despite its potential as a display of knowledge by the student, the indiscriminate use of the I-R-E sequence poses a risk for the establishment and maintenance of trusting relationships between teacher and student as the basis for further learning. It carries the potential to ostracise already marginalised students from the classroom community of learners.

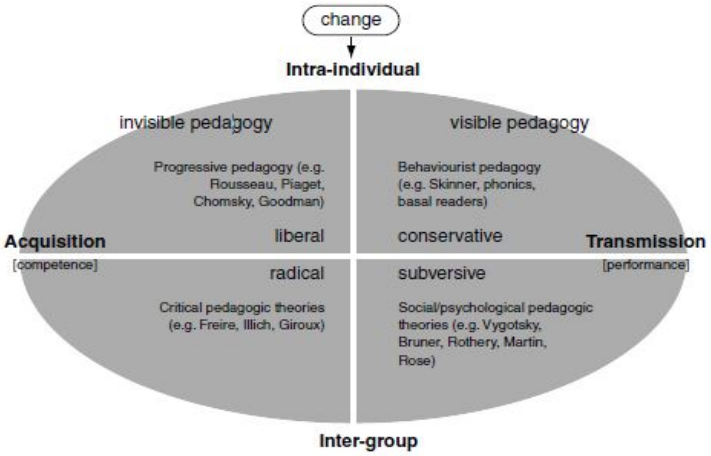
The summary of critiques of the I-R-E sequence presented earlier raises a dilemma: is it possible for this form of questioning to be a useful pedagogic tool, without undermining good will and trust in the classroom which is essential for learning? If display questioning assumes a high level of intersubjectivity which is not yet present, can the teacher couch questions in a manner which builds common knowledge through the questioning? Gray proposed modifications to the I-R-E sequence which not only eliminate the need for students to 'guess what's in the teacher's head' but help to build common knowledge in the classroom, supporting not just the answer, but building knowledge about the motivations behind the question and answer (Gray, B. 2007, 1998). These modifications, known as preformulation and reconceptualisation, will be discussed in Section 2.5.3.

2.4.2 Bernstein's pedagogic discourse

If the Vygotskian notion of scaffolding represents the processes by which adults support children towards culturally valued learning and development, Bernstein highlights the differential effects of particular pedagogical choices on access to participatory citizenship. He defined the process of teaching and learning as a 'pedagogic device' which serves as a recontextualising tool, the process through which external discourses or activity systems are selectively appropriated, relocated, and refocused. The pedagogic device aligns with or rejects other allied discourses with the motivation of building shared cultural knowledge (Bernstein, B. 2000:Ch 2).

The pedagogic device is enacted through pedagogic discourse choices which are able to potentially colonise, complement, privilege and marginalise (Bernstein, B.B. & Solomon, J. 1999:270). Previously, in Chapter 1, three pedagogic paradigms were introduced: traditional transmission pedagogy, progressivist pedagogy and socio-historical scaffolding pedagogy. Bernstein proposed a topology of pedagogies which includes yet a fourth paradigm, as shown below in Figure 3:

Figure 3. Forms of pedagogy (Adapted from Bernstein, B. 1990:72; In Martin, J.R. 2011:39)



Progressivist and transmission or conservative pedagogies share an attribute: they both regard learning as an individual accomplishment. Socio-historic scaffolding pedagogy perceives learning as a social act. Consequently it fits into the bottom right-hand quadrant of socio-psychological pedagogy, alternatively labeled by Martin as 'subversive' because of its *attempt to challenge social order by giving away the keys to knowledge then almost exclusively appropriated by agents of symbolic control* (Martin, J.R. 2011:39).

It is joined by another social paradigm in the lower left quadrant, that is radical pedagogy such as that proposed by Freire (Freire, P. 1972; Giroux, H.A. 2010). Sometimes known as 'critical' pedagogy, Freire's pedagogy had a deep distrust of the official curriculum, and foregrounded the importance of democratic relationships within learning:

> *Giving students the opportunity to be problem posers and to engage in a culture of questioning puts in the foreground the crucial issues of who has control over the conditions of learning and how specific modes of knowledge, identity, and authority are constructed within particular classroom relations* (Giroux, H.A. 2010:26).

Critical pedagogy has similarities with progressivist education in its attention to classroom democracy and issues of voice. Its difference is its commitment to political and social change, through the empowerment of groups and individuals. In Australia, work in the field of Aboriginal education fits into this quadrant. Advocacy for the use of Aboriginal English in the classroom (Malcolm, I. 1994a, 1994b, 1980) and for Aboriginal ways of learning (Hughes, P., More, A.J. & Williams, M. 2004) came from a concern for the lack of engagement and success by Aboriginal students in school. They argued for a pedagogy that made use of Aboriginal learning and communication styles:

> *A teacher can inhibit the Aboriginal children's participation in an interaction by the way in which he participates in it. He may take over from the children the initiative in determining the subject matter and the discourse pattern. Aboriginal children (like many others) will talk most freely when they can control the subject matter and the way they participate (Malcolm, I.G. 1982:182).*

In other words, Malcolm argued that student engagement and participation is fostered if the focus of teaching and learning shifts from the target vertical discourses identified in the curriculum back to students' familiar horizontal discourses. While those from a socio-historic perspective would agree that student participation is a necessary foundation for learning and development, what is not apparent from Malcolm is how this basis for engagement might in turn lead to students gaining control of the language and cognition necessary for participation in the vertical discourses of schooling.

Like Freire's critical pedagogy and the learning style theorists of Aboriginal Education, the subversive socio-historical quadrant in which scaffolded pedagogy sits is motivated by a commitment to social justice and recognises learning as socially constructed. Unlike the former, scaffolded pedagogy acknowledges the need for unequal and changing power relationships in teaching and learning, and, while never overlooking the power relationships which determine curriculum choices at any point in history, takes responsibility for ensuring that powerful cultural knowledge for engaging in contemporary society is visible and accessible to all. Intrinsic to this idea is the notion of an explicit, visible pedagogy.

The visibility or invisibility of pedagogy is characterised by the interplay of two codes evident in pedagogic discourse: classification and framing (Bernstein, B. 2000:6). The first code, classification, refers to the power relationships between discourses, for example the differences in focus and status of school subjects. Classification determines what counts as a legitimate voice inside the discourse. The degree of strength of the classification depends on the degree of insulation; that is the depth of the boundary between discourses. In the case of strong classification, each discourse has its own unique identity and voice. Strong classification explicitly marks discourse boundaries, and enables all students to recognise the differences between discourses, to 'read' the changing context (ibid: p17). Weak classification carries less specialisation, less marking of the boundaries between discourses. The principle of strong classification keeps discourses apart. Weak classification attempts to bring discourses together, to find commonalities between them (ibid: p11).

The second code is framing. Framing refers to the process of discourse acquisition, to the decisions made about which language choices are selected, how the teaching and learning is sequenced, the pacing of the teaching, the criteria for evaluation, and who has control of relationships in the teaching and learning context. Classification is the 'what', framing is the 'how':

> *When framing is strong, the teacher has explicit control over selection, sequence, pacing, criteria and the social base. When framing is weak, the learner has the more <u>apparent</u> control (his emphasis)* (ibid: p13).

The choices made in framing and classification determine which quadrant the pedagogy fits within in Figure 3 above. In each of the quadrants, different choices create different pedagogic devices. Bourne (2004:63) elaborates on the differences between the quadrants:

Table 4. Attributes of masked and visible pedagogies (adapted from Bourne 2004)

Progressivist pedagogy	**Traditional transmission pedagogy**
• masked pedagogy • competence-oriented, intra-individual pedagogy • curriculum pacing and sequencing are weak • children are offered choices in activities • the teacher becomes a background 'facilitator' rather than an instructor • students are recognized as progressing 'at their own pace' • an *apparently* weak classification of knowledge and weak boundaries between home and school practices and activities • *apparently* weak 'framing' in the selection, sequencing and pacing of activities BUT teachers still *evaluate* children's productions against selected fixed norms of attainment. • biologise children's attainments, and place responsibility for what is perceived as 'success or failure' firmly with the child, as evidence of their own 'natural' capacity • evaluation replaces instruction • certain children are not given access to the vertical discourses on which the development of subject–knowledge concepts ultimately depends.	• visible pedagogy • performance-oriented, intra-individual pedagogy • strongly classified, strongly framed in selection, sequencing and pace. • very little choice • achievement is also individualised but openly competitive • students who can't keep up leave • success or failure also correlates significantly with social class background • inequalities arise out of differences in cultural capital • stratification leads to less successful acquirers being offered 'operations, local skills rather than the exploration of principles and general skills' • consciousness of students is differentially regulated according to social class background. • certain children are not given access to the vertical discourses on which the development of subject–knowledge concepts ultimately depends.
Revolutionary (critical) pedagogy	**Radical (subversive) pedagogy**
• intra-group, not inter-individual • masked pedagogy • content, pacing, sequencing and evaluation rules are relaxed • voices, knowledge and understanding of disadvantaged groups are politically valorised • access to the vertical discourses on which the development of subject–knowledge concepts ultimately depends is not important • In context of state Year 12 examinations, where the specific content is assessed, the results impact upon students' life chances. • local valorisation of disadvantaged groups' knowledge in this evaluative context can only lead back to a masked pedagogy.	• intra-group, not inter-individual • visible pedagogy • objective is different from conservative transmission pedagogy • transmission pedagogy aims to produce differences between individuals, leading to hierarchical ranking • strong framing, weaker classification to begin with, leading to apparently weaker framing, strong classification to provide access to the vertical discourses on which the development of subject–knowledge concepts ultimately depends. • radical pedagogy aims to produce changes in the relations between social groups by providing powerful knowledge to all

The world of science is strongly classified, resulting in strong intersubjectively-related identities inside the discourse. As previously discussed, this clearly classified discourse means that students have to make a shift from every-day, segmentally organised horizontal discourses to hierarchically organised vertical discourses. For Bernstein, boundary recognition is in itself an important step in student development (2000:xx). The teacher can help to consciously establish boundaries through marking of the setting, the costumes, and the concrete artefacts. More importantly, the shift is marked linguistically through a new Register: a change in topic, a move

to a more formal, less personal Tenor, and to a higher degree of abstraction, a move towards decontextualisation.

Returning to the reviews of Australian science education introduced in Chapter 1, Tytler highlighted the popular nature of hands-on primary science, and contrasted it with the dreary transmission pedagogy commonly found in secondary science (Tytler, R. 2007). Seen through the lens of Bernstein's topology, causes for the mismatch are apparent: students move from weakly framed, weakly classified pedagogy in the primary years to be confronted with strongly framed, strongly classified pedagogy in the secondary years. Transitioning students, whose prior experience of science is weakly classified, are not prepared for the rigours of science in the secondary arena. The strong framing of secondary science, that is the inexorable pressure of sequencing, content and pacing, means that the pedagogy lacks flexibility in accommodating marginalised students who do not have a scientific orientation. Both primary and secondary science education would benefit from a shift from their current paradigms into scaffolded pedagogy, however difficult.

Scaffolding, in working towards the goal of intersubjectivity inside the world of science, requires sensitive control by the teacher over the strength of framing and classification. At early stages of the scaffolding process, when levels of intersubjectivity are low, framing needs to be strong, with scientific learning goals and the means to achieve those goals explicitly stated and modeled for imitation. The teacher has control of the process, ensuring that she builds meaning through language so that students move towards the goal without losing confidence. At the same time, classification needs to be temporarily weaker to create a permeable boundary. The teacher builds a bridge so that students can cross into the world of science by initially accepting every-day language from students, while at the same time systematically reconceptualising or recasting, adding successive layers of new meanings and language.

As handover is evident and intersubjectivity increases, framing can become *apparently* weaker if the students are able to take over the classroom talk in ways which reflect those previously modeled by the teacher. The word 'apparent' is used because the explicitly stated goals and means to achieve those goals have not changed. However, because they are now common knowledge within the classroom, the frame can now become unspoken, inferred.

To demonstrate the differences between a weaker, and stronger pedagogic frame, here are two instances of contrasting teacher talk which might appear at the beginning of a new topic about energy transformation, working, for example with a battery.

Example 1 Okay, today, on your tables, I've put lots of interesting things for you to work with, because we're looking at energy. You've got some wires, and a fan, and a battery, and I want you to have a play in your groups and see if you can work out how to make the fan work. Off you go.

Such pedagogy is weakly framed: the teacher has provided materials and the time, but no apparent expectation that the task needs to be approached in a scientific manner. The process of working out how to make the fan work is unspecified, and will depend on trial and error, or perhaps students calling on prior knowledge. Importantly, there is no indication that, at this stage at least, language is being called on by teacher or students as an explicit mediating tool. The engagement is social or dyadic, not academic or triadic: students will have a pleasant time; the teacher may enjoy moving from group to group as students discover the workings of a fan (or not), but evidence of this activity being scientific may be scant.

In contrast, here is an example of a more strongly framed pedagogy:

Example 2 Okay, today we're going to keep on learning about energy and how it changes from potential to kinetic energy. Today we're looking at one kind of potential energy; that is chemical energy. Can you say that? Chemical. Yes, good. This battery is an example of how chemical energy is stored. We know what batteries are used for, don't we? Yes, they're used to make little machines work, like torches and the mouse on your computer. The chemical energy is stored inside the battery, waiting to be used when the torch is turned on. It would look a bit like juice if you opened the battery up, but we won't because it is very acidic and it would burn you. And can you remember what sort of energy it is, if it's stored inside, waiting to be used? Yes, potential energy. And this special sort of potential energy, this juice inside the battery is…? Yes, potential chemical energy.

In this instance, the teacher has selected the topic and its focus, she dominates the talk, she controls the pace and the students have hardly had a chance to say anything. Expectations are clear: students are expected to attend, to repeat new words, and respond to questions posed from previously learned information. The teacher frames this lesson as part of a sequence of lessons with her reminders of 'can you remember…'.

From a progressivist perspective, such a teacher-dominated lesson would be anathema. From a socio-historical perspective, it is the teacher's responsibility to build this common knowledge. Such an extended monologue as part of scaffolded pedagogy would be typical at an historical point in the topic; that is the beginning, to explicitly establish common knowledge, including the introduction of new language, such that all students in the class can participate in activity with a scientific orientation. The activity still involves material objects, handled at this point only by the teacher, but is mediated strongly through new scientific language. The intended engagement is academic.

If strongly framed pedagogy is used well at the beginning of the topic to build common knowledge, then the following third example might effectively appear at the end of the topic:

Example 3 Okay, we have here a fan, a battery and wires. How do these work?

Example 3 appears to be weakly framed. The criterion for a successful answer is not stated. The question is open to all kinds of interpretation. If this example followed the type of pedagogy exemplified in Example 1, also weakly framed, the teacher would have to accept all sorts of answers. There is a high risk that much of the talk would come from students' everyday experience, and would not have crossed the boundary into scientific discourse. However, if a high level of intersubjectivity has been built within the class around scientific knowledge and language on this topic, such as that suggested in Example 2, the students know what the teacher expects as an answer. It would include not only the process of how to make the fan work, but the principles of energy transfer to explain the work, using new scientific language in the process. The criteria for successful knowledge display are jointly understood.

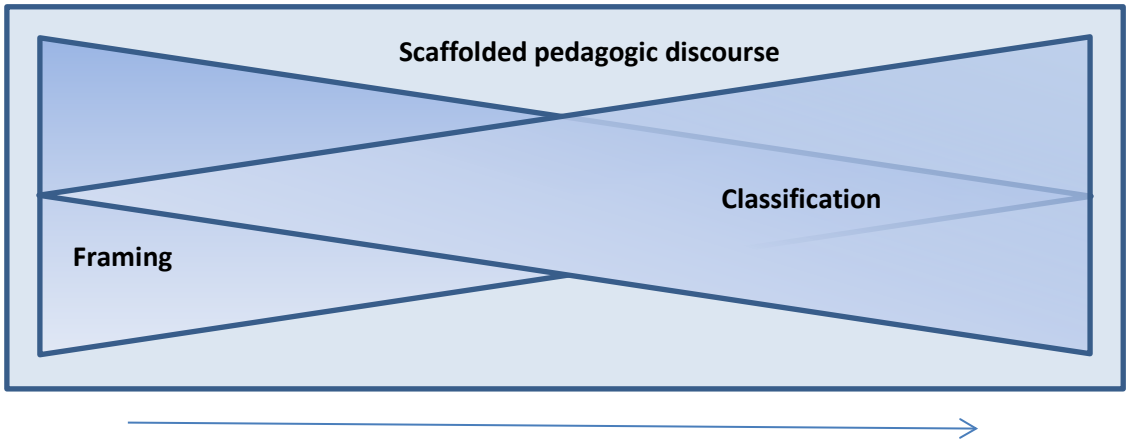
Bernstein argues that weak framing is likely to indicate invisible pedagogic practice where *the rules of regulative and instructional discourse are implicit, and largely unknown to the acquirer* (Bernstein, B. 2000:14). He refers to such weak framing as progressive. However, this is not always the case. Although Example 3 above is apparently weak, if it has been preceded by lessons with strong framing, it can be expected that the operational rules are not invisible to the student, but rather internalised. Intersubjectivity is high.

In scaffolded pedagogy, framing can and must change as students appropriate cultural resources, in order that they can be put to use. Strong framing, once intersubjectivity is high, is counterproductive to the intended outcomes of the teaching by inhibiting student control. The teacher has to release responsibility, to handover control to students for the process to be complete.

It is not just framing that changes in the scaffolding process, classification changes too, but in the reverse direction. Classification can be tightened as intersubjectivity is established. As ways of communicating within the target discourse are progressively shared and strengthened, more specific scientific language use by students can be expected, rendering the commonsense terms increasingly redundant.

If scaffolding is effective, framing and classification move in inverse directions: framing from strong to weaker, and classification from weaker to stronger. The relationship can be represented in the following way:

Figure 4. Weakening and strengthening of pedagogic modes in a scaffolded pedagogic discourse



The arrow represents change over time. The starting point for teaching and learning negotiation of any topic would depend on the level of intersubjectivity already shared in the class. If there is a certain level of intersubjectivity to begin with, the starting point can be further towards the right. The sensitive control of this process is easier to write about than accomplish. The challenge is in how to achieve this in the classroom with 30 students, each in their different zones of proximal development. Despite the neat diagram, changes in framing and classification do not move in such a neat trajectory. Contingent scaffolding requires that if students begin to fail once the framing is weakened, the teacher strengthens it to provide additional support. If students struggle with technical language, the teacher may call on commonsense language to help build the bridge.

The second aspect of Bernstein's analysis relevant to this study is his further elaboration of framing and the two sets of rules or discourses which govern it. The set of social rules within the classroom Bernstein calls the *regulative discourse.* The other set of rules are to do with the language choices which realise the learning goals. Bernstein calls this the *instructional discourse (Bernstein, B. 2000:12-13).*

Christie renamed Bernstein's pedagogic discourses as the *regulative and instructional registers* (Christie, F. 1991b:204). The use of linguistic terms reflects the fact that within each discourse, the teacher is making lexico-grammatical choices which can be analysed through the contextual lenses of Field, Tenor and Mode (refer Section 2.2.3, p23ff).

Distinguishing between the regulative and instructional registers enables a fine-grained analysis of classroom discourse because it enables a distinction between two aspects of classroom talk which carry different purposes.

The regulative register is described by Bernstein as 'embedding' the instructional register. It attends to particular aspects of teaching: pace, sequencing, social arrangements and evaluation. Christie describes it as 'projecting' the instructional register (Christie, F. 1991b). In socio-

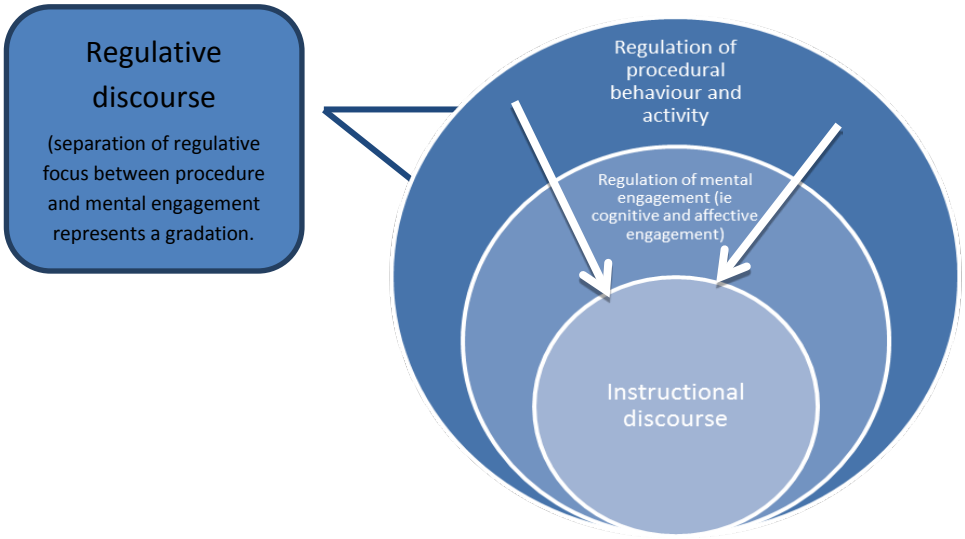
historic terms, the regulative register 'mediates' between the student and the instructional register in that it has the potential to explicitly show students what to attend to, and the actions and roles available to learners in that context.

More recently, Gray elaborated specifically on the role of the regulative register, describing it as working on two levels, with one level projecting the next. Firstly the regulative register guides students in classroom processes and how they are expected to behave in the here and now, in other words, procedural activity. Secondly, the regulative register has the potential to regulate mental engagement, that is, to guide students in the appropriate orientation and attention needed to successfully engage with the instructional:

> *…there exists a potential within the regulative discourse for the teacher to direct different emphases and strategies towards orchestrating what might be termed behavioural/ procedural control on one hand and towards negotiating and shaping the actual thinking and reasoning processes through which children engage with the content presented* (Gray, B. 1998a: 53).

Gray demonstrates the embedding relationships of the regulative and instructional discourses in the following model (Gray, B. 1998a: 54):

Figure 5. Relationships between the regulative and instructional discourses of pedagogic discourses



The regulative register has the potential to mediate between and within two activity systems simultaneously. Firstly, Gray's outer level of procedural regulation builds intersubjectivity within the activity system of school and the classroom, for example what is expected in classroom routines, how respect is shown, turn-taking and self-regulation. Secondly, what Gray terms 'mental regulation' potentially builds intersubjectivity about the target activity system of each subject or target discourse, including the goals, roles and intent. For example, the teacher orients students to what to attend to and why, or thinks out loud as a scientist, or provides explicit instruction on scientific values and motivations.

The instructional register is the language realising the learning, the curriculum content. This register can be strongly or weakly framed. Strong framing provides close attention to, and explicit guidelines about the lexico-grammatical resources available in and required for the target discourse. Weak framing in the instructional register allows or even encourages students to draw on their own everyday language to represent the target discourse as best they can.

Both the regulative and instructional registers play their role in developing intersubjectivity; that is in developing common knowledge within the classroom. The instructional register has the potential to make explicit the lexico-grammatical choices preferred to represent that knowledge in the target discourse. The regulative register manages the operation of the classroom during the lesson as well as having the potential to build common knowledge about the intentions, values, and dispositions of the target discourse; in other words, the mental and affective orientation to the discourse which help students to understand the reasons for the choices made in the instructional register.

The term 'potential to…' has been used in referring to the function of the regulative and instructional registers. This is because their effectiveness is not a certainty. The capacity of the two registers to achieve their potential purposes depends on the choices made by the teacher about how the regulative and instructional registers might work together at any particular point in time. Isolating the roles of the two pedagogic registers and their potential functions helps to clarify to some extent the effect of the interplay of teacher choices within these two pedagogic registers as the lessons unfold.

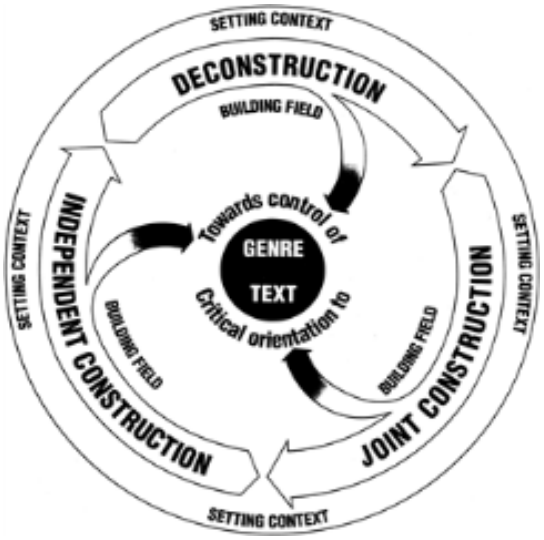
2.4.3 The contribution of systemic functional linguistics to pedagogy

The previous section, Section 2.4.2 included Christie's interpretation of Bernstein's pedagogic sub-discourses as regulative and instructional registers. The systemic linguists have contributed to pedagogic theory in their work with the sociologists on finding common ground, and building a strong position for promoting an explicit, subversive pedagogy (Christie, F. & Martin, J.R. 2007; Hasan, R. 2005; Martin, J.R. 2011; Rose, David 2005).

In addition to the analysis of scientific genres, grammar and language choices previously mentioned, the systemicists' contribution to subversive pedagogy is the Teaching and Learning Cycle, the product of collaboration between the Linguistics Department at the University of Sydney and the Metropolitan East Region of the New South Wales Disadvantaged Schools program (DSP) (Christie, F. 1991a; Cope, B. & Kalantzis, M. 1993; Martin, J.R. 2000, 1992; Rothery, J. 1989). The cycle provides a macro-scaffold that supports students in moving systematically from reading and analysing subject-valued genres, to constructing new texts, drawing on the language resources identified in the model text. The Teaching and Learning

Cycle marked the advent of 'genre-based' pedagogy and has increasing currency within professional learning programs in Australian schools (eg DECD 2012c):

Figure 6. The DSP Teaching and Learning Cycle (Rothery, J. & Stenglin, M. 1996)



The Teaching and Learning Cycle begins by building an understanding of ideational, interpersonal and textual language choices through activities which include close text analysis. As students are scaffolded through the stages, they begin to reconstruct and construct written texts, firstly as joint activity, and finally independently. The cycle pays close attention to the development of language in the instructional register, including the relationship between language and culture:

> *The point of this cycle is to emphasize the instrumentality of shared understandings about disciplines/institutions in their cultural contexts for scaffolding to proceed effectively (Martin 1998b) in order to establish effective zones of proximal development, in other words, the knowledge that teachers and students can all assume is vital (Martin, J.R. 2000:118).*

Martin emphasised that, for language development to be effective, it was important for students to understand the social purposes of discipline-valued texts. He highlighted the contribution made by linguists during and following from this DSP project: work on generic structure, language for evaluation (appraisal), Register analysis and the study of multi-semiotic texts (ibid).

Martin observed that increasingly within the science classroom, the emphasis is on 'doing' science, rather than pedagogy focusing on the development of language as part of the instructional register. He called for text to be seen as technology, as much as any concrete materials, developed by scientists for use in solving problems:

> *Here we have the model of the child as mini-scientist, participating in activities analogous to those undertaken by scientists centuries ago as they began to formulate their picture of the world. The effect… is to foreground doing (observing and experimenting) and background language, especially written language (reports and explanations). This means that children are not taught to access the genres science has evolved to store information which leads to tremendous inefficiency in the science curriculum* (Martin, J.R. 1993:201).

One additional contribution to an understanding of pedagogy and classroom discourse from systemic functional linguistics is the description developed by Martin and Christie of lessons and topics as 'macrogenre' and 'genre'. These terms, already used to describe coherent and logical written and oral texts, describe the logical unfolding of a topic and the lessons within a topic. This is an important concept used in the classroom discourse analysis in this study, and will be discussed in detail in the next chapter. Christie argued that a successful teaching and learning negotiation should result in logogenesis, the joint construction of a coherent and logical pedagogic text over time (Christie, F. 2005a:97). This may be across lessons, or within a lesson, but stands in contrast to one-off lessons of instruction with no link to past or future learning.

A systemic functional linguistic perspective on the roles and purposes of pedagogy might be summarised in the following way: the role of the teacher is to reconstrue meaning, to reframe experience to meet new academic, rather than simply interpersonal purposes. To fulfill this role, the teacher must be conscious of, and attend closely to the forms of language chosen, not simply the function, because form realises function in subject-specific ways. Reaching the goals of education requires the development of an academically oriented lexicogrammar which in turn requires the systematic shift along the Register continuum from situated to decontextualised language (Christie, F. & Maton, K. ; Halliday, M.A.K. & Webster, J. 2007; Hasan, R., Martin, J.R. & Halliday, M.A.K. 1989; Martin, J.R. 2011, 1992).

2.4.4 The intersection of the pedagogic elements; the curriculum, the learner and teacher

The theoretical propositions of socio-historical theory, sociology and systemic functional linguistics together create a strong interconnected foundation for scaffolded pedagogy in science education.

The goals of science education are clear: at the very least, education must enable access for all to the vertical discourse of science sufficient to provide scientific understanding, mediated through language, for participatory citizenship. As a matter of social justice, the more challenging goal of scientific orientation sufficient for future employment must not be

overlooked, with teachers determined that marginalised students in the primary and middle years will build scientific knowledge and language sufficient to persevere with post-compulsory science education.

2.4.5 What is effective pedagogy for marginalised students?

Child development has been established as a culturally bound, joint scaffolded process between a knowledgeable other, the adult, and the child. In the school context it leads the child beyond independent performance towards new culturally identified and socially valued learning. Language is central to this process, and student appropriation of language is both the beginning of meaning being established, and a tool for further negotiation and consolidation of meaning.

The responsibility of the adult is to provide contingent scaffolding, to develop and maintain strong and positive dyadic engagement, building intersubjectivity in scientific activity that leads to a shift into triadic engagement with the subject of science.

The framework for effective pedagogy for marginalised students emerges from these principles: the best chances for success are likely to come from a subversive, visible pedagogy in the form of contingent scaffolding. Effective pedagogy requires close and conscious attention to how the curriculum is framed and classified through the regulative register, which has the dual role of orientation to class procedures and scientific motivations and values; and the instructional register which has to orient students to not only the function of scientific communication but the form in which it is realised.

Unlike progressivist and transmission pedagogies, scaffolded pedagogy challenges teachers to a nuanced and sensitive moment-by-moment monitoring of classroom talk to assess the next contingent response required. This is the challenge taken up in this study, as teacher and researcher attempt to put these principles into action.

Over the past two decades, academics and classroom practitioners have tried in various ways to apply learning from Vygotsky, Bernstein and Halliday in the classroom. This chapter concludes with an examination of three significant approaches, firstly a group of ‘dialogic’ approaches developed principally in the United Kingdom; secondly a brief revisit of the Teaching and Learning Cycle developed in Australia; and thirdly Scaffolded Literacy, now known as Accelerated Literacy, developed initially for marginalised Australian Indigenous students.

2.5 Vygotskian influenced classroom interventions

2.5.1 Dialogic pedagogy approaches

Dialogic pedagogy is a perspective taken by a number of academics in the United Kingdom (Alexander, R.J. 2004a; Mercer, N. 2011; Wells, G. 2007) as well as Michaels in the United

States (Michaels, S., O'Connor, C. & Resnick, L. 2008). Their emphasis has been on the importance of dialogicality in teaching and learning, with several influenced by the work of Bakhtin (eg Bakhtin, M.M. 2004). Wells and Michaels in particular foreground a socio-cultural, rather than socio-historical approach to pedagogy, in that their goals have tended to focus in the first instance on reciprocal and democratic social processes in the classroom rather than on the correlation between these processes and student outcomes. They are concerned with shifting the locus of control from 'other regulation' to 'self-regulation', to use Wertsch's terms (Wertsch, J.V. 1979). Their approaches can be summarised as the valorisation of 'authentic' dialogue between students in opposition to teacher monologue, as well as expressing concern with the ubiquitous 'triadic dialogue', or the Initiation-Response-Evaluation sequence that is so prevalent in western classrooms (Wells, G. 1993). As will become evident, the pedagogic strategies offered by these dialogically influenced approaches focus on language resources that are useful in the regulative register.

Wells attempted to limit the use of the teacher-led I-R-E sequence in a quest for extending student talk and student initiation of new topics. He aimed for 'dialogic co-construction' of knowledge, arguing that the process of discussion itself deepens student understandings even if no consensus is reached (Wells, G. & Arauz, R.M. 2006:45) and that the role of the teacher in dialogic talk should not be that of primary knower, but that of facilitator. He favoured students working in groups, with the teacher circulating to provide occasional support. Despite his clear commitment to Vygotskian principles of child development, his examples of co-construction of knowledge provided in classroom discourse analysis fit better into the progressivist paradigm (e.g. Wells, G. 1999b).

Mercer's research investigated the use of student dialogue within group situations as a tool for learning. He aimed to structure and explicitly teach 'exploratory talk', that is *talk which combines challenges and requests for clarification with responses which provide explanations and justifications* (Mercer, N. 1996:369). Students were given explicit ground rules to assist with conversations: ask everyone for their opinion, ask for reasons why, listen to people, be prepared to change your mind, think before you speak, respect other people's ideas (Mercer, N. & Wegerif, R. 1999:100). Mercer found that the students engaged in this talk did indeed solve problems more effectively (Mercer, N. 2008b:98). His hypothesis for the effectiveness of this approach was that students internalised the exploratory talk as a tool for self-regulation so that they could carry on a rational internal dialogue with themselves. The success of the use of 'ground rules' is understandable, in that students who can effectively use them have taken control of the pedagogic regulative register. However, that leaves the big question of the instructional register: what pedagogic processes are in play to ensure that students have

appropriated the instructional register such that their explanations and justifications are crossing the boundary into the learning area discourse, and not remaining in the commonsense?

Alexander (Alexander, R.J. 2004a) conducted several years of intervention in British schools with a focus on changing teacher questioning and student talk to foster dialogue. Alexander characterises dialogic teaching as collective, reciprocal, supportive, cumulative and purposeful (ibid: 24). Strategies for the teacher include less bidding (opening the question to all) and more nomination (specific naming of a student) to better scaffold each learner; less rotation of questions around the class and more extended questioning of the student to encourage deeper thinking; less reformulation of a student response, and more asking another student to comment; more tolerance of silence as thinking time; and fewer cued elicitations (that is giving small clues to the answer, such as mouthing the beginning letter). Alexander aims for five qualities in classroom dialogue. The first three qualities; supportive, reciprocal, and collective focus on the affective context. They are concerned with the regulative pedagogic register. The remaining two qualities; cumulative and purposeful, relate to the logical unfolding of the content and are concerned with the instructional register. While teachers in his research performed well in enabling the former three qualities in classroom dialogue, they struggled to develop the qualities of content-challenging cumulative and purposeful dialogue leading to new learning (Alexander, R.J. 2004a:5).

Michaels' work on 'Accountable Talk', like Alexander's, does not abandon students to independent group work, but rather introduces a number of 'talk formats', many of which involve the teacher. Accountable talk identifies teacher-guided whole group discussion as 'the richest and most varied of the talk formats' (Michaels, S. *et al* 2008:19) but also the most complex to do well. Student talk is accountable in three ways: to the learning community, to accurate knowledge, and to rigorous thinking. The teacher is provided with moves and practices to support these differing foci. Examples of the moves identified to promote rigorous thinking are *pressing for reasoning* (Why do you think that?); and *expanding for reasoning* (Take your time, tell me more) (ibid: 31). What is not clear from these examples is under what circumstances these questions might be appropriate. When might such regulating questions be useful for marginalised students? What is the effect of such questions if students don't know the answer, despite their efforts at thinking rigorously?

The brief summaries of four dialogic approaches highlight some differences in focus amongst them. For Wells, the important message of activity theory, in response to traditional transmission and monologic teaching, was that teaching and learning are reciprocal, that students have to co-construct knowledge. Shared activity requires a shared goal: for Wells the goal was to democratise the classroom so that the teacher talked less and the students talked more, assisted with regulative strategies that sustained the dialogue. However, his work was not

concerned with any clear correlation between increase in student talk and improved student outcomes. In contrast, Mercer, Alexander and Michaels all attempt to link classroom talk with learning outcomes: Mercer to improve logical reasoning and make the ground rules for discussion explicit; Alexander to ensure that extended talk is purposeful and leads to some improved learning outcome; and Michaels to structure talk such that students are challenged and provided with time to display what they knew.

Two apparent issues with dialogic teaching are evident in these examples. The first is the lack of historical or longitudinal perspective in many studies: under what circumstances are particular teacher choices the appropriate ones? Are there times when to ask 'Why' is appropriate, and other times when it is not? When is the appropriate time to move students into independent group discussion? When is the appropriate time to withdraw teacher support? What work needs to precede a discussion and how does this influence outcomes?

Mercer's more recent work recognised this issue. By 2008 he was arguing for a temporal analysis of classroom discourse:

> *In order to understand how classroom education succeeds and fails as a process for developing students' knowledge and understanding, we therefore need to understand the temporal relationship between the organization of teaching-and-learning as a series of lessons and activities and how it is enacted through talk. To put it another way: as learning is a process that happens over time, and learning is mediated through dialogue, we need to study dialogue over time to understand how learning happens and why certain learning outcomes result. We may then see more clearly how the precious resource of the time that a teacher and a class spend together can be used to good effect in the pursuit of children's education, or how it may be squandered (Mercer, N. 2008a:5).*

The second gap in dialogic teaching comes to light when the strategies are viewed through the lens of Bernstein's pedagogic discourse, and its regulative and instructional registers. Much of the strength and development of language in dialogic pedagogy has been in the regulative register: giving students the language tools to self- and co-manage sustained discussion; for example by asking for clarification, by lengthening wait time, by asking questions that might help link to prior knowledge. Alexander, in his studies, identified the difficulty of ensuring that talk was purposeful and cumulative, leading to the establishment of common knowledge (Alexander, R.J. 2004a:5). It is possible that issues with developing purposeful and cumulative talk arose in part because the students and/or teacher did not have the resources needed in the instructional register, that is the content knowledge and the lexico-grammatical resources realising that knowledge. The descriptions of dialogic teaching suggest that it is relatively strongly framed, and relatively weakly classified.

The question then becomes how useful these self-regulating strategies are if the students do not have reasonable control over the content knowledge and its language representations. For example, Michaels' strategies for extending student thinking about a topic is to encourage teachers to ask students 'why' they think what they do, to wait or simply to ask them to say more (Michaels, S. *et al* 2008:30-33). If the student does not have the language resources to express a causal explanation in that context, then asking why or providing wait time is unlikely to help.

For marginalised students, the most important resource for mediating content knowledge is the teacher. Yet the dialogic approaches which encourage extended student talk may have misjudged the level of intensive and sensitive teacher input needed in the instructional register, to enable students to develop ideas and the language they need to sound authoritative. By attending to the regulative register without explicit teaching of the instructional register, it is possible for classroom talk to go around in respectful and interpersonally sensitive circles.

2.5.2 The teaching and learning cycle

The teaching and learning cycle was introduced in Section 2.4.3, p68 (DSP 1994; Rothery, J. 1989). The teaching and learning cycle, as it is currently introduced in professional learning workshops for teachers, provides a systematic routine that supports teachers in explicitly teaching the target language of a topic (DECD 2012c). The learning focus is on the language resources made available in a model text on the same topic, written at an appropriate level of complexity. Through the teaching and learning cycle, students gradually appropriate features of the text and apply them in their own writing.

In contrast with dialogic pedagogy, the teaching and learning cycle does not pay close attention to the language of the regulative register but provides extensive support for the instructional register. It is a macroscaffold in that it aims to provide a broad framework, a scope and sequence to support teachers in planning and to help them become conscious of the language features they need to explicitly teach .It does not address what the teacher needs to say and do at classroom discourse level for students to move from the commonsense to discourse-specific language.

The developmental nature of the teaching and learning cycle is evident through the changes in framing and classification. The changing relationship between framing and classification has been mapped in the following way by Martin and Rose (2005:3) :

Table 5. Waves of classification and framing through the teaching/learning cycle

	FRAMING	CLASSIFICATION	[comments]
Deconstruction			
- setting context/field	-F	-C	starts where learners are at, including valuing their voice
- modelling	+F	+C	authoritative visibilising, including critical literacy
Joint construction			
- setting context/field	-F^+F	-C^+C	weaker for gathering ideas, stronger for sorting them
- negotiating text	+/-F	+C	learners controlling content, teacher controlling genre
Independent construction			
- setting context/field	-F	-C	return to learners' contexts, if possible beyond simulation
- writing	-F	+C...-C	control/evaluation... then interested renovations

Key: - weaker, + stronger, ^ sequence.

The cycle begins weakly framed so that student 'voice' is valued. The framing and classification both strengthen as the focus on modelling and joint construction of text increases. The classification and framing of the later independent construction appears weaker, but only because the common knowledge established in the previous stages of the cycle is expected to be internalised by students, giving them the capacity for more autonomy.

Put simply, the dialogic pedagogues pay attention to the regulative register, without similarly considering the importance of the instructional register. The systemic functional linguists attend in very useful ways to the instructional, but limit their focus on the regulative to a macroscaffold, not to the teaching and learning negotiation inside that scaffold. The theoretical foundations introduced in this chapter would suggest that both need to be carefully considered.

The final example of a scaffolding pedagogy influenced by Vygotsky, Accelerated Literacy pedagogy, exemplifies an approach that concerns itself with both the regulative and instructional registers. The pedagogy provided the introduction to socio-historical theory for the research team in this study. Salient aspects will be described in some detail because of the significance of the pedagogy to the study.

2.5.3 Accelerated Literacy pedagogy

Accelerated Literacy pedagogy, also known as Scaffolded Literacy, originated as Concentrated Language Encounters for Indigenous students (Gray, B. 2007, 1998, 1984; Gray, B. & Cazden,

C.B. 1992). Salient aspects of the approach will be described in some detail because of its significance to the study.

Gray's pedagogic routine is a teaching sequence similar in structure to the teaching and learning cycle previously mentioned. It serves as a macroscaffold to support teachers in planning a logically developed topic; moving from reading to writing, from analysis of grammatically and language appropriate texts to synthesis of texts using those same grammatical and language features.

The teaching sequence supports teachers in making conscious and intentional pedagogic choices in both the instructional and regulative registers:

> *…in order to learn to control the production of a text, a learner must acquire access to both the language elements from which the text is constructed and the interaction or negotiation process through which it is produced and comprehended within the discourse in which it constitutes a product (Gray, B. 1998:19).*

Two important features of the pedagogic sequence help the teacher to pay conscious attention to each of the registers. They are the development by the teacher of focus texts which contain important language resources for students to appropriate; and the use of a particular questioning technique to help students engage with the learning interactions within the classroom.

The more recent version of the pedagogy, Accelerated Literacy is concerned primarily with the learning area of English. This is due to Gray's observation that Aboriginal student engagement with the strong interpersonal themes of high quality narrative served as a strong intermediary link to more academic, and less interpersonally engaging texts in other learning areas (Wignell, P. & Harper, H. 2009). The earlier iteration of the pedagogy, Concentrated Language Encounters, is particularly relevant to this study. It centred learning around language rich real life contexts such as hatching chickens or visiting an entomologist. In this early iteration, specific text types and topics were selected and pre-constructed in planning, for example 'How to Make Yummy Toast' (procedure) or 'From Egg to Chicken' (temporal explanation). The teacher kept these 'focus' texts in her mind to guide the initially oral descriptions and explanations of phenomena and concepts arising during activities.

When the teacher judged that students had sufficient control of meaning and language, the class would jointly write a similar text, with the teacher negotiating the construction with students in a way that closely approximated the focus text. The focus text provided clear direction for text structure, technical language choices and more complex grammars in the instructional register (Gray, B. & Cazden, C.B. 1992).This planning of language resources before teaching was an important strategy in helping the teacher to remain consistent in her instructional register use,

thereby ensuring that students heard new language many times and had opportunities to appropriate it.

The second feature of the teaching sequence developed by Gray is a modification of the I-R-E sequence so prevalent in classrooms. It aims to help build familiarity and share the intent of this common form of classroom communication so that all students can successfully participate:

> *…teachers typically ask questions to find out what the child knows or to probe the child to work something out by himself/herself. However, to respond to questions in the manner teachers expect, children must already share with teachers, considerable inter-subjectivity concerning how questions function in academic/literate discourses* (Gray, B. 2007:37).

Building intersubjectivity around the purpose and significance of questions enables students to participate meaningfully in classroom discussion. To draw students' attention to important information, Gray proposed the expansion of the I-R-E sequence with the addition of two scaffolds, one preceding the I-R-E sequence, and one following it. Each had a different purpose. The first scaffold is a 'preformulation'. This strategy was developed by Gray from an idea proposed by French and MacLure of a 'preformulator' (1979, 1981). A preformulation is a statement or question that prefaces a teacher's question. It acts as a orienting prompt so that the students understands 'what is in the teacher's head' when the question is given. Gray describes it as a *buffer*…which attempts *to ensure that the context from which the question arose was clear and commonly held by as many participants as possible* (1998:178-9). In Bernstein's terms, preformulation creates a strong frame. It cues the student in to attend to the important information:

> *The preformulation element focuses the students' response upon the object or concerns that are appropriate for constructing an effective response. It represents an attempt to align the intentionalities of both teacher and the students and to help the students see "This is how what or where I attend to in order to produce a response"* (Gray, B. 2007:38).

Unlike the traditional I-R-E question sequence that can serve to distinguish between students whose thinking happens to be aligned with the teacher and those who don't understand, an effective preformulation enables all students in the class to successfully, or at least partially answer the question, building strong positive affect within the class community and guaranteeing an affirming evaluation from the teacher. If the student cannot answer the question successfully, the teacher has not provided an effective preformulation and will need to repair. Accountability for successful communication rests with the teacher.

The second scaffold, and the second part of the 'buffer', follows the student's answer and is called a 'reconceptualisation'. This concept is described at length by Cazden (2001:71-75) as

providing something like a 'world view' (ibid: 72). Gray argues that it is not adequate to call this step a 'reply' or a 'response':

> *Because reconceptualisation makes visible the motivational and organisational intentionalities inherent in an effective response to all other students, it provides a means through which differences in understanding across the classroom can be reconciled through the development of commonly held perceptions and knowledge* (2007:49).

Reconceptualisation shifts the frame of reference. It answers the question 'So what? Why is this answer important?' by adding further layers of cultural meaning, generalising, or rewording in a more discourse-appropriate way, to build common knowledge in the class about the significance of this question and answer.

To illustrate the function of the questioning sequence, here is an example of the questioning sequence with a class of remote Aboriginal students studying 'Nails' by Paul Jennings (Jennings, P. 1994). The sentence that the teacher is focusing on is the topic sentence of a suspense passage when the main character, Lehman, is about to encounter a scary creature: *Lehman walked through the water past a deep, black cave in the rocks.* In this excerpt, the teacher wants the students to attend to the word choice in the noun group 'deep, black cave'.

Question stage	**Classroom talk**	**Interpretation**
Preformulation (tells students what to attend to)	Then Paul Jennings tells us more about *where* Lehman walked.	Students are cued with the word 'where' to look for a circumstance of place
Question	Can anyone see the words that tell us that?	Question is directed generally to the class. When there is little intersubjectivity, nominating a student is high risk: they may feel put on the spot. Students are directed to look at the words, rather than rely on recall.
Student Response	*Past a deep, black cave in the rocks.*	Student identifies the words successfully.
Reconceptualisation	That's right. See those words *deep* and *black?* Paul Jennings couldn't have had a shallow cave, could he, because then there wouldn't have been anywhere for the scary thing to hide.	Teacher affirms response, and expands on the adjectives preceding cave: the author had to choose a place where the scary thing could be slowly revealed in order to maintain suspense. This is important information for future writing.

Preformulation and reconceptualisation are scaffolds, which need to be contingently applied. As intersubjectivity about the topic builds over a sequence of lessons, the scaffolds are gradually removed. When high levels of intersubjectivity are present between teacher and student, when there is a high level of common knowledge about the teaching and learning negotiation, the children know what to attend to and preformulations are no longer required. As discussed previously (Section 2.4.2, p65), the framing becomes apparently weaker. The reconceptualisations have been appropriated by the students as important cultural knowledge and the teacher's role changes from 'telling' to 'checking for handover'.

The use of focus texts and the elaborated questioning sequence are only some of the scaffolding techniques used in this teaching and learning routine. Teachers are shown how to adjust their talk depending on the level of intersubjectivity in the classroom. They are shown how to adjust the regulative register with Mood choices (statements and questions), with their choice of vocatives (how they nominate and bid for student answers); they are shown how to shift from closed preformulated questions to open-ended 'wh-' questions so that students can display what they know. Teachers control the instructional register with a growing understanding of the language resources evident in the texts with which they work. They learn how to analyse and talk about the intentionality of authors and to share that knowledge through their reconceptualisations and joint construction of texts. These strategies are outlined in more detail in Chapter 3.

In summary, Gray's scaffolded pedagogy incorporates understandings of child development from Vygotsky, of language as social practice from Halliday, and of the crucial role of pedagogic choice from Bernstein. It provides guidelines for both the regulative and instructional pedagogic registers. For teachers proficient in the Accelerated Literacy teaching routine that can be highly effective in the learning area of English, the challenge is how the underpinning principles can be employed to induct students into the more objective world of science in a way that is effective for students, and also logical and systematic for the teacher. This study documents the efforts by researcher and teacher to put these principles into action in the learning area of science.

The following chapter, Chapter 3, moves to placing the study in its historical context, providing an account of previous analytic methods in classroom discourse analysis, and introducing the research processes undertaken by this study.

CHAPTER 3

Methodology

3.1 Research focus

Chapter 2 introduced the three theories informing this study; socio-historic or sociocultural theory, systemic functional linguistics and sociology, and their contributions to the three elements of pedagogy; the curriculum, the learner and the teacher. The chapter proposed that the development of academic intersubjectivity in the learning area of science was a demanding but important goal of education; that the teacher and students need to develop alignment in its intent, goals and processes, rather than just sharing physical artefacts. It also argued for the appropriation by students of scientific language as a useful indicator of developing intersubjectivity.

The chapter outlined the differences between Piagetian and Vygotskian stances on child development and the implications for pedagogy. Using the motivation of social justice and equity, it argued for a shift from progressivist, child-centred learning to the alternative Vygotskian position of a negotiated, scaffolded pedagogy, with attention required in both the regulative and instructional registers, and careful attention paid to language choices used in the teaching-learning negotiation. It provided an overview of some Vygotskian- and Hallidayan-informed pedagogic interventions, and acknowledged the particular influence in this study of Accelerated Literacy pedagogy developed by Gray.

It described how the scaffolding strategies employed in Accelerated Literacy attempted to develop teacher practice in both the regulative and instructional pedagogic registers. Finally, it explained that this study sought to investigate how the principles and strategies now employed by scaffolded literacy in the learning area of English could be called on to develop effective scaffolding in the learning area of science.

Informed by the three theories, this study, referred to as *Scaffolding Science*, established a number of pedagogic principles which were put into practice in one classroom. The purpose was to investigate what pedagogic choices might support or hinder the development of academic intersubjectivity between teacher, student, and scientific discourse in a primary classroom.

Three research questions were established:

1. Student performance: what changes in student language use are evident from the beginning to the end of the study?

2. Enabling processes: which teaching processes enable the scaffolding of effective learning negotiation with disadvantaged learners within subject science?
3. Issues: what presumptions and issues underlying current teaching practice are confronted as the teacher incorporates scaffolding principles into her science education repertoire with disadvantaged learners?

The study employs classroom discourse analysis to address these questions, focusing closely on the pedagogic interactions between teacher and students in one science topic. The study tracks student language development across the topic in two ways. Firstly it examines student appropriation of scientific language, both in the lessons and through a number of case studies of student pre- and post- oral performance. Secondly, it examines the teaching and learning processes, including the teacher's use of the regulative and instructional registers across lessons.

The discourse analysis draws on a number of sources: firstly from the work of Christie (2002, 1998c; 1995; 1998b; 1998a), specifically her development of the notion of macrogenres as a framework for analysis of classroom discourse, and her reconstrual of Bernstein's regulative and instructional discourses as pedagogic registers. Secondly, it builds on the work of Gray (Gray, B. 2007, 1998) in tracking the changing nature of classroom talk across time. Each of these approaches is discussed later in the chapter.

Before explaining the study design in detail, Section 3.2 acknowledges the contributions of previous classroom discourse analysis approaches, with a more extended elaboration of the analytic resources appropriated from Christie and Gray for use in this analysis. Section 3.3 summarises the premises on which this analysis rests. Finally, Sections 3.4 to 3.6 explain the research design.

3.2 Classroom discourse analysis: previous approaches and issues

Classroom discourse analysis has been evolving since the early 1970s with interest drawn from many disciplines including ethnomethodology, linguistics and psychology. These fields have developed a number of different approaches to discourse analysis. Early versions are represented by the 'systematic observation' approaches of the 1970s and the 'insightful observation' approaches of the 1980s and 1990s. More recent approaches include ethnomethodological studies, critical discourse analysis, socio-linguistic and systemic functional linguistic analyses, and socio-historically influenced approaches. An approximate timeline, beginning in the United Kingdom in the 1970's, is represented in the following table:

Table 6. Approaches to classroom discourse analysis 1970-2010

1970	1980	1990	2000	2010
Systematic observation approaches (Flanders, N.A. 1970; Galton, M.J., Simon, B. & Croll, P. 1980)				
Insightful observation approaches (Barnes, D. et al. 1971; Rosen, C. & Rosen, H. 1973; Barnes, D. & Todd, F. 1977; Barnes, D. 1990; Britton, J.N. 1990)				
Early linguistic approaches (Coulthard, M. 1992, 1977; Coulthard, M., Montgomery, M. & Brazil, D. 1981; Sinclair, J.M. 1980; Sinclair, J.M. & Coulthard, R.M. 1975; Stubbs, M. 1983; Stubbs, M. 1981a)				
	Socio-historic approaches (Edwards, A.D. & Furlong, V.J. 1978; Edwards, D. & Mercer, N. 1987; Gray, B. 1998a; Wells, C.G. 1999; Alexander, R. 2000; Mercer, N. 2000, 2004; Alexander, R.J. 2004a; Wells, G. & Arauz, R.M. 2006; Alexander, R.J. 2006a; Gray, B. 2007; Mercer, N. 2011)			
	Sociological approaches (Bourne, J. 2004, 2003; Mehan, H. 1979; Morais, A., Neves, I. & Pires, D. 2004; Morais, A.M. 2002)			
		Ethnographic approaches (Heath, S.B. 1983; Moll, L.C. *et al* 2005)		
		Socio-linguistic approaches (Cazden, C.B. 1988; Cazden, C.B., John, V.P. & Hymes, D. 1985) (Michaels, S. *et al* 2008)		
			Conversation analysis (Freebody, P. *et al* 1995), and later investigations particularly in language classrooms (Hall, J.K. & Walsh, M. 2002; Huth, T. 2011)	
			Systemic functional linguistic approaches (Christie, F. 2002, 1991b, 1998b; Gibbons, P. 2002; Gray, B. 1998; Hammond, J. 2001; Lemke, J.L. 1998; 1993; Yang, X.P.D. 2010)	
				Critical discourse analysis (Fairclough, N. & Wodak, R. 1997; Gutierrez, K.D. *et al* 2002; van Dijk, T. 2001) (Corson, D. 1999; Muspratt, S., Luke, A. & Freebody, P. 1997; Wodak, R. 2004)

While these researchers hold in common the site of study; that is the classroom, the motivations, purposes and processes of analysis vary. To position this study in a historical context, an outline of some of these important approaches follows, identifying the contributions they have made to

the research paradigm, and some of the issues and questions which each approach has left unanswered.

3.2.1 Early coding approaches

Early observations of classrooms were called 'systematic observation', or 'interaction analysis' (Edwards, D. & Mercer, N. 1987:24) They included Classroom Interaction Analysis (Flanders, N.A. 1970) and the Observation Research and Classroom Learning Evaluation (ORACLE) following from the Plowden Report in Britain (Galton, M.J. *et al* 1980). The motivation for these early evaluations was a reaction against 'transmission' teaching, and an interest in improving student engagement through more inclusive teaching. Without the benefit of recent video technology, the early research relied on observations made by highly trained observers who coded language on the spot. For example, Flanders' observers made a judgment on language function every three minutes (1970:37). Despite the motivation for this approach, not all outcomes were positive: Galton provided provoking insights into the unanticipated effect of the Plowden Report recommendations as realised in classrooms. He concluded that higher order thinking conversations were reduced with the individualising of learning because of the high level of management talk needed to hold everything together (Galton, M.J. *et al* 1980:158).

The products of these early coding approaches were quantitative: inventories of classified teacher-pupil interactions. For example Flanders, with his 10-category system, developed descriptors of utterances such as *accept an attitude or the feeling tone of the pupil in a non-threatening manner,* or *enhance the authority of ,* and distinguished between student *response* and *initiation* (ibid 40-49). Several limitations are apparent here. Firstly, the analysis attends to isolated single lessons. Consequently, it cannot examine a correlation between any particular pedagogic practice and subsequent student outcomes. The analysis codes count linguistic categories within a lesson, but the researchers do not address how the frequency and presence of any category affect the achievement of educational goals. In a 1974 review of these systematic observation approaches, Dunkin and Biddle took issue with the assumption that an inventory of teacher behaviour represented effective teaching:

> *…any meaningful analysis of teaching must involve sequential elements. Indeed, perhaps the greatest single flaw in much of the research we have reviewed is the persistent assumption… that teaching can somehow be reduced to a scalar value that can be indicated by a frequency of occurrence for some teaching behaviour.*
>
> *We also suspect… that smaller units of sequence must be conceived to form parts of larger sequences… and that the key might ultimately be a linguistic one (Dunkin, M.J. & Biddle, B.J. 1974:353).*

Dunkin and Biddle's response to the early coding approaches foreshadowed the need for closer attention to the linguistic realisation of these categories, and for the need to look beyond single instances of classroom interaction to longitudinal studies of pedagogic activity.

The second limitation is the use of coding. The codes are the data, rather than the corpus of teacher language choices that have prompted these categories. Consequently, the language interactions themselves are not available for further scrutiny or alternative interpretations by teachers or researchers.

Despite its limitations, the legacy of the early coding approaches remains in contemporary education. Though 40 years has lapsed since this work, the 'two-thirds' rule of teacher talk still has currency in education. Interaction analysis quantified classroom interaction with the following precision: teacher talk 68%, pupil talk 20%, and silence or confusion 12% (Flanders, N.A. 1970:101). Put simply:

> *(a) for about two-thirds of the time someone is talking;*
>
> *(b) about two-thirds of this talk is the teacher's;*
>
> *(c) about two-thirds of the teacher's talk consists of lecturing or asking questions* (Edwards, D. & Mercer, N. 1987:25)

From this data, teachers have extrapolated rather simplistically that they should reduce the quantity of teacher talk and provide more opportunities for student talk. However, this somewhat crude proportioning of 'use of air space' fails to demonstrate any causal or correlational link between the quantity of teacher talk at any point in a teaching sequence, and student learning outcomes. As Edwards and Mercer comment:

> *The kind of data obtained from systematic observation studies does not allow researchers to reconstruct the course of any given lesson; the only information available about the course of events after the lesson has finished is in the form of numerical frequency codings. One feels, therefore, that there was surprisingly little of the right kind of information available to researchers wishing to explain why teachers did one things rather than another, or why certain patterns of classroom interaction seemed to work better in the teaching of some topics rather than others* (ibid: 25).

In contrast, the next phase of classroom discourse analysts, the 'insightful observation' approaches (Edwards, D. & Mercer, N. 1987:26) paid close attention to classroom interactions, and particularly the minute by minute inequalities between 'transmission' teachers and their students.

3.2.2 Insightful observation approaches

Unlike the 'systematic observation' approaches, the 'insightful observation' researchers recorded and reflected on classroom language in a manner that allowed for review and revision. Included in this group are Barnes, Britton, Rosen and Torbe (Barnes, D. 1976, 1982; Barnes, D. *et al* 1971; Barnes, D. & Todd, F. 1977; Rosen, C. & Rosen, H. 1973; Rosen, H. 1971). This group has had a strong influence on classroom pedagogy in the western world, particularly through its emphasis on the value of open-ended teacher questions which remains to this day (eg Erdogan, I. & Campbell, T. 2008; Lowery, L. 2010; Meth, J.M. 2010; Weizman, A., Shwartz, Y. & Fortus, D. 2008). From a sociohistoric perspective, important questions remain unanswered from this research. As an example, a brief critique follows of one prominent insightful researcher in secondary classrooms, namely Britton (1990).

Britton's research in secondary classrooms brought to prominence the paucity of open-ended teacher questions, and the prevalence of closed questions asking for recall of facts. In response, Britton proposed that active participation by students, employing their own home ways of using language would lead to more successful outcomes. He argued that this change would lead to take-up of new learning and lexico-grammatical resources:

> *It is the language of their own intimate musings, their inner reflections upon experience that will serve both to bring their commonsense concepts to the point of engagement with the scientific concept, and to carry out the reconciliatory interpretation.*
>
> *Expressive talk and writing are a means, therefore, rather than an ends. Any expressive formulation of some piece of knowledge about the world is a potentially useful approximation to a more impersonal, objective, 'public' statement* (Britton, J.N. 1990:108).

Unfortunately, Britton did not identify the pedagogic processes which would enable this shift from 'intimate musings' to public language to occur. For the purposes of this study, two issues in the insightful observations are evident. Firstly their attention was on the short-term educational goal of achieving classroom democracy, rather than the long-term goal of academically successful students. Secondly, despite the preference for democratic classrooms, there was no longitudinal study that examined the correlation between either transmission or progressivist pedagogy and student outcomes over time. No conclusion can be drawn from Britton's study on the efficacy of either pedagogy.

Another criticism leveled at this early approach to classroom discourse analysis was its somewhat haphazard approach to the study of language. Stubbs described it as 'ad hoc and unprincipled'. He gave two reasons: firstly the unprincipled selection of data, allowing

researchers to *feel justified in picking out, as evidence, any feature of language which appears to be intuitively interesting* (Stubbs, M. 1981b:116-7). Stubbs argued that the insightful observers' arbitrary selection of linguistic items from different levels of analysis, that is word level, grammar level and text level was less than systematic.

Secondly, Stubbs asserted that once interesting language was selected, insightful researchers did not attend to *the linguistic and socio-linguistic systems and structures in which they are terms* but rather allocated these terms directly to social-psychological categories. *These claims relate features of language to a very mixed collection of social-psychological concepts* (ibid) . They glossed over the grammatical choices and patterns through which teacher pedagogic intentions and the content of the subject were realised and did not systematically study the language.

Criticisms of the ad hoc nature of data gathering led to the development of new, systematic analyses of classroom talk, arising from the field of linguistics. This field was led by Stubbs, Sinclair and Coulthard, who sought to map classroom talk as part of a system of language choices.

3.2.3 Early linguistic approaches

The new imperative to focus more systematically on the linguistic system realised in classrooms led to important work by Sinclair and Coulthard (Coulthard, M. 1992, 1977; Coulthard, M. *et al* 1981; Sinclair, J.M. & Coulthard, R.M. 1975) and later Stubbs (1983; 1981a; 1981b). Unlike the rather random selection by Barnes and Britton of interesting linguistic features, Sinclair and Coulthard were interested in *the level of the function of a particular utterance, in a particular social situation and at a particular place in a sequence as a specific contribution to a developing discourse* (Sinclair, J.M. & Coulthard, R.M. 1975:13). Their description of a lesson structure, identified as an array of ranks and levels, provided the means for analysis of all utterances in a lesson in a systematic way, in contrast to the more subjectively selected cameos attributed to the insightful analysts.

Sinclair and Coulthard represented the lesson structure in this manner (1975:24):

Table 7. Levels and ranks of classroom discourse

Non-linguistic organisation	**Discourse**	**Grammar**
Course		
Period	Lesson	
Topic	Transaction	
	Exchange	
	Move	Sentence
	Act	Clause
		Group
		Word
		Morpheme

The lesson structure categorisation was important in that Sinclair and Coulthard recognised the language used for teaching and learning negotiation in the classroom as a system. Their framework enabled researchers to place examples of classroom talk within a finite number of categories within a lesson, and thereby examine more systematically the linguistic purpose and function of any utterance. This categorisation was the first of two significant contributions to classroom discourse analysis. It The second, long-lasting contribution was their highly influential description of teacher-student interactions at the Exchange level of classroom discourse: the Initiation-Response-Feedback ' I-R-F' pattern, also known as I-R-E (Initiation-Response-Evaluation). The I-R-E pattern was discussed in Chapter 2 (Section 2.4.1.2, p55ff).

The limits of Sinclair and Coulthard's analysis were identified by the next wave of classroom discourse analysts, Edwards and Mercer (1987). The principal interest of Sinclair, Coulthard and Stubbs was linguistic; that is to identify and classify linguistic structures for their own sake, rather than to investigate how these structures contributed to educational goals. Their analysis could help a teacher identify transactions, exchanges, moves and acts within a lesson, but did not assist teachers in evaluating which linguistic choices should be made under what circumstances within this structure to achieve their educational purpose. While the insightful observers, Barnes and Britton, focused on pedagogic choice without systematic reference to linguistic realisations, the early linguists focused on linguistic structures without due reference to pedagogic purpose. In fact, Edwards and Mercer declared that such a linguistic analysis, made without reference to the role of classroom talk in contributing to student development, was merely 'scratching the surface'(ibid: 10).

3.2.4 Sociocultural and socio-historically influenced approaches

By the 1980s, translations of Vygotsky's work were beginning to have an influence in the field of educational psychology and became a catalyst for examining classroom teaching and learning from a socio-psychological perspective. Interestingly, the translation of these theories into Western contexts often became somewhat diluted: the application tended to *ignore the social beyond the interactional, and celebrate the individual at the expense of socio, cultural and historical factors* (Davydov, V.V. 2008). This diversion in focus calls for a further categorisation of Vygotskian approaches into those taking a socio-historic stance, looking longitudinally at the ongoing effect of teacher pedagogic choices on student learning outcomes; and those with a strong socio-cultural focus, harnessed with the motivation of strengthening student voice and classroom democracy.

The following sections provide examples of these approaches: firstly the socio-historic, but non-linguistic research of Edwards and Mercer, secondly a number of socio-cultural researchers which I have loosely termed the 'dialogics' because of their attention to developing student

participation in classroom interactions, and finally Gray's Australian socio-historic approach of Concentrated Language Encounters on which this study builds.

3.2.4.1 Edwards and Mercer: Common Knowledge

Edwards and Mercer heralded the beginning of a number of classroom research projects influenced by sociohistoric theory (Edwards, A.D. & Westgate, D.P.G. 1994; Edwards, D. & Mercer, N. 1987; Edwards, D. & Potter, J. 2001; Mercer, N. 1994; Mercer, N. & Wegerif, R. 1999),. Sometimes called discursive psychology (Edwards, D. & Potter, J. 2001), this approach to classroom discourse analysis distinguished itself as not so much concerned with language as with cognitive and educational processes:

> *Our concern is more with content than with form. That is, we are interested in what people say to each other, what they talk about, what words they use, what understandings they convey, and with the problematics of how these understandings are established and built upon as the discourse proceeds. … And we shall be looking for continuities of talk and of shared experience that transcend the moment-to-moment flow of talk, the alternation of turns at speaking and listening that are the principal object of Sinclair and Coulthard's analysis* (Edwards, D. & Mercer, N. 1987:10).

In *Common Knowledge* (ibid), Edwards and Mercer were particularly interested in classroom practice informed by the progressivist-promoting Plowden Report in Britain (Plowden, B. 1963). They investigated several British primary science classrooms, in which teachers were strongly influenced by the principles of discovery and inquiry learning, and identified the 'progressivist teachers' dilemma'. The dilemma is that teachers are responsible for the achievement of certain curriculum outcomes, yet the principles of discovery learning require that, if students don't already have the information, the progressivist teacher is required to 'inculcate knowledge while apparently eliciting it' (Edwards, D. & Mercer, N. 1987:126), leading to a pressure for implicit forms of pedagogy.

Edwards and Mercer have contributed to this study strong arguments for pursuing pedagogic strategies that support learning and development in the ZPD. Importantly, Edwards and Mercer were the first to argue for analysis of sequences of lessons, rather than one-off lessons. This enabled them to examine the effect of teachers' pedagogical choices over time.

Unfortunately, because of their psychological orientation, and in reaction to Sinclair and Coulthard, they dismissed the value of close linguistic analyses of classroom discourse, arguing that the interests of the early linguistic researchers were not primarily in education but in *textual cohesion in a convenient setting* (ibid: 9). As Gray pointed out, this rejection was premature:

> *Given that classroom discourse is, at the present time, still poorly understood and that the offerings from research for classroom teachers are so limited, this exclusion of an important aspect of linguistic insight is a cause for concern. A more cautious position would be to look for circumstances where there existed a level of compatibility and even overlap between approaches characterized as ethnographic and sociolinguistic and approaches which provided a systematic consideration of language choice at the level of lexicogrammar* (Gray, B. 1998:126).

In positioning their work as an alternative to linguistic analysis, Edwards and Mercer focused on how content knowledge and language was developed (or not) by students in the teaching-learning negotiation in progressivist classrooms. Yet such an analysis may have been strengthened with a more systematic analysis of the contribution of teacher's language choices in supporting learning goals.

3.2.4.2 A focus on dialogue

In the decade following from *Common Knowledge*, socio-cultural theory increasingly informed classroom discourse analysis, influencing the perspectives of socio-linguistic and educational researchers. These studies ranged from Wells in Canada to Alexander and Mercer in Britain, to Michaels in the United States. While an understanding of the social nature of learning is clear in their research, it will become evident that another important aspect of sociocultural theory, namely the historical aspect, was somewhat overlooked in some of these studies.

Unlike Edwards and Mercer, who rejected a linguistic perspective on classroom discourse in favour of a socio-psychological perspective, Wells' research brought together the fields of sociocultural activity theory, systemic functional linguistics and the work of Bernstein in sociology (1994a, 1994b, 1999a, 1981, 2008, 1987, 1998, 1993, 2007; Wells, G. & Arauz, R.M. 2006). Wells argued that the transformation from every day to synoptic (ie academic) texts…

> *…is most likely to occur when activities are carried out in situations of collaboration with or other children, in which the new, synoptic mode of construing experience is related to the more familiar dynamic mode through talk that moves back and forth between the two modes, building bridges between them* (Wells, G. 1999a:45).

Wells supposed that more student collaboration and less teacher talk would provide the appropriate conditions for 'bridge-building' between every-day and academic language, increasing the level of academic intersubjectivity. From a socio-historic perspective, Wells' analysis raises many questions about the teacher's role in providing guidance over time within each student's ZPD. Despite his advocacy for active student participation and group work,

Wells' study did not demonstrate how the processes in group work, with sporadic input from the teacher in the form of prompts, might facilitate a shift for all students from the commonsense to the academic. His work suggests that Daniels may be right when he says that *the emphasis on interpersonal interpretation and interaction as a setting for developmental processes has removed the instructional invective from Western 'Vygotskian' pedagogies* (Daniels, H. 2001:20).

Because Wells' analysis was restricted to single lessons, the time span did not allow for a study of longitudinal linguistic development as the topic developed over time. While Wells' studies were premised on the importance of developing a high level of academic intersubjectivity, he did not demonstrate how an increase in student group work and talk time might reliably contribute to that goal.

Chapter 2 has already described the work of a number of socioculturally influenced linguists on both sides of the Atlantic were also conducting research around classroom interactions concurrent with Wells (Section 2.5, p70ff). These included Alexander (2005; 2006b; 2004a; 2006a), Mercer (2010, 2008a, 2004, 2008b, 2000; Mercer, N. & Howe, C. 2012), and Michaels (Michaels, S. *et al* 2008), following from Cazden (Cazden, C.B. 2001).

Alexander, Mercer and Michaels all found the development of subject knowledge and language the most difficult to achieve. The focus of the 'dialogic' research has been predominantly on the regulative register rather than the instructional. In their enthusiasm for supporting effective student talk, teachers have explicitly taught regulative language, such as asking for clarification, and the language for reaching consensus. While this language might help to frame student conversations, it does not easily develop student language resources in the instructional register:

> *The dialogicality of instruction [cannot] be judged in terms of the how of instruction – question / answer sequences evidenced in face-to-face interaction – alone… The what of instruction – the content and subject matter- is critical to learning as well* (Nystrand, M., Gamoran, A. & Kachur, R. 1997:73).

In other words, the instructional register also requires attention. If students do not understand the target concepts, then refined self-regulative talk can only take them so far. Dialogic research has not answered the question of how teachers might consciously and systematically project the instructional register in supporting control of new language and learning.

3.2.5 Ethnomethodology and conversation analysis

Contributions to the field of classroom discourse analysis have also come from the field of sociology, particularly ethnomethodology (Garfinkel, H. 1974, 1967; Mehan, H. & Wood, H.

1975; Ten Have, P. 2004). Ethnomethodology examines how orderly cultural life is realised and evident through every day collaborative practices by members of a particular culture.

A particularly influential contribution was made by Heath, describing and contrasting the incongruent literate practices between home and school and the effect on student participation in the classroom in situations where there is little shared intersubjectivity between teacher and students (Heath, S.B. 1983). While Heath's work was not focused on teacher pedagogy, her research supports the stance taken in this study of the need for teachers to be conscious of discourse differences as part of their everyday business.

From the field of ethnomethodology came conversation analysis, building on the work of Sacks and Schlegloff (Sacks, H. 1992, 1984; Schlegloff, E. 1984). Conversation analysis describes and accounts for the interactional organisation of 'talk-in-interaction', including endogenous organisation, for example, the way turn-taking is organised within a conversation, and how participants achieve, or fail to achieve coherent conversations. Of particular attention is the role of adjacent pairs of utterances in demonstrating the level of intersubjectivity between speakers. Because adjacency provides a basis for assumed relevance, any apparently irrelevant response marks a lower-than-expected level of intersubjectivity between speakers, and generates the need for the first speaker to take another turn and rephrase in order to repair the breakdown in communication:

> *From a speaker's point of view, next-position thus offers a location in which to find the recipient's analysis of the utterance – to see whether an anticipated response is confirmed. From a recipient's point of view, next-position offers an opportunity to reveal aspects of the understanding of prior talk to which own talk will be addressed… Thus, next position is a crucial location for the building of intersubjectivity: each next turn provides an environment in which recipients can display many understandings, including problematic understandings (ie misunderstandings) that lead to "third position repair"* (Schiffrin, D. 1994:237).

If coherence in adjacency pairs is the intention of any interaction, then a breakdown in coherence marks a point in conversation where assumed intersubjectivity within the interactional system is missing (ten Have, P. 2001).

Importantly, when identifying interactive trouble, conversation analysts do not clearly separate the observer from the observed. In fact, it is the familiarity of the observer with the cultural values, roles and expectations of the context that enable them to identify when the interaction has become troublesome:

> *(o)ur resources as members of a culture who know about "values", "motivations", "classroom work", and so on, are*

> *recruited to inform our observations and our documentation of how people engage in everyday activities, how they convey to one another 'what is going in' and how their talk shows, to the other participants as well as to the analyst, how they account for and construct the significance of their actions* (Freebody, P. *et al* 1995: 189-90).

Within a classroom, conversation analysis validates the subjective and intersubjective nature of the turn-by-turn analysis of teacher-student interactions. From this perspective, only observers with an understanding of the intersubjectivities of the classroom are in a position to look for coherence, or lack of coherence between conversational turns to monitor the level of intersubjectivity between teacher and students.

One important Australian study drawing on conversation analysis to reflect on teacher-student intersubjectivity was *Every day literacy practices in and out of school* (Freebody, P. *et al* 1995). It analysed and compared conversations in socially disadvantaged and non-disadvantaged early primary classrooms. The study identified 'interactive trouble' in classroom conversations, in other words the breakdown of adjacency pairs. 'Interactive trouble' refers to points of breakdown in the teaching and learning negotiation *when one speaker is taken to have failed to comply with the warranted directives given by the other speaker* (ibid: 199). Interactive trouble is sensed by the observer as a lack of smoothly flowing interaction, and failure to repair the communication creates disjunction in teaching and learning.

By identifying interactive trouble within teacher-student conversations, Freebody was able to attend to both the lack of intersubjectivity between teacher and students in disadvantaged classrooms, and the largely ineffective strategies that teachers used in their attempts to repair this trouble. Freebody et al identify several categories of interactive trouble requiring repair from the teacher (ibid:298). Some trouble arose through lack of content knowledge, either on the part of the student or on the part of the teacher. Some arose through confusion about behavioural processes and routines in the classroom. The categories are listed as Table 8 below:

Table 8. Categories of interactive trouble (Freebody, P. *et al* 1995:298)

Categories of interactive trouble (Freebody, P. *et al* 1995:298)
Epistemological: where student does not know the answer
Reasoning: where out-of-school and in-school logic is divergent
Pedagogical: dispreferred theory of literacy is offered
Stylistic: certain forms of expression are preferred by teacher with no explication

Organisational: uncertain selection of next-speakers
Relational: incongruence with pitch, volume, pace, eye contact, humour etc

Freebody's study compared the interactions in non-disadvantaged and disadvantaged classrooms. The teaching-learning negotiation in the non-disadvantaged classroom displayed a high level of intersubjectivity between teacher and students, a feature which Freebody et al described as a classroom of 'consociates': *those whom he or she knows or can be taken as known as individuals, complex and always-already varied, and typified only in terms of their cultural congruence to the self* (Freebody, P. et al 1995:246).

In contrast, the relationships in the disadvantaged classrooms were described as those of 'contemporaries', *taken to be more culturally remote… 'known' through typifications arising from category memberships* (ibid). What is not clear from the Freebody *et al* study is the reason for this difference: are the high levels of intersubjectivity in the non-disadvantaged classroom a consequence of effective teaching, or is the teacher merely making use of, and building on the high level of intersubjectivity arising from already established congruence between home and school cultural and linguistic practices? Without observing how that intersubjectivity has been built, that is without a longitudinal perspective on the teaching-learning negotiation in the classroom, it is impossible to say:

> *Within a socio-historical perspective, it is important not to decide the function of strategies associated with teacher intervention on the basis of their realization in a socio-historically isolated instance. For example, what appears as an informing or questioning move on the part of the teacher at one point in time may, under certain sets of conditions, constitute a precondition for a seemingly 'spontaneous' initiation on the part of a child in interaction at a later stage of discourse evolution. Consequently, it can be argued that a particular interactive strategy cannot be adequately interpreted unless it is considered as a dynamic component of a socio-historical system that occurs as the discourse develops over time (Gray, B. 1998:115).*

Because of the absence of historical data, some important questions are beyond the scope of the Freebody research. Because the purpose of conversation analysis is to describe how communities interact and maintain coherence, its intention is not to make recommendations about how coherence might be improved (Gardner, R. 2008). For this reason, the analysis tends to be 'fragmentary' (Eggins, S & Slade, D 1997:7); it stops short of pointing to what principles and processes might assist teachers in systematically and methodically structuring topics, lessons and turns in ways that would build and maintain intersubjectivity within the classroom.

3.2.6 Critical discourse analysis

Critical discourse analysis (CDA) arose from the Lancaster school of linguistics, particularly the work of Fairclough (Fairclough, N. 2003; Fairclough, N. ; Fairclough, N. & Wodak, R. 1997). Fairclough's description of CDA explains that it has no distinct methodologies; it is cross-disciplinary and is a loose and divergent group of approaches to language. What identifies CDA as a research approach is its commitment to examining how language and other semiotic systems realise unequal relations of power in different social contexts. Other contributors in this field include Gee (Gee, J.P. 1996, 1990; 1998), Wodak (2004; Wodak, R. & Chilton, P.A. 2007; Wodak, R. & Meyer, M. 2009) and Kress (1988, 1985, 2010). CDA represents a loose affiliation of research approaches, allied through their shared commitment to the study of power relations in social contexts.

While this study shares with CDA a commitment to social justice and a motivation for power sharing amongst all citizens, a socio-historical theoretical perspective does not therefore conclude that striving for equally shared power in the classroom is the means to that end. The aspirational pedagogy for those involved in CDA belongs in the fourth quadrant of 'Radical Pedagogy' along with Freire (ref. Ch 2 Section 2.4.2, p58). From a socio-historical point of view, the means for achieving power is the transformational sharing of powerful cultural resources through education. The balance of power and power relationships within the classroom are expected to change over time. Although any asymmetry of power in the teacher-student relationship might be viewed adversely from a CLA perspective, such asymmetry is not an issue from a socio-historic perspective as long as it progressively moves towards student control of the learning. In fact, asymmetry is essential for the creation of the zone of proximal development from a Vygotskian point of view. As students take on new learning and progress within the zone of proximal development, in other words, as they appropriate new learning and intersubjectivity between adult and child increases, asymmetry decreases (Edwards, D. & Mercer, N. 1987:158). Through this gradual and extensive process, a more equal sharing is possible. The end goal is for a move towards a new asymmetry, this time with the teacher relinquishing control as students become able to use and apply newly acquired cultural resources in new settings.

3.2.7 Systemic functional linguistic approaches

Recent linguistic approaches to classroom discourse analysis have built on the work of M.A.K. Halliday and systemic functional linguistics. Two studies have significance here: Gibbon's work brings together Vygotskian socio-historical theory and systemic functional linguistics (2003; 2002) and Frances Christie's work brings together the work of Halliday and Bernstein (2005a; 2002).

3.2.7.1 Gibbons: mediating language learning

Gibbons (2003; 2002) investigated the use of scaffolding as a pedagogic device in a series of science lessons with eight to nine-year-old learners of English. Employing an analysis of lessons across time, and investigating the role of teacher as language mediator, Gibbons was able to demonstrate how student language moved across the Register continuum from most spoken-like language to more academic and written-like language as the lessons progressed.

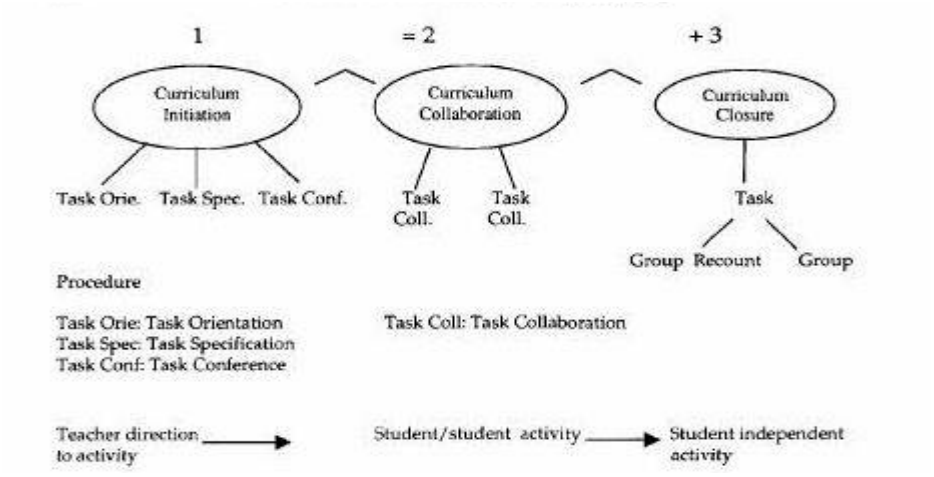
Gibbons identified several pedagogic 'scaffolds' used at different stages of the lesson sequence, explaining how teacher and student talk changed over time. Her study was socio-historical. That is, it followed one topic across a series of lessons. It provided systematic linguistic analysis, and, although not identified as such, paid attention to both the regulative and instructional registers. Her analysis supports the value of contingent scaffolding, of tracking of student content knowledge and language across time, and demonstrates how both the regulative and instructional registers change over time in a scaffolded pedagogy.

3.2.7.2 Christie: pedagogic registers

Christie's classroom discourse analysis drew on the field of systemic functional linguistics to offer an alternative analysis of lesson structures, replacing those of Sinclair and Wells. Rather than categorising parts of lessons according to form, Christie identified their function more broadly as it related to the unfolding of the topic.

In her study of three classrooms (2002; 1995; 1991b), Christie employed Martin's notion of macrogeneric structures (Martin J, R. 1995). Her study extended classroom discourse analysis beyond the single lesson to a sequence of lessons as she tracked the development of one topic, identified as a curriculum *macrogenre*:

Figure 7. Christie's macrogeneric structure (Christie, F. 2002:16)



In Christie's analysis, each macrogenre consists of a series of genres, often but not necessarily equivalent to a lesson. These genres, identified in Figure 7 above as Curriculum Initiation, Curriculum Collaboration and Curriculum Closure, are in turn comprised of a number of stages, identified above as Tasks. The broad categorisations of macrogenre, genre and stage provide a useful tri-level framework for investigating pedagogic purpose and describing pedagogic structure. Nevertheless, the stability of Christie's categorisations in all classroom contexts cannot be assumed. For example, Gray's analysis, following after Christie, proposed alternative pedagogic categories at the level of genre and stage which are explained below (Gray, B. 1998:134).

Following from her identification of the macrogeneric structure of a teaching topic, Christie argued for the importance of longitudinal study of classroom talk, so that the logogenesis, that is the unfolding and development of a coherent text within the class, displaying shared language and understandings about new learning, was observable across time:

> *(A complete text is) a complete unit of curriculum activity, which will typically extend over several lessons, sometimes lasting a week or a fortnight, and sometimes taking as long as a whole school term. Its presence in the discourse will be marked by some clearly initiating stage which signals the commencement of some new learning about a topic, and it will also be marked by a clearly defined closure, expressed for example, in completion of a piece of work which normally has significance as a tool for evaluation of the students' learning. Only when one has such a complete text for analytic purposes, I shall argue, can we make reasonable judgements about the meanings made in the overall teaching learning cycle and about the significance and placement of any language usages (Christie, F. 2002:23).*

Christie's second important contribution to classroom discourse analysis applied in this research is her refinement and application of Bernstein's notion of pedagogic discourse as pedagogic regulative and instructional registers. Because they were discussed at length in Chapter 2, the Registers will not be elaborated further (refer Section 2.4.2, p65). Christie used the registers as a tool to identify and analyse the impact of weakly framed and weakly classified teaching on low socio-economic students in an early years classroom.

The third contribution is Christie's use of the fine-grained description of language made available within systemic functional linguistics to understand what language is doing in the classroom. Christie draws on the three metafunctions of language first described by Halliday (1994): the ideational is concerned with how language represents the world; the interpersonal is concerned with how language represents relationships; and the textual is concerned with the organization of language as a message (Christie, F. 2005a:12). Closely observed through one or

more of these three metafunctional lenses, the purpose of particular language choices within a text can be quite specifically identified.

3.2.7.3 Analysis of scaffolding pedagogy: Gray

Concurrent with Christie, Brian Gray was researching the development of Concentrated Language Encounters in Alice Springs with fringe dwelling Indigenous students. Drawing on the work of Vygotsky, Bruner, Halliday and Bernstein, Gray developed a macrogeneric structure in the form of a principled teaching routine, as well as attending to the scaffolded teaching and learning negotiation that occurred within each stage of the routine. Chapter 2 outlined the Scaffolded Literacy program that resulted from this research (ref Section 2.5.3, p75ff).

Gray's pedagogic macrogenre consisted of two, rather than the three genres identified by Christie and shown in Figure 7 above. Each genre spanned several lessons. The first genre, the Macrogeneric Task Orientation, consisted of a number of orienting activities, or *orientation formats* (Gray, B. 1998:134). They consisted of oral discussions around a text or activity. The formats oriented students to the Field knowledge, with the teacher using consistent language to express that Field knowledge. Each iteration of an orientation format aimed to incrementally support handover of the new language to students. The second genre, the Macrogeneric Task, consisted of a joint construction of the written text across a series of lessons. The move from Orientation to Task was predicated on the teacher's judgment that the level of intersubjectivity was sufficient to proceed. Gray's macrogeneric structure of a science topic was represented in the following manner:

Table 9. Gray's macrogeneric lesson structure: Macrogeneric Task Orientation – Macrogeneric Task

Macrogeneric Task Orientation	→	Macrogeneric Task
TOa^TOb^TOc^TOd^TOe^…TOn	→	[TSa^Ta] ^… [TSb^Tb] ^…[TSn^Tn]

(TO=Task Orientation, TS=Task Specification, T=Task)

Like Christie, Gray used the distinction between the regulative and instructional registers and the fine-grained descriptions of language and grammar available in systemic functional linguistics to provide close and careful analysis of the function of teacher talk.

This study employs many of the analytic tools used by Christie and Gray: the multi-leveled, longitudinal analysis of lessons using the notion of the macrogenre, and the observation of language through three metafunctional lenses to identify the regulative and instructional registers and the function of language inside the registers.

3.2.8 Conclusions from this historic overview of classroom discourse analysis

Section 3.2 has outlined the development and contributions of classroom discourse analysis over the past few decades. It has outlined the contributions, but also some important limitations of early studies from a socio-historic point of view. Firstly, most early analyses did not clearly demonstrate the correlation between particular pedagogic choices and subsequent student outcomes. Secondly, early studies tended to attend to either systematic linguistic analysis or equity issues, but the complementary relationship between these paradigms was not yet apparent. Thirdly, many analyses were 'snapshots', consisting of analysis of a number of one-off lessons. Such methodology limits the ability of the analysis to evaluate the effect on student outcomes of teacher pedagogic choices over time.

Developments in classroom discourse analysis drawing on Halliday, Bernstein and Vygotsky have shown potential in ameliorating these issues. More recent studies in classroom discourse have shown ways of analysing the development of teaching and learning over time, examining the pedagogic processes involved with student appropriation of knowledge and language. Drawing on this previous research, two premises form the basis of this study.

The significance of socio-historical study

The approach taken to teaching and learning in this study is a Vygotskian socio-historical approach (Vygotsky, L.S. 1978, 1986; Wertsch, J.V. 1998, 1991), being both goal-oriented and longitudinal. A socio-historical analysis of classroom discourse has to take into account the intended learning goals, and includes an examination of how new learning is mediated by the teacher across time.

The benefits of multi-leveled linguistic analysis

A multi-leveled linguistic analysis using the tools provided by systemic functional linguistics allows for important insights into the changes in, and effect of the teacher's pedagogic choices at differing degrees of refinement, ranging from the broad macrogeneric structure of the topic, to the structure of the lesson, to the minute by minute language use by teacher and students within the lesson.

Analysis of the language performance of particular students before and after the teaching of the topic provides evidence of the degree to which they are appropriating new learning. Although use of new language forms does not demonstrate that meanings are fully established, it does mean that students can now employ these terms as a means for continuing dialogue and concept development and *are enabled to construe their own experience with reference to it* (Halliday,

M.A.K. & Matthiessen, C. 1999:614). Appropriation of new language is a sign that students are working in the ZPD, not that they have reached a new level of development.

These premises underpin the research design which follows, beginning with the broader research context.

3.3 The study context

3.3.1 Historical context

This study, *Scaffolding Science,* is the third iteration of an action research project into science pedagogy that began in 2008 with Dr John Walsh from the University of South Australia as lead researcher (Walsh, J. 2008). The project has focused on the use of scaffolding pedagogy in science education, with each iteration examining more closely the effect of language used in the scaffolding process in the classroom.

While *Scaffolding Science* focuses on classroom discourse analysis, it is embedded in this ongoing action research project. It is underpinned by many of the principles of action research as outlined in the literature: it is a product of a recursive process, it is self-reflexive, it aims to empower participants through collaboration and carries a commitment to bringing about social change through strategic selection of social practice susceptible to improvement (Avgitidou, S. 2009; Grundy, S. 1988; Kemmis, S. & McTaggart, R. 1988; Kemmis, S. & McTaggart, R. 2000; Masters, J. 1995).

3.3.2 The school context and rationale for selection of the site

The study took place in one Year 2/3 classroom in a mainstream, low socio-economic inner-suburban school in Adelaide, Cowandilla Primary School. At the time of the study, the school was highly multi-cultural, with a New Arrivals Program (NAP) for migrants and refugees. Many of these students remained in mainstream classes at the school once they had completed their time in the NAP. Approximately 15% of school enrolments were Indigenous students, which is comparatively high for the Adelaide metropolitan area. (89% of Indigenous learners are enrolled in low socio-economic status mainstream schools (DECS 2009e).) At that time, the school was rated Index of Educational Disadvantage 2, the second highest level of disadvantage within the South Australian Department of Education. (Ranking takes into account parental economic resources, parental education and occupation, Aboriginality and student mobility (DECS 2009a:14).)

The school had a number of additional attributes that contributed positively to the *Scaffolding science* research:

a. The school principal was committed to classroom research and recognised the potential contribution of this study to the school focus on literacy and science. She had herself been involved in action research projects previously with university colleagues through the Spencer Research Foundation, and has a background in systemic functional linguistics, and teaching English as a Second Language.

b. The study built on experience with Accelerated Literacy pedagogy. The school had used Accelerated Literacy pedagogy as a whole school strategy for several years. Five teachers have a Graduate Certificate in Accelerated Literacy and two have been involved in previous action research projects in scaffolding science. Consequently, ongoing involvement in this school built on previously established professional relationships.

c. The school has a strong commitment to science education, with Climate Change Focus School evident in large letters on the main building. The following explanation is found on the school website:

> *Climate Change is the phenomenon that drives our learning in science and Social Studies.*
>
> *As the children progress through the years they learn about our atmosphere, the greenhouse effect, how energy is generated, fossil fuels, greenhouse gases, weather, climate, the effects of global warming on the polar ice caps, acidification of the oceans, changes ocean currents, sea level rise, rainfall trends, biodiversity, melting of glaciers, agriculture and weather patterns.*
>
> *The school has made a commitment to reduce its ecological footprint and to lobby for investment in alternative energy before it's too late* (Cowandilla, P.S. 2009).

3.3.3 Rationale for the selection of the teacher

The classroom teacher had been involved in the previous two iterations of the *Scaffolding Science* project, and this long-term collaboration developed common understandings, as well as a high level of trust between teacher and researcher.

The teacher has been involved with Accelerated Literacy pedagogy for many years, both as classroom teacher and as a teacher consultant. She completed a Graduate Certificate in Accelerated Literacy with Dr Brian Gray at Charles Darwin University. Consequently, both researcher and teacher hold in common the theoretical underpinnings of the pedagogy, as well as a common language to describe pedagogic strategies informed by these theories. Her expertise as a high level classroom practitioner is held in high regard.

3.4.4 The students

The composite Year 2/3 classroom in the study is representative of the school population. Nineteen 7-8 year-old students were enrolled at the time of the study, comprising Indigenous, Torres Strait Islander, Sri Lankan, Iranian, Chinese, Italian, Greek and Caucasian. 42% of the class qualified for School Card, meaning that their caregivers earned a gross annual salary of less than $35000 (DECS 2009b:6).

3.4.4.1 Rationale for the case study students

From this group of students, a smaller number were selected as individual case study students, in order to analyse their language development across the span of the topic. The teacher selected seven students, representing a spread of characteristics pertaining to educational disadvantage. Six students meet at least one criterion identified by MCEETYA as having a correlation with educational disadvantage; Aboriginality, Language Background Other than English (LBOTE), and low socio-economic status (MCEETYA 2009). The seventh student, the daughter of a teacher, provided the opportunity to sample the effect of the pedagogy on an educationally advantaged student.

Caution must be taken, when identifying students according to these criteria, not to stereotype groups of disadvantage on the basis of the outcomes of one student. To partially ameliorate this problem, at least two students were chosen to represent each characteristic, with the class teacher using class assessments to select pairs of students; one who was performing at an average level or above in the class, and one who had more difficulties in learning.

LBOTE is a very broad term. The challenges facing refugee students are becoming increasingly apparent when compared with students whose parents are trained migrants or involved in tertiary study and who bring congruent cultural resources to school learning (Hamilton, R.J. & Moore, D. 2004; Miller, J. 2009; Miller, J., Mitchell, J. & Brown, J. 2005). For this reason, three LBOTE students were selected; two refugee students, and one whose parents had migrant, rather than refugee status.

Transience is another MCEETYA characteristic correlated with disadvantage. It was not relevant here as most students were regular attenders and had been enrolled at the school since their foundation year. Attendance was an issue for some however: of the three Indigenous students in the class, one was absent on average one day per week, and one attended regularly but often arrived late. The only regular Indigenous attender was excluded as a case study student because of severe learning disabilities. High rates of absenteeism compounded educational disadvantage for the two Indigenous students selected. The final selection of students and the criteria which they represent is as follows. (Real names have been replaced with pseudonyms):

Table 10. Characteristics of case study students using MCEETYA criteria of disadvantage

Student	*Socioeconomic status*	*LBOTE/ ESL*	*Indigenous*	*Gender*	*Learning difficulties*	*Attendance issues*
Amina	Low	Refugee	No	Girl	Yes	No
Nadif	Low	Refugee	No	Boy	Yes	No
Amanthi	Middle	Migrant	No	Girl	No	No
Alan	Low	No	No	Boy	Yes	No
Alex	Middle	No	No	Girl	No	No
Elijah	Low	No	Yes	Boy	No	Yes
Natalie	Low	No	Yes	Girl	Yes	Yes

The shaded cells indicate criteria correlated with disadvantage. With the exception of Alex, a girl with no learning or attendance issues, and who came from a middle class family, and Amanthi, with English as a Second Language but not a refugee, each of the students was representative of three or more factors influencing educational disadvantage. The study provides no basis on which to generalise about the educability of any student, or to make links between learning outcomes and any single factor of disadvantage. Chapter 4 analyses the language outcomes of each of these students.

3.4.5 Ethical safeguards

Agreeing to her teaching being the sole focus of a research project is a high-risk decision for a teacher, and the researcher has immense respect for this teacher's willingness to be involved. A formal agreement was signed by teacher and school principal before the project began. This agreement outlined exit strategies and an understanding that the teacher could veto use of any video footage (refer Appendix 2). Because this iteration of the project will lead to the production of a thesis, the rights to authorship belong to the researcher. However, the teacher has read and approved the parts of the thesis which refer to her and her teaching (specifically Chapter 4).

Permission was provided by all caregivers for their children to be part of this study, and to collect data in the form of videoed lessons and artefacts. Copies of the request and the permission form are found as Appendix 3.

3.5 The study design

The study spanned a series of seven science lessons on the topic of energy transformation across one term of a school year.

3.5.1 The topic

The topic of energy transformation followed from an introductory topic on energy the previous term, and was motivated by the school focus on Climate Change. The goal was for students to understand that what they ate for recess impacted on the production of greenhouse gases. To this end, the topic addressed how energy was transformed from potential to kinetic energy in the process of food production so that students could eventually compare the energy used in getting an apple from farm to table, with the energy expended to produce and deliver a packet of chips.

3.5.2 The seven lessons

A series of seven lessons was devised, taught in two sets. The first set, consisting of four lessons, consolidated student understanding about energy from lessons taught the previous term, and introduced the concepts of potential and kinetic energy, and energy transformation. The content would be demonstrated and explained through a number of simple demonstrations of energy transformation, using concrete materials.

Once a basic understanding of energy transformation was established, the second set of three lessons expanded on energy transformation, to observe and explain a number of energy transformations in a farm-to-table food chain. An outline of the content of the seven lessons follows as Table 11:

Table 11. Outline of the seven lessons comprising the study language sample

Set 1: Introduction to energy transformation	**Lesson 1** (77:30) Revision of understanding of energy. Introduction to potential and kinetic energy through four demonstrations showing different types of energy transformation (marble run, chicken wing, cotton-reel machine and battery-operated fan).
	Lesson 2 (75:00) Repeat energy transformation demonstrations with teacher in whole class, and in small groups with teacher.
	Lesson 3 (75:30) Revision of one of the four demonstrations, and joint construction of written explanation about energy transformation.
	Lesson 4 (70:30) Revision of another demonstration. Second joint construction of written explanation about energy transformation.
Energy transformation in a farm-to-	**Lesson 5** (96:00) Introduction to farm-to-table chain via video clips. Observe and describe the processes observed in that chain.

	Lesson 6 (78:30) Describe stages in the farm-to-table chain, explain how energy is being transformed at each stage of the sequence
	Lesson 7 (82:00) Talk through whole sequence, describing the process, and explaining the energy transformations taking place.

3.5.3 The development of a principled pedagogy

The study's challenge was to transform science lessons in this classroom from 'hands-on', progressivist discovery to a pedagogy that contingently scaffolded students, systematically building intersubjectivity between teacher, students and the activity system of science.

Influences on the pedagogic principles and strategies use in the study came from a number of sources: the broad theoretical base outlined in Chapter 2 of this thesis; the familiar pedagogic principles of Accelerated Literacy; and learning from the previous iterations of this research project. The principles developed for the study can be classified into those focused on building affective intersubjectivity i.e. maintaining positive student engagement, and those focused on building academic intersubjectivity, that is, bringing students into the discourse of science. The following list summarises these principles, developed over the period of the study:

Table 12. Scaffolding principles employed in this study

Principles aimed at supporting and maintaining positive affective engagement	**Principles aimed at supporting the shift to academic engagement**
Always begin the lesson by reviewing previous learning and stating lesson goal so that students know what this new learning builds on, and where it's going	
• Maintain a respectful invitation into the discourse in the following ways: o Limit time spent on behaviour management talk, and if you have to use it, keep it positive. o Find respectful ways, including less obtrusive non-verbal methods for gaining students' attention. o Address students using non-specific nominations when intersubjectivity is low, e.g. 'anyone' rather than student names. • Control modifications to I-R-E questioning: o Use preformulations preceding questions	• Mark the boundary of science as the 'un-commonsense' i.e. make it different from other subjects in the school day, and from the everyday. • Use the regulative register to orient students to the role of the scientist. • Frame the instructional register through creation of focus texts to guide scope and sequence of the topic and language of the topic. • Keep the boundary permeable through the use of 'bridging' talk: careful choice of teacher language is central to mediating the transition from

as required, cuing students in to what to attend to. o Look back – look forward: cuing statements to help students track where the discussion has been, and where it's going o Always respond positively to student answers (if you've scaffolded appropriately, the answer will be at least partially correct). o Use question openers such as 'Does anyone remember…' and 'Can anyone tell me…' to reduce risk for students by opening up question to all. o Use oral cloze, i.e. statement begun by teacher, then pause to allow for students to answer, with teacher completing the statement if no-one else can. o Use question tags after statements to signal common knowledge and identify students as authorities. • Use inclusive 'we' to signal learning as shared activity between all class members. • Acknowledge and build on student contributions to common knowledge.	horizontal into vertical discourse. • Consciously and systematically shift language along the Register continuum from situated language to decontextualised language, from personal instances to general and abstract phenomena. o Use the focus text to guide the shift to scientific language, especially through reconceptualisations of student answers. o Use 'bridging' talk i.e. commonsense phrases to support the technical, but gradually remove the commonsense when it is no longer needed. o Support decontextualisation of experience by changing scientific materials, shifting from real life to decontextualised representations (i.e. from hands-on to models, photos and videos). • The end goal is handover of new language, not just engagement and participation. • Make sure the instructional register focuses not just on process but principle (i.e. not just how but why).

The principles aimed at developing academic intersubjectivity caused particular challenges for the research team. There were few precedents to guide what this might look like. For example, if Bernstein says that marked boundaries are important for students crossing into the vertical discourse of science (2000:6), what can the teacher say and do to mark that boundary? Should we dress all students in lab coats? When Gray proposes that the regulative register should provide an affective orientation to the new discourse, beyond simply maintaining order in the classroom (1998:54), what words can the teacher use to convey that? Should the teacher make occasional orienting comments throughout the lesson, should it be evident in her responses to student answers, or something more formal and explicit? When Martin argues for the need to shift along the Register continuum towards the academic, decontextualised end (Martin, J.R. & Veel, R. 1998), how is that achieved? How much of a language shift is appropriate for seven- and eight-year olds? What language features should be taught?

The strategy employed to engage with many of these challenges was the development of a series of focus texts, a strategy used by Gray in his work at Traeger Park (Gray, B. & Cazden, C.B. 1992). The focus text provided guidance in how to express the instructional register, addressing many of the language challenges presented by a language-focused, scaffolded approach to teaching and learning. A brief description of the process of text development follows.

3.5.4 Development of focus texts

Chapter 2 discussed Gray's notion of establishing a focus text (Section 2.5.3, p77). A focus text, carefully constructed by the teacher, frames the instructional register. It helps the teacher to keep mindful not just of the scope of the content, but also of the language choices through which that content is to be expressed.

Focus texts were developed for the two sets of lessons. The first set of lessons required four sequential explanations, one for each demonstration, each structured in a grammatically similar way. Careful attention was paid to the level of technicality, the choice of words to bridge from the commonsense to the scientific, and to the level of grammatical complexity.

The development of the focus texts forced teacher and researcher to make considered decisions about language choices well before any teaching occurred. Decisions about how far to move along the Register continuum towards the formal, academic end were made in the planning, rather than 'on the run', and provided consistent guidance to the teacher on the language resources which would express new learning. For example, the use of passive voice was included in the texts, but technical nominalisations such as 'transformation' were avoided, based on Halliday's expectation that nominalisations should appear in the late years of primary school and would be a challenge for seven- and eight- year olds (Halliday, M.A.K. & Matthiessen, C. 1999).

In conjunction with these academic texts, consideration was given to the selection of 'bridging' language: commonsense language used to support the shift along the Register continuum from the everyday to the technical. The use of commonsense language was intended to maintain the permeability of the boundary and support the students in crossing from a horizontal to the vertical discourse. For example, the term 'potential energy' was accompanied by 'resting inside, waiting to be used'. Further support was provided through gesture, with the teacher extending a limp arm resting on her lap to show energy in waiting. The commonsense language and the mnemonic of the physical gesture were used as long as necessary to support meaning until students could use the new technical language on its own. Table 13 represents the texts developed for the first set of lessons:

Table 13. Focus texts from the first set of four lessons

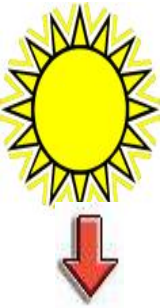
Demonstration	**Focus text**
Marble run	*The marble has height and weight. When it is at rest at the top of the marble run, it has potential gravitational energy waiting to be used. When it is given a little push, it runs down the marble run. Potential energy in the marble changes to kinetic motion energy to do the work of rolling.*
Chicken wing	*When the chicken wing is at rest, potential chemical energy in the muscles is waiting to be used. When the wing moves, the potential chemical energy in the muscle changes to kinetic motion energy to do the work of flying.*
Cotton-reel machine	*When the rubber band is wound up tight, it has potential mechanical energy. When you let go, the potential mechanical energy changes to kinetic motion energy to do the work of rolling.*
Battery and propeller	*When the wires aren't attached, the potential chemical energy is stored in the battery, waiting to be used. When the wires are attached to each end of the battery, the potential chemical energy in the battery changes to kinetic electrical energy to make the motor and the propeller move.*

Each of these texts demonstrates similar grammatical patterns. Each has two phases: the first phase describes energy in the object at rest; the second describes energy transformation when the object moves. Each text uses a 'when' (dependent) clause in Theme position to foreground the time element; passive voice; expanded noun groups; and in each text, the final sentence was expanded with a non-finite clause of purpose. A complete grammatical analysis of one of the focus texts is included later in this chapter when the analytic tools of functional grammar are outlined.

The focus text for the second set of lessons repeated and consolidated many of the language features of the texts used in the first set of lessons. It provided further challenge, not through more complex grammar, but by its length and the increased frequency of use of the new language resources. To support students in sequencing the chain of events, the text was multi-modal: some small images were added, each representing one step in the chain.

The focus text for the second set of lessons is produced in Figure 8 on the next page. A detailed analysis of this text is included as Appendix 4.

Figure 8. focus text for farm-to-table chain



Almost all the earth's energy comes from the sun. Kinetic energy, heat and light, is sent down to the earth in rays.

When the heat and light reach the apple tree, kinetic energy changes into potential chemical energy to make the trees and apples grow. Potential chemical energy is also stored in the

When the apples are ripe, the pickers pick the fruit and the tractor comes to take the bins to the farm shed. Potential chemical energy in the petrol tank of the tractor changes to kinetic movement energy to do the work of lifting and carrying the apples.

In the shed, first the apples are washed in big machines. Kinetic electrical energy changes to kinetic movement energy to do the work of washing and packing the apples.

Once the boxes of apples are packed, the semitrailer arrives to take the apples to the supermarket Potential chemical energy stored in the petrol tank changes to kinetic movement energy to do the work of carrying.

When the apples arrive at the supermarket, the customer comes to buy the apples and take them home. Potential energy in their muscles changes to kinetic energy to do lots of work: pushing the trolley, packing the apples, paying for them....

..and taking them home.

When the children are hungry, they do the work of eating the apple. Potential chemical energy in the apple changes to potential chemical energy in their muscles, stored ready to do work.

Finally the children go outside to play. Potential chemical energy in their muscles changes to kinetic movement energy to do the work of throwing, kicking, climbing, etc.

3.5.5 Data collection

The lessons were taught once a week, and lasted approximately 70 minutes. Each lesson was videoed, and the talk transcribed. Each week, the researcher and teacher met to review video footage, discuss issues and plan the following week's lesson.

Before the lessons began, individual case study students provided an independent *oral* sample of a scientific explanation on the topic of energy transformation. The same exercise was repeated after the topic was completed. Both pre- and post- oral explanations were transcribed for analysis.

Independent *writing* samples were also collected from the case-study students before and after the topic. However, the pre-topic written sample was an *information repor*t, in contrast to the post-topic written *explanation*. Because the language requirements of an information report differ from those needed for an explanation because of their differing purposes, it was subsequently decided that it was not possible to make a logical and supportable comparison between the pre- and post- written samples. The pre-topic writing samples were removed from the study corpus, and the post-topic written explanation was used to compare post-topic oral and written student performance.

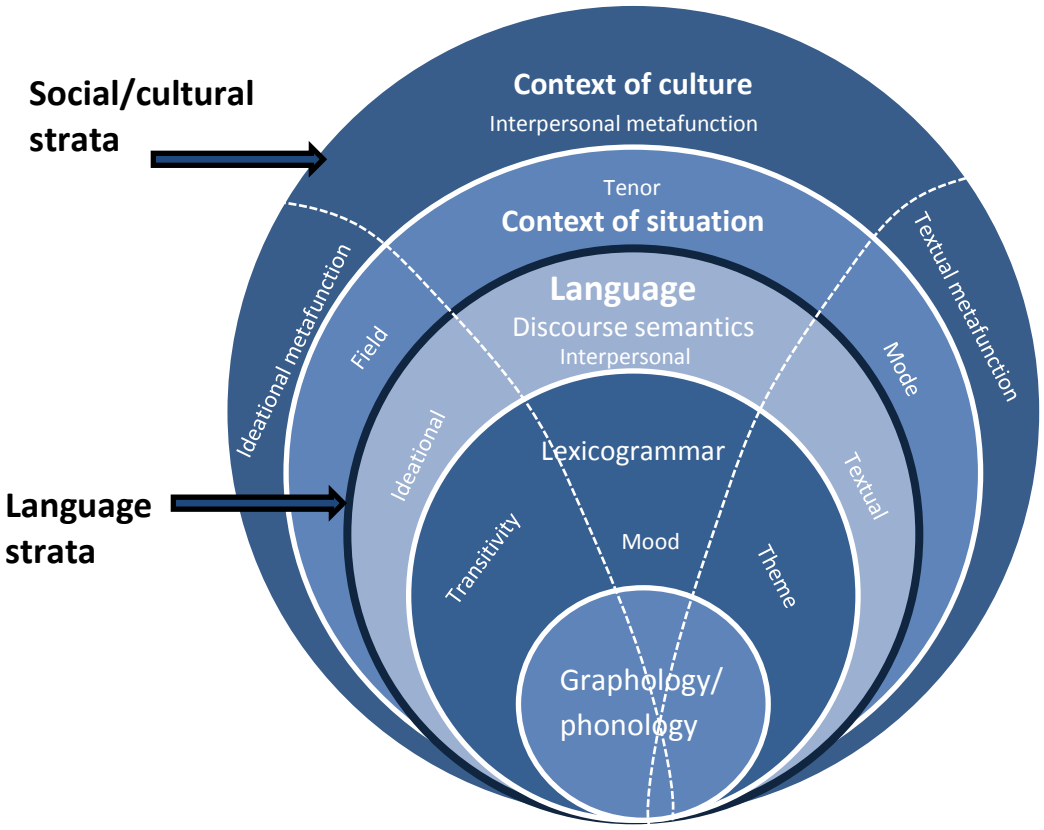
3.6 Data analysis

Chapter 2 introduced systemic functional linguistics, and explained how it provided detailed information on the language of science, its structures and features. Systemic functional linguistics enables refined and nuanced analysis of classroom discourse, providing a foundation for reflection on the effect of language choices in the classroom. Before explaining how systemics is employed as a tool in this study, the system of language proposed by Halliday is introduced in more detail.

3.6.1 Halliday's systemic functional linguistics as an analytic tool

According to Halliday, language in all human cultures has developed to serve three 'metafunctions' or broad social purposes: the ideational (culturally filtered representation of the world and experiences), the interpersonal (negotiating available roles and relationships); and the textual (how messages are conveyed so they are recognised and understood by other cultural members) (Halliday, M.A.K. & Matthiessen, C. 2004:Ch 1). As represented in the Figure 9 below, the three metafunctions create systems of meaning that extend coherently from broad cultural purposes to specific social situations, and from social situations down to the specifics of language which realise these broader social purposes (Eggins, S. 1994:Ch 1). The black border in the diagram marks the interface between context and language.

Figure 9. Stratification of meaning (adapted from Eggins, S. 1994:Ch 2-4)



The description to follow of these strata is derived from a number of sources (Christie, F. 2005a; Eggins, S. 1994; Halliday, M.A.K. & Matthiessen, C. 2004; Martin J, R., Matthiessen, C. & Painter, C. 2010; Unsworth, L. 1993).

At the broadest level of *context of culture*, language choices are influenced by the beliefs, values, motivations and purposes generated by different cultural groups. Activity theory would recognise this level as the level of activity system. These cultural motivations and purposes lead to the development of genres: text types habitually used to address specific cultural purposes.

At the next level or stratum is *context of situation*, the level of semantics. The meaning choices at this level are known collectively as Register. Register consists of three variables from which language users select to communicate with others: Field (what's happening), Tenor (interacting with others) and Mode (forming language into texts). This social level is the interface between the metafunctions in the context of culture above, and the first stratum of language below.

Discourse semantics is the level at which language begins to encode the meanings generated in the social context. This level describes how a text is constructed to constitute a discrete and cohesive unit of language. The ideational meaning system shifts to look at word strings (semantically related strings); the interpersonal system addresses appraisal (evaluative language) and conversational structures (negotiation); and the text system looks at reference and

conjunctions. These systems together enable an examination of text coherence (Eggins, S. 1994:112-13; Martin, J. R. & Rose, David 2007:Ch 1).

At the level of *lexicogrammar*, analysis focuses on clauses and clause complexes (sentences), groups of words inside the clause, words and morphemes. Inside the clause, Transitivity (realising Field meanings) analyses the parts of a sentence according to their function; Mood analyses how the relationship between the composer and the receiver of the language is evident within the text; and Theme explains mode, or which aspects of the message are foregrounded.

The final stratum is *graphology/phonology*; that is the sounds and letters used to encode the meanings established. This stratum consists of the script and sound systems developed by languages to finally encode meanings established in the previous strata.

This complex but systematic model of language provides a highly sophisticated system which enables very specific analyses. The following chart summarises the system of choices introduced in the model above, showing the potential for the examination of language in nuanced ways (summarised from Eggins, S. 1994; Martin, J. R. & Rose, David 2007):

Table 14. Detail of language choices demonstrating finely nuanced analytic potential

Social strata	**Context of culture (metafunctions/meaning systems)**		
	Ideational	**Interpersonal**	**Textual**
	Genres (single purpose texts) Macrogenres (multi-purpose texts) Schematic structure -constituency (stages, phases)		
	Context of situation (Register)		
	Field	**Tenor**	**Mode**
	Commonsense-technical Everyday - specialised	Power (equal to unequal) Contact (frequent to occasional) Affective involvement (high to low)	Spatial/interpersonal distance Experiential distance
Language strata	**Discourse semantics (text level: cohesion / coherence)**		
	Lexical relations: taxonomic: classification, meronymy composition: part/whole expectancy: noun-verb connection	Appraisal: attitude (affect, judgement, appreciation) amplification source Conversational structure speech function exchange structure	Coherence: situational, generic use of macro- and hyper Themes Reference: endophoric, andophoric, cataphoric, comparative Conjunction: elaboration, extension, enhancement

	Lexico-grammar (sentence, clause, group, word, morpheme)		
	Transitivity (processes, agency, circumstances) Participant roles: actor, senser, behaver, sayer, receiver, carrier, attribute, goal, range, recipient, phenomenon, token, value Process types: material, mental, verbal, relational, possessive, intensive Circumstances: extent, cause, location, matter, manner, role, accompaniment	Mood (roles and relationships) Interaction: giving and demanding of information and goods and services Modality: modulation, modalisation Tense Adjuncts: experiential, interpersonal, textual	Theme/Rheme (logical relations) Within clause Within clause complexes (sentence)

In summary, systemic functional linguistics shows how cultural meanings are realised from the genre down to the morpheme. In this study, an examination of word and grammar choice enables reflection on the meanings created through classroom talk, the possible reasons for those choices, and the effect of those choices both on the establishment of intersubjectivity within the class and on the achievement of the expressed learning goals.

3.6.2 Deployment of systemic functional linguistics analysis in this study

The central focus in the study is the analysis of classroom discourse across and within lessons; that is moving from topic and lesson structure, to classroom talk. The research questions with which the analysis engages are:

1. Student performance: what changes in student language use are evident from the beginning to the end of the study?
2. Enabling processes: which teaching processes enable the scaffolding of effective teaching and learning negotiation with marginalised learners within the subject of science?
3. Issues: what presumptions and issues underlying current teaching practice are confronted as the teacher incorporates scaffolding principles into her science education repertoire with marginalised learners?

Drawing on the theories introduced in Chapter 2, the following definition of *effective teaching and learning negotiation* in science education guides the analysis:

> *Effective teaching and learning negotiation in science education requires the teacher to provide contingent levels of scaffolding, attending to both the regulative and instructional pedagogic registers to develop and sustain affective and academic intersubjectivity with all members of the class and with the activity system of science. It is supported by logical structures (macroscaffolds) at the level of topic and lesson. The outcome of effective teaching and learning negotiation is successful student*

> *appropriation of knowledge, expressed significantly through language.*

The definition accounts for the scope of the analysis: firstly student appropriation of new scientific language; secondly the logical structuring of topic and lessons; and thirdly the moment-by-moment classroom negotiation, looking at the role of both pedagogic registers. The applications of systemic linguistic tools at each level are introduced in the next three sections. Section 3.6.2.1 explains the use of systemic linguistic tools to analyse student appropriation of new language. Section 3.6.2.2 shows the application of these tools in looking at the topic and lesson structure. Section 3.6.2.3 provides a rational for the corpus selection, and Section 3.6.2.4 explains the application of the systemic linguistic tools in looking at the moment-by-moment teaching and learning in the classroom.

3.6.2.1 Analysis of individual case study data

The study uses changes in student language performance to gauge the extent of their appropriation of language. The analysis text for both oral and written performance was the farm-to-table flow chart, a sequential explanation introduced earlier in this chapter (Figure 8, p108).

The pre- and post-study *oral* assessment required each of the seven case study students to provide a text sample consisting of a retell of the farm-to-table sequential explanation. Each student held in front of them a copy of the farm-to-table flow chart (images only, no text) as the researcher twice read her copy, which included the accompanying text, pointing to each stage on their chart as she went. The students then retold the explanation, using the flow chart as a prompt. Each sequence was videoed and transcribed. The samples were collected before the first lesson of the topic, and after the final lesson. The protocol followed to collect these samples is included as Appendix 5.

The *written* assessment was an explanation of the same farm-to-table sequence, independently produced by each student over a number of days. The booklet in which it was recorded included a prompt in the form of one image from the farm-to-table flow chart on each page.

The text samples, both the transcribed oral and written, were analysed for the presence and frequency of the specific language resources available in the focus text. While some of the language resources are evident at the level of grammar, and some at the level of discourse semantics, the criteria for analysis shown in Table 15 do not distinguish between the two levels:

Table 15. Language resources used as criteria for individual case study assessments

Meaning	Language resources
Language resources realising experiential meanings	-Use of technical terms (e.g. potential chemical energy) to move students towards the scientific and the authoritative. -Extension through circumstances of place and time, performing an experiential function (e.g. to the shed). -Extension through the addition of two clauses: one a clause of time, and the other a clause of purpose.
Language realising interpersonal meanings	-Use of the passive voice, performing an interpersonal function: by omitting the agent of the process removes irrelevant human agency, making the text less personal.
Language realising textual meanings	-Coherent staging of the text, with each stage including both process (i.e. observable activity) and scientific principle (i.e. explanation of energy change). -Clause complexes including two types of dependent clauses: a clause of time in Theme position (e.g. when the apples have been picked), performing a textual function of logical development of the text by maintaining the Theme/Rheme, new/given pattern. -Use of the passive voice, performing a textual function: passive voice enables the manipulation of the Theme of the clause and clause complex for text cohesion, and can also increase lexical density of a text by omitting the agent. -Increased lexical density through expanded technical noun groups, nominalisation and use of passive voice.

Using these criteria, comparisons were made between the students' pre- and post-study oral texts to look at changes in language use over time, and between their post-study oral and written texts, as the students moved from oral to written modes. The analysis of student language begins Chapter 4 of this study.

3.6.2.2 Analysis of topic and lesson structure

The next stage of analysis is the evaluation of the structure of the seven lessons. Christie and Martin describe the structure of a curriculum topic and the lessons within it as a macrogenre, further divided into genre and stage (Christie, F. 2005a; Martin J, R. 1995). A curriculum macrogenre is:

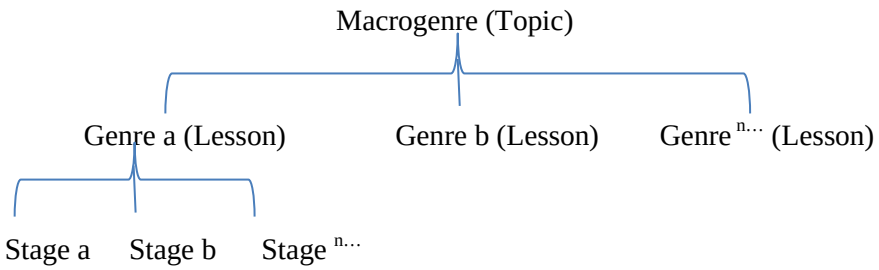
> *…a sequence of lessons or cycle of teaching-learning activity focused around a topic or content area, staged in a logical manner that builds development towards the attainment of specific learning goals as the culmination of an educational process which occurs over time (Christie, F. 1998a: 154).*

A curriculum macrogenre is comprised of lessons. As staged purposive activities, they can therefore be identified as genres in their own right (Christie, F. 2005: 136). Each lesson consists

of a number of stages. While Christie identified particular typical stages in the writing planning lessons she observed, she made no claim that these stages were characteristic of all possible writing planning lesson structures. Rather, the staging of a lesson is the result of the teacher's understanding and expectations of the teaching and learning context (Christie, F. 2005b). The staging of the lessons in the study reflects the principles of scaffolding outlined previously in the thesis.

The macrogeneric framework in the study is shown in Figure 10:

Figure 10. Analysis of macrogeneric structure



The macrogeneric structure is identified with the help of the ideational and textual metafunctions. The ideational tracks the gradual development of the topic and lessons by identifying the strings of information across lessons. The textual metafunction identifies the macro- and hyperthemes which identify the purpose and scope of each lesson.

Within the lesson, stages can be marked linguistically, as Christie and Gray observed, by changes in components of language register, Field, Tenor or Mode (Christie, F. 1991b; Gray, B. 1998). The lexical chains might be different, for example talk about potential energy might switch to talk about a battery and fan. Teacher dominated whole class discussion might switch to independent group work. A focus on talk might move to a focus on writing.

Theme is a particularly useful marker: often textual adjuncts such as 'Right', Okay', 'Okay then', 'Now…' mark a stage shift. Non-linguistic data provide supporting evidence. For example, a change in staging may include a change of physical setting (e.g. moving from or to the floor, outside, or at desks), and changes in artefact use (e.g. a shift from the interactive white board to a worksheet or concrete materials).

Once the macrogeneric structure has been described at the level of topic, lesson and lesson stage, its effect on developing affective and academic intersubjectivity will be evaluated. The evaluation completes the analysis of the macrogeneric structure.

The analysis then moves to a close analysis of the language involved in teaching and learning negotiation across a series of lessons. Section 3.6.2.3 explains the rationale for corpus selection for analysis. Section 3.6.2.4 explains the application of the three meaning systems of English to

the discourse analysis. It begins with the criteria used for distinguishing between the regulative and instructional pedagogic registers, and continues by explaining in turn how the three metafunctions; interpersonal, ideational and textual, are deployed for use in the analysis of classroom talk. Section 3.7 summarise the methods.

3.6.2.3 Rationale for selection of language corpus for analysis

The central focus in the study is how classroom negotiation of the topic led to the development of new student language. Ten extracts are provided to demonstrate a number of scaffolding strategies, their effects and any issues arising.

The analysis begins with a whole class activity, demonstrating how the teacher introduced the concept of potential energy to all. The teaching and learning negotiation between the teacher and a group of three boys is then followed across the lessons that constitute Set 1 *Introduction to Energy Transformation* (refer Table 11, p103). The language negotiation in Extracts 1-7 is concerned with two activities: either the battery-operated fan, or the marble run. Each activity served to demonstrate energy transformation in action. Following the interactions between the three boys across time has enabled a close study of their gradual appropriation of new language.

The final three extracts, Extracts 8-10, come from the lessons that constitute Set 2: *Energy in the Farm-to-Table chain*. They show how the teacher built on language resources established in the first set to scaffold students towards a more extended explanation. The extracts from Set 2 are all concerned with whole class activities. The extracts are summarised in Table 16:

Table 16. Summary of extracts for analysis, and their focus

Extract	Lesson	Focus
1	1	Introduction to potential and kinetic energy
2	1	Introduction to potential chemical energy in the battery
3	1	Small group battery-operated propeller activity
4	2	Review of potential and kinetic energy
5	2	Review of the battery-operated propeller
6	4	Three visiting scientists explain the marble run
7	4	Interrogation of the audience
8	5	Introducing passive voice in the farm-to-table chain
9	5	Introducing the dependent clause in Theme position
10	6	Putting it all together, one step at a time

Chapter 2 has explained the work of Bernstein, Christie and Gray in distinguishing between the function of two pedagogic Registers, the regulative and the instructional (Refer Section 2.4.2, p65ff). Christie proposes that the demarcation of these registers within sentences is possible by attending to the three grammatical meaning systems (Christie, F. 1995). A description of the analytic processes used in this study follows as Section 3.6.2.4.

3.6.2.4 Use of the three meaning systems to examine classroom discourse

Distinguishing between the regulative and instructional registers

The regulative and instructional registers perform important but distinct pedagogic functions. They are distinguished by examining register variants within language. In grammatical terms, the Ideational and Textual metafunctions become the important tools of analysis. An analysis of lexical strings and Transitivity will identify both the processes at the centre of the classroom activities and the participants engaging with the different types of processes. Together the processes and participants in a clause express the function of the activity, i.e. whether they relate to classroom arrangements as part of the regulative register; or the content knowledge as part of the instructional register. In expressing the Textual metafunction, Theme analysis will identify what is foregrounded in the sentence: the regulative or the instructional register (Christie, F. 1991b; Gray, B. 1998:153).

The regulative register manages the unfolding of the lesson and student behaviour, so it stands to reason that the participants expected in the regulative register will be to do with the immediate classroom context: references to the teacher, students, and classroom artefacts. The expected processes might be to do with action, thought or speaking by those participants.

However, as outlined in Chapter 2 (Section 2.4.2, p66), Gray proposed an extension of the role of the regulative register to that of providing an affective and mental orientation to the new learning, one that orients students to the target discourse. Chapter 2 interpreted this as meaning that the regulative register has the task of dual orientations: the first to the dispositions and roles of the classroom activity system, the second to the dispositions and roles of the activity system of science. This secondary role is by no means an essential requirement of the regulative register; for example it is not evident in Christie's data (1995) . If such a role *is* taken up by the regulative register, then additional science-specific participants, processes and circumstances might appear. For example, the register might include participants to do with the scientific world such as 'scientist', 'explanation', or 'taxonomy'; processes that can be identified with scientific activity, such as 'observe', 'hypothesise', 'disprove'; and circumstances that express how or why particular actions might be conducted to be aligned with the scientific world, such as 'like a scientist', or 'in science' or 'accurately'.

The instructional register is concerned with the content of the topic. In an utterance solely concerned with the instructional register, clause participants relate to the content of the lesson. They could be concrete, such as 'battery' or 'marble', or abstract, such as 'energy'. Processes and circumstances refer to the content of the lesson and may explain the processes or principles underpinning the activity.

There are times when the participants in the instructional register are more difficult to identify, particularly in hands-on activity. Because language in such activity is exophoric, that is referring outside the text to the activity surrounding it, participants may be simple reference items, such as 'it'. Nevertheless, such participants are still part of the instructional register. They still meet the criterion of referring to the content of the topic.

The regulative and the instructional registers often appear in the one sentence together. This is because, as Christie explained, when the regulative register projects the instructional register it is foregrounded in the sentence (Christie, F. 1991b). It organises how the class is going to interact with the content. This may include procedural arrangements, but also, as Gray argued, an affective orientation to the content (Gray, B. 1998).

Finally, both registers may be conflated in the one word or phrase, if such a word expresses content that also requires action by students in the class. This configuration will be explained soon.

In summary, register variations may include sentences that fully express the regulative register, sentences that fully express the instructional register, and sentences that include both. Examples of the range of register configurations are now provided. Examples 1 and 2 illustrate clauses wholly realising the regulative register. The first exemplifies the regulation of student classroom behaviour, the second exemplifies an orientation to the world of science. Example 3 describes a sentence belonging wholly in the instructional register. Examples 4 and 5 both exemplify conflation of the registers. Example 4 describes conflation in a clause while Example 5 describes the conflation within one word.

Throughout the analysis, the underlining laid out in Table 17 identifies the various registers:

Table 17. Underlining key for identification of regulative and instructional registers

Underlining	Pedagogic register
Single underline	Regulative register (coordinating classroom activity & student behaviour)
Double underline	Regulative register (orienting to activity system of science)
No Underline	Instructional register (no underlining)
Dotted underline	Convergence of regulative and instructional (e.g. 'wh-' words)

Example 1: clause wholly realising the regulative register (regulating student classroom behaviour)

	Now if	*you*	*'d just like to turn*	*your bodies*	*this way*	*for a moment…*
Discourse semantic level -Lexical strings		Student: 2nd person plural, indicates personal participant	Expected process in this context, referring to student action	Referring back to student (lexical string)	Use of reference item 'this' demonstrates situated talk, referencing outside text.	
Lexico-grammar-Transitivity		Participant Actor (concrete, human)	Processes: mental (like) and material (turn)	Participant Goal (concrete, human)	Circumstance of place	Circumstance of extent
Lexico-grammar -Theme	Dependent clause of condition in Theme position. Remainder of sentence ellipsed.					
	Textual adjunct marks next lesson stage, conjunctive adjunct is of condition, topical Theme 'you'.	Rheme				

This sentence exclusively realises the regulative register. The ideational analysis at discourse semantic level shows that the participants and the verb form a coherent lexical string, that is, a chain of related meaning: the participants are 'you', that is students, and 'your bodies', again referring to students. The verb 'turn' is a process which might be expected of students in this context. The reference item 'this' in 'this way' indicates that the reference is exophoric, that is referring outside the text to the physical context of the classroom. Transitivity analysis at the level of lexico-grammar identifies all participants as human and physically present.

Theme analysis identifies the marked textual Theme as 'Now'. Like other word choices in this category such as 'Right', and 'Okay', this textual Theme is a useful indicator of the regulative register. It is often used to mark a new stage in the lesson, as it does in this instance. The other important Theme in this sentence is the topical Theme, the subject of the sentence. Here the reference item 'you' is foregrounded, referring to students. The Rheme, or remainder of the sentence, continues with processes that regulate student behaviour.

Example 2: clause wholly realising the regulative register (orienting students to the activity system of science)

	So	*as a scientist*	*yes,*	*we*	*did have to observe*	*didn't we?*
Discourse semantics: -Field		Circumstance linked to world of science		1st person plural reference item: agency linked to world of science through circumstance and process	Process identified as being part of what scientists do	
Lexico-grammar: -Transitivity		Circumstance of manner		Behaver participant	Behavioural process	
Theme	Textual: conjunctive (so) continuity (yes) and topical: circumstance of manner (as a scientist)			Rheme		

Discourse semantic analysis here shows an interesting scientific lexical string of related meanings linking the circumstance of manner (as a scientist) with the process (observe). This chain is used by the teacher to make a link between the process undertaken by the students (have to observe) with the disposition of a scientist.

Transitivity analysis identifies the participant and process as belonging in the category of 'behaving'. The behaving process 'observe' is modified by the circumstance of manner. In other words, students are oriented to 'how' to observe with the phase 'like a scientist', linking student behaviour to the world of science.

An analysis of Theme puts the circumstance of manner, 'as a scientist' in Theme position, along with a 'yes', to render the circumstance more emphatic.

Together, the teacher choices attempt to make an association between their immediate classroom activity and the activity system of science.

Example 3: two clauses wholly realising the instructional register

	That	*'s*	*one kind of potential energy*	*and*	*it*	*'s all stored*	*inside*	*ready to be used.*
Discourse semantics-Ideational	Lexical string refers to energy: *one kind of potential energy – it – stored*							
Lexico-grammar - Transit-ivity	Token	rela-tional pro-cess	Value		Carr-ier	Relational process (attributive)	Attribute	Attribute
Theme	Topical Theme (subject)	Rheme		Conjuncti ve adjunct and topical Theme		Rheme		

The ideational analysis at discourse semantic level shows a coherent lexical string referring to energy. Transitivity analysis indicates two clauses with grammatical patterns typical of scientific talk. The Theme of both clauses is the subject, namely 'energy'. Both contain a relational process 'is'. The first clause consists of a relational process 'is' linking a token 'that' with its value 'one kind of potential energy'. This grammatical pattern is typical of scientific definitions. The second clause is not a definition, but identifies two attributes of energy 'inside and ready to be used', important to understanding potential energy.

The absence of lexical strings related to the classroom, the presence of scientific topic-relevant participants stands in contrast to Examples 1 and 2, and places this sentence fully in the instructional register.

Example 4: clause realising both regulative and instructional registers

	Who	*can remember*	*some of the things about energy [[we were talking about]]?*
Discourse semantics- Ideational	Two lexical chains: Who can remember – we were talking about (regulative) Who can remember - some of the things about energy (instructional)		
Lexico-grammar - Transitivity	Sensor	mental process	Phenomenon
Theme	Topical/inter-personal Theme	Rheme	
Mood	Mood (Wh/subject)	Finite	Residue (Complement)

In this example, one clause expresses both registers. The first part of the clause, 'who can remember', is asking for a response from students, that is regulating their behaviour, and is therefore in the regulative register. The complement of the clause, the noun group 'some of the things about energy…' refers to the topic of the lesson, belonging to the instructional register. However, that same noun group is extended with an embedded relative clause '(which) we were talking about'. Because that clause refers to previous student activity, it can be claimed simultaneously as part of the regulative register.

Example 5: clause where a word or phrase realises both regulative and instructional registers

	What	*happens to*	*the sun's rays,*	*Amanthi?*
Discourse semantics - Ideational	Two lexical strings: what – Amanthi (regulative), and what – sun's rays (instructional)			
Lexico-grammar- Transitivity	Effect	material process	Affected	
Theme	Topical/interpersonal Theme	Rheme		Vocative adjunct
Mood	Mood (Wh/subject)	Finite	Residue (Complement)	

When a teacher asks a question of students, the question may realise both the regulative and instructional registers through the use of the interrogative 'what'. To understand the role of 'what', the interpersonal meaning system (Mood) is called on in analysis. Mood identifies whether a clause is a statement or a type of question. In example 4 above, 'What' signals to students that a response is required, thereby placing it in the regulative register. At the same time, the expected answer is information about the sun's rays, part of the content, thereby showing that 'what' is simultaneously part of the instructional register.

It will be evident from the above examples that a systemic functional linguistic analysis allows for interpretation at many levels of meaning, with the initial task of separating the regulative from the instructional registers relying predominantly on Transitivity and Theme analysis, and Mood called on to identify 'wh-' questions. To expedite this finely grained analysis, the

following guidelines have been developed for the study to aid in the differentiation of the instructional and regulative registers:

Table 18. Guidelines for distinguishing between the regulative and instructional registers

Regulative register		
Classroom talk that orients students to the activity system of the classroom (underlined)		
Experiential meaning and transitivity	**Participants**	**Examples**
	Students and their body parts (human)	*eyes, bodies, people*
	Classroom artefacts (concrete or abstract)	*board, list, pencil, class rules, reminder*
	Reference items referring to the above including first person plural to refer to whole class	eyes *this* way, e*veryone* sitting up please, *we* know
	Abstract participants referring to learning without specific reference to topic	Remember *what we've been learning about,* Does anyone know *how we write that word?*
	Processes	**Examples**
	Material, mental and behavioural processes that refer to requirements and requests for student behaviour *not* closely identified with Nature of science and *not* accompanied by adverbials related to nature of science.	*tell, sit, have a little look, see, listen, watch, say, hand out, give*
	Mental, verbal, material and relational processes that orient students to generally to learning behaviours and cognition *not* related to nature of science	*have a think, wonder, suppose, write, read, spell, sound out,know, talk*
	Circumstances	**Examples**
	Any adverbials that refer to the above processes *not* related to nature of science	Keep your hands *to yourself,* look *this way, like a writer,* talk *a little bit more*
Theme	Theme position foregrounds in topical Theme vocative adjuncts, textual adjuncts (conjunctive), topical adjuncts to do with classroom or wh- words, modal adjuncts (polarity, comment).	*Elijah, Amina, children, everyone* *Now, so, right, okay* *You, we, this chart* *Yes, no, really*
Classroom talk that orients students to the activity system of science (double underlined)		
Experiential meaning and Transitivity	**Participants** that are closely identified with the Nature of science	**Examples**
	Any reference to scientists or the scientific community	*Scientists, our science visitors*
	Scientific processes in the form of nominalisations	*Look, experiment, demonstration, hypothesis, explanation, procedure*
	Science artefacts and related reference items not specifically referring to the target topic	*Gloves, toothpick, mat*
	Language used to negotiate the reading, talking and writing of specifically scientific texts	Headings, e.g. '*What we need', 'Discussion'*
	Processes (and adverbials) that are closely identified with the Nature of science	*hypothesise, inquire, have a close look, look closely, explain, describe, observe*
	Circumstances	**Examples**
	Circumstances of manner that relate student behaviour to the dispositions of scientists	*like a scientist, as scientists, scientifically*
Theme	Circumstances of manner related to science are foregrounded in Theme position in clause	*As scientists,* we have to observe very carefully

Instructional register		
Classroom talk referring to the scientific learning content (no underline)		
Experient-ial meaning and Transitivity	**Participants** Nouns related to the Field knowledge of the topic, guided by, but not limited to the words from the focus text. May be technical or commonsense terms used by the teacher as bridging terms, and commonsense words used by students from their lexis. May be abstractions, nominalisations, or concrete terms referring to scientific artefacts. Mostly non-human participants	**Examples** *Potential chemical energy, the things that use energy* *Chicken wing, battery, wire, marble, power* *Thingummy, spinny thing* *It, that*
	Processes Technical material processes related to the non-human participants Commonsense nonspecific material processes referring to scientific processes	**Examples** Attach, roll, expand, contract Go on, happen, do
	Circumstances Any adverbials that refer to the above processes	**Examples** *…at the top of the marble run*
Theme	Clauses which wholly realise the instructional register have Field vocabulary as topical Theme. When the regulative projects the instructional register, instructional register is in Rheme.	*Most of the world's energy comes to the earth by rays.* And Elijah has told us *that most of the world's energy comes to the earth by rays.*
Words realising both the regulative and instructional registers		
Words and phrases shared by two registers (underlined with dotted line)		
Mood	**Wh- words** Wh- words in Theme position signal both regulative register (asking for response from students) and instructional register (response required is in instructional register)	**Examples** *What* happened to the battery
Experient-ial meaning and Transitivity	**Participants** Noun groups referring to scientific processes that consist of, or are qualified by clauses including students as participants	**Examples** *What we did* *The type of energy we're talking about*
	Processes Processes are identified as belonging in both registers if the participant is a human actor in a scientific procedure and the participant range or goal is in the instructional register.	**Examples** …when we *attached* the wires? We*'re going to make* the marble *roll*

Once the first step of distinguishing between the pedagogic registers is complete, the next step is to interrogate the data to determine the effect of those particular pedagogic choices at that point in time in building intersubjectivity to achieve the learning goals. This second step requires a more refined look at the language choices within each pedagogic register, and at the way in which the registers work together to build intersubjectivity.

Application of the interpersonal metafunction in analysis

The interpersonal metafunction has only been mentioned in passing to this point as, with the exception of Mood to determine the register of 'wh-' questions, it is not generally required for distinguishing between the pedagogic registers. Within the pedagogic registers however, an interpersonal analysis plays an important role.

Firstly, within the regulative register, the interpersonal metafunction becomes an important lens through which to evaluate the development of, and possibly issues with affective intersubjectivity. At discourse semantic level, interpersonal analysis attends to the exchange structures of the conversation, and provides information on how roles are established and maintained and the attitudes of participants towards the interaction (Eggins, S. 1994:111). It also addresses the system of appraisal, or evaluative language. Within the lexico-grammar, questions of interaction types become relevant: whether the clauses are questions, statements or commands, and whether they concern the transaction of goods and services or information. Such analysis becomes crucial in determining the contingency of teacher talk in the regulative register: whether the teacher asks open-ended questions or simply tells, and the effect of those choices at that point in time.

Secondly, within the instructional register, use of the interpersonal lens tracks the take-up by students of particular scientific interpersonal meanings embedded in the focus text. In this context, the important focus is the reduction of interpersonal resources achieved through the use of passive voice, and non-human participants. Using the interpersonal lens will assist in tracking the development of academic intersubjectivity.

Three examples of analysis follow, using the interpersonal metafunction. The first demonstrates the application of the interpersonal metafunction in the regulative register and the information it provides on affective intersubjectivity in the classroom. The second example is part of the instructional register: it is an interpersonal analysis of the focus text developed around the marble run activity and identifies the interpersonal resources of that focus text available for student appropriation. Finally, to demonstrate the value of the interpersonal analysis in classroom discussion, an example is provided of the use of discourse semantic level analysis in understanding the effect of exchange structures in the classroom.

First, here is example 1 again, a clause already identified above as wholly realising the regulative register. To look at the effect of language choices within the regulative register, the sentence is now analysed through the lens of the interpersonal metafunction.

Example 1: Interpersonal analysis of one instance of the regulative register

		Now if	*you*	*'d just like to turn*	*your bodies*	*this way*	*for a moment…*
Discourse semantics	**Negotiation-Exchange structure**	Monologic: teacher initiated. Teacher has the floor. Not verbal response but action required.					
	Appraisal - Affect	Clause of condition (if) implies that students have a choice. 'Like to turn' also implies choice: turn only if you want to					
	Appraisal - Amplification	Use of 'just' suggests that this is not an onerous request. 'For a moment' also sends the message that this is not too much to ask, it won't be for long.					
	Appraisal - Judgment	This is a dependent clause in a clause complex. The independent clause to which it should be attached is ellipsed. The implication is that the teacher and students are so aligned in this aspect of the regulative register that the teacher doesn't need to tell students what follows. They already know.					
Lexico-grammar	**Interaction**	Request for service: actually command masked as request (incongruent)					
	Modality (modulation)		'would just like to turn': expanded verb group signals that action is conditional on liking				

Even though anyone who has participated in schooling recognises this as a hidden command, the teacher couched it as a request. A more grammatically congruent and less modulated command would have been 'Right everyone, eyes this way.' The interpersonal effect of this teacher's incongruent language choices is of respect; of implying that the students have freedom of choice, and that she has reduced the onerousness of the task because it's only for a short time. The outcome of these language choices is the maintenance of affective intersubjectivity. The request takes for granted the students' role as co-operating participants in this class.

Example 2: Interpersonal analysis of a focus text

In the instructional register, an interpersonal analysis demonstrates the necessary absence of interpersonal resources available in scientific texts. Here is the marble run focus text, followed by an interpersonal analysis of that text:

> *The marble has height and weight. When it is at rest at the top of the marble run, it has potential gravitational energy waiting to be used. When it is given a little push, it runs down the marble run. Potential energy in the marble changes to kinetic motion energy to do the work of rolling.*

Dis-course semantics	**Negotiation-Exchange structure**	Not able to be analysed as is: stand-alone text intended for incorporation by teacher and students in many instances in teaching and learning negotiation.
	Appraisal – Affect, appreciation	No personal emotions expressed. No valuing of participants or processes expressed.
	Appraisal - Amplification	A *little* push*:* everyday adjective to describe the amount of effort needed.
	Appraisal - Judgment	No judgment of any attribute expressed: it is not better or worse for the marble to be at the top or on the move.
Lexico-gram-ar	**Mood**	All statements provide information. No questions.

What stands out in this analysis is the dearth of interpersonal resources expressed in the text. Indeed, that is one of the important text qualities for students to appropriate. One of the ways that scientific texts claim their authority is in the absence of subjective engagement with the reader. For students whose everyday discourse is concerned with the negotiation of social relationships and exchange of goods and services, a text concerned with the exchange of information and intentionally devoid of interpersonal meanings is likely to be unfamiliar. When looking for student appropriation of new learning, the absence of interpersonal meaning is one attribute of their language for which the analysis will be searching.

The final example of the use of interpersonal analysis is part of a classroom exchange in the teaching and learning negotiation. The next sentence was previously included as Example 3, the two clauses fully realising the instructional register. It is the teacher's response to a student answer, 'chemical energy' and demonstrates the importance of analysing texts at multiple levels to fully understand what is happening:

Example 3: Interpersonal analysis of one instance of the instructional register

		That	*'s*	*one kind of potential energy*	*and*	*it*	*'s all stored*	*inside*	*ready to be used.*
Discourse semantics	**Negotiation-Exchange structure**	Positive acknowledgement by the teacher of student response, and extension of response (and it's all stored…)							
	Appraisal - Affect	Affirms student answer by recognising its place in energy taxonomy.							
	Appraisal - Amplification	Non-amplified.							
	Appraisal - Judgement	Validates student response as 'scientific' by being able to add to it.							
	Interaction	Statement							
Lexic-gram m-ar	**Modality (modulation)**	Mood adjunct 'all'. High degree of certainty.							

The analyses of Example 3 at the level of the lexicogrammar and discourse semantics show interesting and contrasting perspectives in interpersonal meanings. The changes support the effort of analysis at both levels. The lexico-grammatical analysis (sentence level) shows this is a simple two-clause statement. It carries a high degree of certainty: in both clauses energy simply 'is', rather than 'has the potential to be' or 'I think it might be…'. The interpersonal meanings are conspicuous because of their neutrality. As explained above, this is an important feature of scientific texts, where modality is used as required to make statements about the world true, but not to engage the reader's emotions.

However, the analysis also demonstrates the importance of looking beyond the clause to determine meaning construction within an exchange. The discourse semantic level of analysis shows how this sentence, as part of a classroom exchange, has the potential to influence affective intersubjectivity. The fact that the teacher has been able to respond in the affirmative and extend the student's response with more information in a seemingly natural manner, validates this student's contribution to scientific discourse. The teacher didn't amplify any aspect with evaluative comments; she just continued the conversation as a co-participant within scientific discourse.

In this case, the fact that the student had successfully answered the question was not chance but evidence of the success of the teacher's use of the regulative register. The analysis in chapter 4 will demonstrate how the teacher carefully prepared students for her questions to increase the likelihood that all students could participate successfully in the learning discussion.

More needs to be said about exchange functions and structures because they do not always run smoothly, even with the best of teacher intentions. Smoothly flowing interactions depend on intersubjectivity between participants, on shared understandings about the range of possible 'next turns', about what responses might be 'sensible'. A breakdown in adjacent conversational pairs in classroom negotiation initiated by the teacher is signaled to the teacher by an unanticipated student response, one judged to be incongruent, an interaction that has failed to accomplish 'conversational coherence'(Schiffrin, D. 1985:640) .

The communication breakdowns mark a lack of shared understanding by teacher and student which needs to be repaired if the learning is to continue. How can these breakdowns be identified? The mapping by Eggins and Slade of responses in casual conversation identifies a range of 'confronting' responses: participants may choose to *decline, non-comply, disagree, withhold, disavow* or *contradict.* (Eggins, S. & Slade, D. 1997:202). However, the student responses which signal communication breakdowns in the classroom are not intentionally confronting. These students are trying to be compliant and congruent, and their failure to be coherent marks the lack of intersubjectivity between teacher and student. None of the categories

provided for casual conversation aptly describes these incongruent responses by a student in classroom teaching and learning negotiation. Instead, the label of 'interactive trouble' provided by Freebody et al (p 199) will be used to mark these uncomfortable classroom conversational turns.

An example of interactive trouble follows. In this activity the class was reviewing the types of energy displayed on a taxonomic diagram on the interactive white board. At this point, the teacher was talking about the potential energy represented by an image:

53	Teacher	Ah, ready to do some work, isn't it? So yes, we know that energy has something to do with power to do work, and so this kind of energy is just stored ready to do that work.
54		Alright, does anyone want to say something else about this one (the image)? Amina? (Teacher attends to another student before seeking Amina's answer.)
61	Amina	Energy comes from the sun because by rayses to the earth?
62	Teacher	Yes, and now we're talking about the different, Amina, we're talking about the different kinds of energy and how we can put them into two groups.

In line 53, the teacher extended the response of a student by adding further information about power and work, including the use of bridging words 'stored ready to do that work'. This utterance established the topic for the following question. In line 54, she then asked for further information about the same image. Amina, one of the study's refugee case study students, responded with an incongruent answer. It was broadly about energy, but referred to information that the class had learned the previous term rather than staying with the topic of *potential* energy. The question/answer sequence in turns 53, 54 and 61 above is an instance of interactive trouble. The teacher's attempted repair in line 62 showed that she too recognised Amina's answer as an incongruent response, and that Amina needed to have her attention redirected.

Instances of interactive trouble appearing in the study corpus are evidence of reduced intersubjectivity. Initial identification of interactive trouble is made possible through the use of the interpersonal metafunction at discourse semantic level and may be at first intuitive on the part of the analyst. The identification then calls for further analysis to determine whether this is an issue in the regulative or instructional registers, and furthermore, whether this is a breakdown in experiential, interpersonal or textual meanings.

Application of the ideational metafunction in analysis

The ideational metafunction attends to how experience and logic are represented in language. At the discourse semantic level, attention is drawn to lexical strings, and to the level of technicality of word choice. At lexico-grammatical level, attention is drawn to verb choice, such as whether the processes involved are material, mental, verbal or behavioural, amongst others, and who or what gets to participate: abstract or concrete, human or non-human. The circumstances surrounding activity are also a focus: what guidance or information is provided on how activity should be enacted?

Within the regulative register, ideational analysis provides information on the way particular word choices orient student behaviour to activity. The behaviour may be oriented to classroom mores, or the scientific community or both. Within the instructional register, ideational analysis indicates the content of the learning and the level of technicality expected from the language.

Two examples of transitivity analysis are provided. Example 1 demonstrates how students were oriented by the teacher to the task using the regulative register. Example 2 is an analysis of the marble run focus text. It highlights the ideational resources in the text that the teacher wants students to appropriate.

First, here is a new example of four clauses of teacher talk from Lesson 2. It is in the opening stage of the lesson.

Example 1: transitivity analysis of teacher talk

		Last week	*you*	*revised*	*what we had learned last term.*	*And*	*it*	*was*	*amaz-ing*	*how much we could tell each other.*
Dis-course semantics	**Lexical strings**	'You' – 'revised' – 'we' – 'learned' – 'we' – 'could tell' – 'each other'. Apart from first 'you', consistent use of 'we' connected to learning behaviours.								
Lexico-grammar	**Refer-ence**	'You' as first reference, but after that 'we'. 'Each other' reflexive to show mutuality.								
	Verb choice	'Revised' mental verb reminds students that this is not new, that they know this. 'Had learned' in past perfect: task completed. 'Could tell': emphasises student ability.								
	Circ-umstan ces	'Last week': recent event but in the past.								
	Noun groups	'You': focus on students, not teacher. 'We": focus on joint construction of knowledge. 'What we had learned last term': non-specific noun group: assumes that students remember the content and it doesn't need to be said again. 'How much we could tell each other [about what we had learned last term]': implies extent and mutuality of sharing, still not specific. 'Amazing': quality of what we could tell.								

		[We did] lots of explaining about what was going on.	*And [we did lots of] using scientific words as well.*
Dis-course semantics	**Lexical strings**	'Explaining' – 'using scientific words': provides some sort of scientific orientation.	
Lexico-grammar	**Referen ce**	'What was going on': refers to 'what we had learned last term'. Both abstract generalisations.	
	Verb choice	Verbs are ellipsed: consists of two participants, 'lots of explaining…' and '[lots of] using scientific words' which are expansions of 'how much we could tell each other'.	
	Particip ants - Noun groups	Abstract: 'Lots of explaining about…': noun 'explaining' relates to scientific processes, 'what was going on' is very general material verb choice: doesn't remind students of specific past action. '[Lots of] using scientific words': also relates to scientific processes.	

The example above is typical of the opening stage of the teacher's lessons, in that it begins by revisiting prior learning. At discourse semantic level, the lexical strings in the first two

sentences reinforce the joint construction of learning in this classroom: the predominance of the first person plural 'we', the verb choices of 'revised' and 'tell each other' all contribute to the message of mutual responsibility for success in learning. The lexical strings in the second two sentences extend that message to further specify what was amazing: the fact that students explained, and their use of scientific words. These two expansions reinforce the link between student learning and scientific activity.

At lexico-grammatical level, the verbs referring to students are mental or verbal: 'revised', 'learned' and 'tell'. Along with participant first person plural (we), these verbs reinforce the focus on jointly constructed learning in this class. The effect of these choices supports affective intersubjectivity: the students are affirmed for their contribution to the class construction of knowledge.

However, some curious features appear in the noun groups, particularly where clauses act as participants; for example 'how much we had learned last term' and 'explaining about what was going on'. While these noun groups marginally contribute to academic intersubjectivity in that they make the link to prior learning in the most general way, they are non-specific and do not include any language from the instructional register. The first describes the quantity of learning, but not the content of the learning. The second describes the content including a very general non-specific verb, '*was going on*'. Neither of these noun groups remind students with specific information about the topic of previous learning that they are about to build on. Alternative choices might have expanded the noun groups to something like 'how much we learned last term *about the earth's energy and where it comes from*' and 'explaining *about what happened to the sun's energy when it reached the earth*'. The teacher's choices assume a high level of intersubjectivity in the class around previous learning such that they no longer need reminding. The transitivity analysis provokes speculation about the extent to which opportunities to develop academic intersubjectivity at this point in the lesson might have been more effectively exploited.

Example 2: transitivity analysis of a focus text

Within the instructional register, the salient ideational resources expressed in the marble run explanation are as follows. Rather than lay out each clause, each aspect of analysis is summarised in the table below:

> *The marble has height and weight. When it is at rest at the top of the marble run, it has potential gravitational energy waiting to be used. When it is given a little push, it runs down the marble run. Potential energy in the marble changes to kinetic motion energy to do the work of rolling.*

The salient features from the ideational metafunction are as follows:

Dis-course semantics	**Lexical relations**	'Marble – 'height' – 'weight' – 'at rest' – 'top of the marble run' – 'potential gravitational energy' 'waiting' – 'used' – 'push' - 'changes' 'kinetic motion energy' 'work of rolling'. Lexical string consistent with marble run activity: mixture of technical vocabulary and abstractions 'height, weight, energy' and every day vocabulary and concrete materials 'marble', 'marble run'. No human participants. Includes words to describe process (what the marble did) and words to explain principle (explanation of energy transformation).
Lexico-grammar	**Verb choice**	Use of 'has' and 'is' to express attributes of the marble. Two verbs in passive voice: 'waiting to be used', 'is given' mask the agency of the action because it is does not need to be foregrounded. Material process 'changes' selected rather than 'is transformed': latter deemed too complicated for this age group.
	Circumstances	Expansions through circumstances: 'at rest' and 'at top of the marble run', 'down', 'in the marble'. Expressed in sequence, these circumstances track the positions and attributes of the marble from beginning to end of explanation.
	Participants - Noun groups	(See lexical strings above.) Two nominalisations: 'height' and 'weight'. Abstract terms: 'potential gravitational energy' and 'kinetic motion energy'. Commonsense term re-used as technical: 'the work of rolling'. One commonsense noun group: 'a little push'.

There are no human participants in the text, just technical concrete and abstract participants. Agency is not attributed to any person. As with the interpersonal metafunctional analysis, this difference in orientation from the personal to the technical is likely to require a change in orientation for students used to operating predominantly in everyday discourse.

Application of the textual metafunction in analysis

The textual metafunction attends to the placing of language on a continuum from language in action (situated) to language as reflection (decontextualised) (Martin, J. R. & Rose, David 2007:Ch 5). At discourse semantic level, the focus is on reference, that is whether meaning is contained within the text or points to meanings outside the text; and on conjunction; that is the logical relations that hold the text together. At the level of lexico-grammar, the textual metafunction is concerned with Theme; that is what is foregrounded within the clause or clause complex.

Within the regulative register, the choice of topical Theme is relevant for identifying how learning is constructed as individual or joint activity. Also relevant is the teacher's choice of adjuncts as marked Theme: whether she calls on individual students, whether her requests are open to all students, and whether this changes over time. Within the instructional register, the study uses analysis at the level of discourse semantics to look at the issues to do with reference in developing language competence in students.

Two examples are provided here. The first demonstrates the use of textual analysis in evaluating the development of intersubjectivity. The second example is the marble-run text. Careful construction of Theme is very important in scientific explanations in developing the logic of the text, and the thematic structure of the text is outlined.

Example 3 includes both the regulative and instructional registers. It is from lesson 2, early in the topic: a check for handover from students of their understanding of a taxonomic chart on the interactive white board showing types of potential and kinetic energy.

Example 3: textual analysis of teacher request

<table>
<tr><td></td><td colspan="3">Alright, does anyone</td><td>want to say something else about this one?</td></tr>
<tr><td>Discourse semantics-reference</td><td colspan="3">‘Anyone’: general reference to whole class</td><td>‘something else’: non-specific; ‘this one’: non-specific, exophoric reference indicates that this is situated text</td></tr>
<tr><td rowspan="2">Lexico-grammar-Theme</td><td colspan="3">Theme</td><td rowspan="2">Rheme</td></tr>
<tr><td>Alright: Textual adjunct marks next step in lesson</td><td>Does: Interpersonal Theme requiring yes/no response from students</td><td>Topical Theme: non-specific, open to all</td></tr>
</table>

In the regulative register, the teacher opened up the question to ‘anyone’. It invited responses from all. At the beginning of a topic, when intersubjectivity was low, this choice meant that the spotlight was not focused on any one child and children could volunteer to answer if they were willing. The choice of ‘something else’ carries the same intention: it suggests that anything they have to offer would be welcome. In the instructional register, ‘this one’ indicates that the reference is exophoric. The teacher was pointing to a particular part of the diagram on the white board where the information about potential and kinetic energy was laid out.

Theme analysis shows that the request began with a textual adjunct ‘alright’. Such adjuncts are typical of teacher talk when moving activity to the next step. Although such an adjunct is a marked Theme, its use here is not remarkable. The use of ‘anyone’ rather than a specific student’s name is of interest however.

The choice of the non-specific ‘anyone’ was frequent in the early stages of the topic, or whenever the teacher judged that students would be unsure of the answer, that is, when intersubjectivity was low. This conscious choice opened up the floor to anyone who was ready to provide an answer. It was a strategy consciously promoted by Gray to encourage participation so that children *were not placed in a position that highlighted their ‘failure to know’* (1998:180). However, this choice was neutralised by the use of the non-specific ‘this one’ in the instructional register. This reference told students where to look, but gave them no clues about what sort of answer was required by the teacher. Following the example above, four students responded before a student came up with the correct answer, indicating that the students were struggling with this level of support. This example shows that contingency is a requirement in both pedagogic registers for effective teaching to take place.

In the instructional register, thematic analysis identifies the textual resources found in the marble-run focus text, language resources which were part of the topic learning goals. The following textual features were identified as the focus resources:

Example 4: textual analysis of a focus text

	When it is at rest at the top of the marble run,	*it has potential gravitational energy waiting to be used.*
	When it is given a little push,	*it runs down the marble run.*
Discourse semantics-conjunction	Use of conjunction 'when' to stage the explanation in time.	
Lexico-grammar-Theme	Marked Theme: hypertactic clause (dependent clause of time) in Theme position foregrounds the circumstance in which the energy form is present.	Rheme

	Potential energy in the marble changes to kinetic motion energy	*to do the work of rolling.*
Discourse semantics-conjunction	First clause is expanded with non-finite hypertactic clause (dependent clause of purpose beginning with 'to'). Enhances the message of the sentence to explain the outcome of the change.	

In particular, the analysis indicates three important textual features of this text that the teacher wanted the students to learn. First, the use of dependent clauses as marked Theme, to stage the events in the explanation; second, the use of the non-finite clause beginning with 'to' that expands the sentence to show the goal of each stage in the marble run sequence; and third, the thematising of the marble made possible through the use of passive voice.

3.7 Summary

Systemic functional linguistics provides a multi-leveled tool for analysing classroom talk. It isolates aspects of language for further investigation and enables systematical reflection on language choices. The tools will be applied to analyse the interpersonal, textual and ideational meanings realised in classroom conversations, identifying how the teacher's and students' language choices change, and how they affect the development of affective and academic intersubjectivity across the topic.

The analysis exemplars provided to this point demonstrate the detail available in a systemic functional linguistic analysis. The capacity for such detail sometimes makes it difficult to identify the salient features relevant to the research question. The analyses provided in Chapter 4 are the products of a thorough linguistic analysis using all three lenses; the ideational, interpersonal and textual. However, only those aspects of the analysis pertinent for the research questions will be included in the extracts.

The study investigates one teacher's enactment of three principles developed from the literature: firstly the importance of development and maintenance of affective intersubjectivity in the classroom; secondly the need to shift from affective to academic intersubjectivity so that student engagement is focused on goal-oriented activity, not merely on entertaining tasks; and finally, the understanding that appropriation of scientific language is central to learning science, not merely adjunctive. The principles are realised through teacher efforts to contingently scaffold, attending to both the regulative and instructional pedagogic registers.

Chapter 3 has outlined the contributions and issues rising from previous iterations of classroom discourse analysis. The chapter argued that this study required analytic tools with the following qualities: firstly a longitudinal, goal-oriented perspective; secondly the capacity to analyse student pre- and post-lexico-grammatical analyses as evidence of student learning; thirdly, a systematic multi-leveled and fine-grained linguistic analysis which can move from the macro to the micro, from topic to learning conversations and includes the ability to distinguish between the regulative and instructional pedagogic registers; and finally a mechanism for identifying breakdown in teaching and learning negotiation,.

Analytic tools to meet these strenuous requirements were selected from previous analyses of classroom discourse by Martin, Christie, Gray, Freebody and Halliday.

The analysis to follow is laid out in the following way: Chapter 4 begins with a summary of student pre- and post-explanations, oral and written, to identify changes and development in student use of language over the course of the topic and between modes. Space does not allow for a detailed analysis of individual student take up of each language feature.

The chapter continues by providing a macro- and micro-analysis of the topic. The macro-analysis describes the topic scope and sequence, the lessons and the stages within lessons. The remainder of the chapter focuses on the teaching and learning negotiation across the topic, describing the pedagogic strategies used to build and sustain affective engagement, and the work undertaken to shift students into the use of abstract scientific language as the topic progressed.

CHAPTER 4

Developing intersubjectivity through language

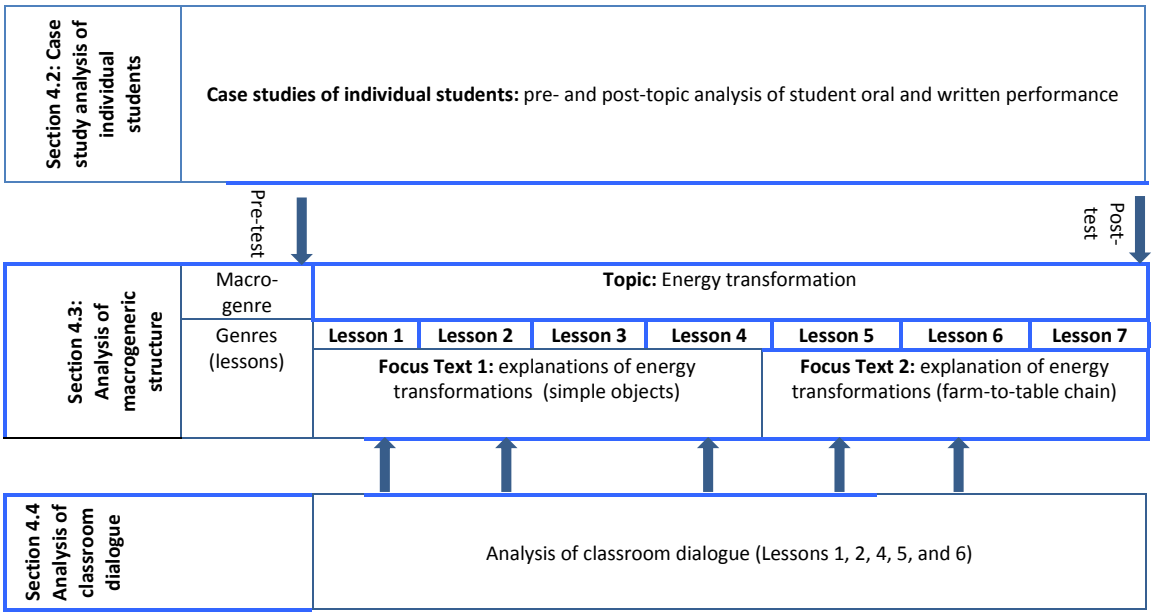
4.1 Introduction

Scaffolding science began with the motivation of investigating an effective pedagogy for marginalised students in scientific literacy. It drew on the synergistic theories of Vygotsky, Halliday and Bernstein and subsequent developments to argue for a sociocultural, language-centred approach to teaching and learning, developing a number of scaffolding principles from the literature to underpin teacher practice. The study has argued that language development is central to the development of scientific knowledge, providing essential resources for ongoing negotiation of learning. To this end, the scaffolding principles were put into action in the classroom to support the process of appropriation by students of new scientific language.

Chapter 4 looks closely at student language within the classroom around the topic of energy transformation, and at the macro- and micro-scaffolding processes used by the teacher. The analysis is comprised of three parts: firstly the individual language performance outcomes of the case study students; secondly the macrogeneric topic and lesson structure, and thirdly the classroom negotiation of teaching and learning that led to the student outcomes evident from the case study analysis.

Figure 11on the following page shows the levels of analysis, from case studies, to the macrogeneric topic structure and finally to the micro-level of classroom dialogue.

Figure 11. Outline of the three levels of classroom discourse analysis in the study



The diagram shows that the analysis covers a sequence of seven lessons programmed around the topic of energy transformation. The sequence was designed to build the children's concepts progressively over time. Three levels of analysis were carried out in this study, and each level is represented by a layer in the diagram. The two arrows linking the top and middle layers indicate that the individual case studies were sampled at the beginning and end of the lesson sequence. The results of these analyses will be discussed in Section 4.2 below. The middle layer identifies the macrogeneric structure of the lesson sequence and the focus topic of energy transformation. The macrogeneric structure of the lesson sequence will be analysed in Section 4.3 of this chapter. The bottom layer represents the analysis of classroom dialogue that was sampled from various lessons in the macrogeneric structure. The arrows point to the lessons from which the samples were taken. The results of these analyses are discussed in Section 4.4.

Section 4.2 provides a performance summary of the case study students, analysing the changes in control of the target language resources of Focus Text 2 (the farm-to-table chain) evident in their pre- and post-tests. It makes two sets of comparisons. Firstly it compares student *oral* performance at the beginning and at the end of the study, and secondly compares post-study *oral* with post-study *written* explanations to describe and account for changes when the mode shifts from speaking to writing. (Pre-study *written* samples constituting an information report were collected, but could not be used because the language resources from such a text were not comparable with the post-test explanation.)

Section 4.3 discusses the classroom program through which the topic unfolded. A structural analysis of the macrogeneric topic and lesson stages (Section 4.3) demonstrates how the teacher carefully planned the use of the two focus texts to provide both a logical unfolding of the topic and at the same time a systematic approach to scaffolding student language.

The structural analysis plots the staging of the lessons across the topic; that is how the teacher planned each part or stage of the lesson to support the topic. The analysis demonstrates how Pearson's model of the 'Gradual release of responsibility' (1983:337) introduced in Chapter 2 (Section 2.4.1.1, p52) was observed in the unfolding of the topic by identifying changes in the classroom dialogue within and across lessons.

Section 4.4 provides an analysis of the selected classroom dialogue extracts. The rationale for extract selection was explained in Chapter 3 (Section 3.6.2.3, p116). The analysis maps the interactions between teacher and students as students gradually appropriated the academic language needed for the explanation of energy transformation. The analysis shows the teacher's pedagogic strategies used to enact the scaffolding principles established in Chapter 3 (Section 3.5.3, p104ff). These principles have been demonstrated in the literature to support alignment towards high levels of intersubjectivity between discourse participants. It shows how teacher language choices in both the regulative and instructional registers worked to build intersubjectivity within the class around science, and how her language changed as intersubjectivity grew.

The teaching and learning negotiation did not always run smoothly. There were many inefficiencies and confusion evident in introducing and handing over new language and scientific understandings, with trouble particularly around the abstract notion of energy. The shift from a progressivist pedagogy highly valuing of 'hands-on' activity to a pedagogy that is conscious of and highly valuing of language development and contingent scaffolding was neither straightforward nor simple. The analysis identifies instances of interactive trouble that serve to highlight the value of using a planned focus text to guide language negotiation.

To begin, the take-up by case-study students of the scientific language offered through the farm-to-table focus text is outlined.

4.2 Students appropriating scientific language

4.2.1 Introduction to the case study analysis

Chapter 3 proposed that because of the centrality of language, student control over new learning could be gauged by monitoring their appropriation of targeted language resources, specifically the lexical and grammatical resources made available through the teaching around the focus texts. If students were exposed to, and asked to replicate a scientific explanation around the topic before and after the topic had been taught, it would be possible to quantify and compare their use of particular language resources. The students' use of language resources was compared orally before and after the topic had been taught. A post-topic comparison was also made to assess differences between their post-test oral and written performances.

A number of case study students were selected, with each representing at least one of the criteria for educational disadvantage developed by the Commonwealth Government (MCEETYA 2009). A middle class student was also selected for comparison. As a reminder, Table 12 from Chapter 3 is reproduced below as Table 19. Pseudonyms are used for all students.

Table 19. Characteristics of case study students using MCEETYA criteria of disadvantage

Student	*Socioeconomic status*	*LBOTE/ ESL*	*Indigenous*	*Gender*	*Learning difficulties*	*Attendance issues*
Amina	Low	Refugee	No	Girl	Yes	No
Nadif	Low	Refugee	No	Boy	Yes	No
Amanthi	Middle	Migrant	No	Girl	No	No
Alan	Low	No	No	Boy	Yes	No
Alex	Middle	No	No	Girl	No	No
Elijah	Low	No	Yes	Boy	No	Yes
Natalie	Low	No	Yes	Girl	Yes	Yes

Chapter 3 explained that the focus texts in the topic were intended to move students along the Register continuum from more spoken to more written-like language (Section 3.5.4, p106ff). The specific language features which were the goal of student language appropriation are as follows:

At the discourse semantic level:

1. Coherent staging of the text, with each stage including both process (i.e. observable activity) and scientific principle (i.e. explanation of energy change)
2. Clause complexes including two types of dependent clauses: a clause with a temporal conjunction ‘when’ to indicate the temporal relationships necessary within the explanation (e.g. when the apples have been picked); and a non-finite clause of purpose to extend Field knowledge (e.g. to do the work of…). This goal included the positioning of the dependent clause of time as the marked Theme of the clause complex (e.g. when the apples have been picked, they are taken to the shed…), performing a textual function of appropriate information flow within the text by maintaining the Theme-Rheme pattern.

Within the clause:

1. Use of technical lexis within noun groups (e.g. potential chemical energy) to move students towards the authoritative end of the Register continuum

2. Use of circumstances of place and time, performing an experiential function of more contextual detail (e.g. to the shed)
3. Use of the passive voice, performing a textual and interpersonal function: passive voice enables the manipulation of the Theme of the clause and clause complex for text cohesion, and can also increase lexical density of a text by omitting the agent of the process when it is not relevant
4. Increased lexical density through expanded technical noun groups, nominalisation and use of the deleted agent.

The analyses will show that, under test conditions, all students displayed the use of language resources at the end of the topic that were not evident in the pre-test, and that some clear patterns emerged in student appropriation of these resources. The analyses also show marked differences between some students in the shift from an oral to a written performance of the same text.

4.2.1 Pre- and post-test comparison of student *oral* use of language resources

The model farm-to-table explanation focus text was twice read out aloud to the each student individually and separately. Each could see the flow diagram but not the text (Ref. Chapter 3, Section 3.6.2.1, p113). Each student was then asked to retell the explanation, using the flow diagram as a reminder. The pre- and post- oral texts were transcribed and analysed for evidence of the language resources listed above. A count was made of each occurrence of each language resource. The number of instances for each student was then compared with the number of instances appearing in the model text.

The following provides a summary of the most salient features in student oral performance, pre- and post-topic. It demonstrates an increase in frequency of most target language resources for most students. Some of the most 'written-like' resources such as the passive voice proved to be difficult for the most marginalised students.

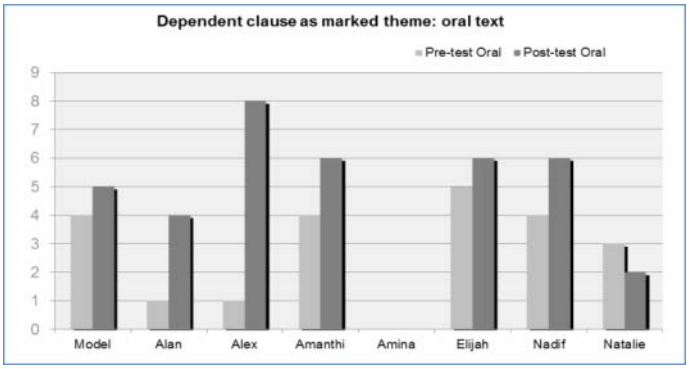
Coherent staging of an explanation genre

All students accurately provided a logically staged explanation genre which covered each of the seven steps of the farm-to-table process in some detail. This was as true for the pre-test as the post-test and is not surprising since the structure was provided through the flow diagram which the students were describing. The flow diagram provided a framework for student talk. Hence it would have been a concern if the students had *not* been able to structure their talk through the staging.

Each stage in the text consisted of two phases: firstly a description of the process and secondly an explanation of the energy change that occurred during that process. At the phase level, and under test conditions, many of the students omitted the energy phase in the oral explanation until prompted, but when prompted with *and tell me about the energy*, they added this phase to their explanation.

Dependent clause as marked Theme

Figure 12. Dependent clause as marked Theme in the clause complex: pre- cf post- oral test



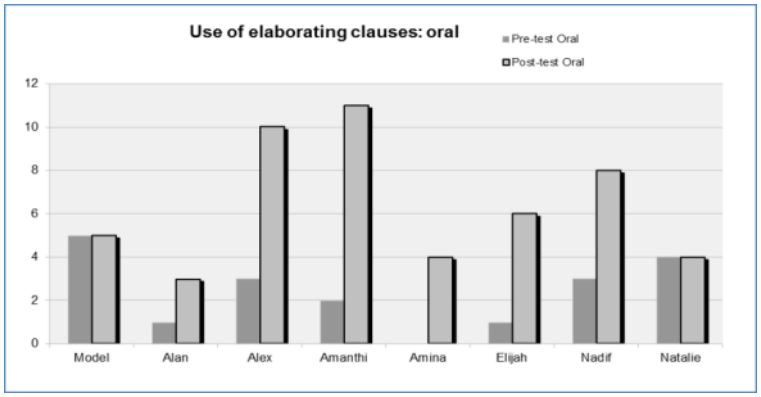
Placing the dependent clause in Theme position in the explanation provides a logical flow to the sequencing of the text. Most students used at least one instance of a dependent clause as marked Theme in the pre-test performance, so for most it was not a new grammatical structure. Five of seven used the resource more frequently in the post-test. Four of the seven students used more marked Themes than the model text in their post-test. This 'over-use' can be explained by the unedited nature of oral performance: it included repetitions of some clauses as students worked to 'get it right', self-correcting or beginning again. Alex increased from one clause as marked Theme in the pre-test to eight in the post-test.

Natalie, the Aboriginal girl, used three time clauses in her pre-test, but decreased to two in her post-test. Amina, the refugee girl, did not use a dependent clause as marked Theme in either pre- or post-oral test. However, she produced an unprompted time clause and a clause of condition in a retell of the same process as part of Lesson 7, when not under test conditions:

> *…and when they go to the shed they get cleaned and see if they have like any black stuff on them and then if they're alright they get on a truck…*

Extending non-finite clause

Figure 13. Extending non-finite clause: pre- cf post- oral test (to do the work of…)

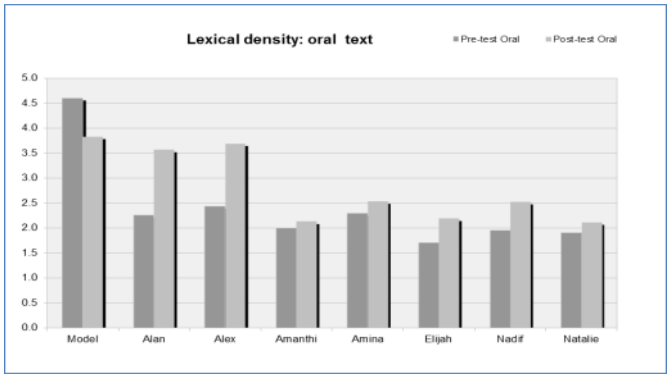


The model text employed non-finite clauses to provide additional scientific information within the explanation phase. It explained the purpose of the energy change in each stage. This involved various versions of *to do the work of* … Instances of these clauses were accepted from students whether prompted or unprompted, as long as they were not the result of a prompt which included the word *work*.

The use of this grammatical resource in student pre-tests suggested that this grammatical resource was to some extent familiar to six of the seven students. With the exception of Natalie, all students at least doubled their use of extending non-finite clauses in the *oral* post-test. Natalie used these extending clauses four times in both the pre- and the post-test. Amina was the only student without this type of clause in her oral pre-test. Her use increased from zero in the pre-test to four instances in the post-.

Lexical density

Figure 14. Lexical density: pre- cf post- oral test (content words per clause)

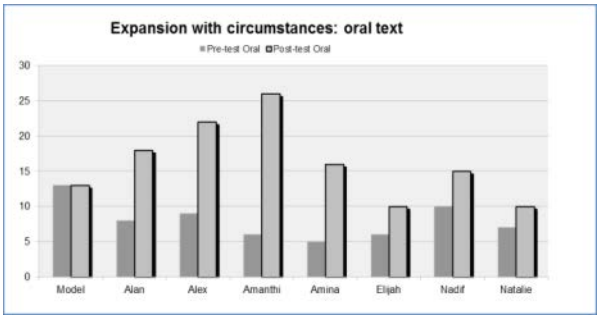


Lexical density is an indicator of the content within a text. It is determined by *dividing the number of lexical items in a text by the number of ranking clauses* (Korner, H. *et al* 2007:143).

Generally, as text moves along the Mode continuum from the oral towards the more written, the lexical density increases. The lexical density of student texts in the *oral* post-test was higher for all students, although none was as high as the model text. The texts of Alan and Alex showed the greatest increase, and were very close to the lexical density of the model text.

Expansions through circumstances of time, place and manner

Figure 15. Expansion through circumstances of time, place and manner: pre- cf post- oral test

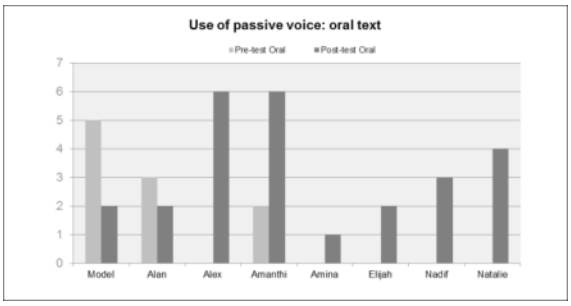


Expansions through the use of circumstances provide important additional information. In the model text, circumstances provided information in each process phase about where and when the processes occurred. In the energy phase, circumstances of place identified where potential energy was stored before it was used.

All students used more circumstances in the *oral* post-test when compared with the pre-test. These were mostly circumstances of location (to the supermarket, in the muscles) but also included a circumstance of cause (from his storing kinetic energy) and manner (by rays). In fact, five students used more circumstances than the model text. The over-abundant use of these circumstances can be accounted for because of the mode of delivery. Amanthi, for example, was determined to get the text correct, and her performance included many false starts and repetitions. Amina, a refugee student, increased her frequency of use from five circumstances in the pre-test to 16 in the post-test.

Use of the passive voice

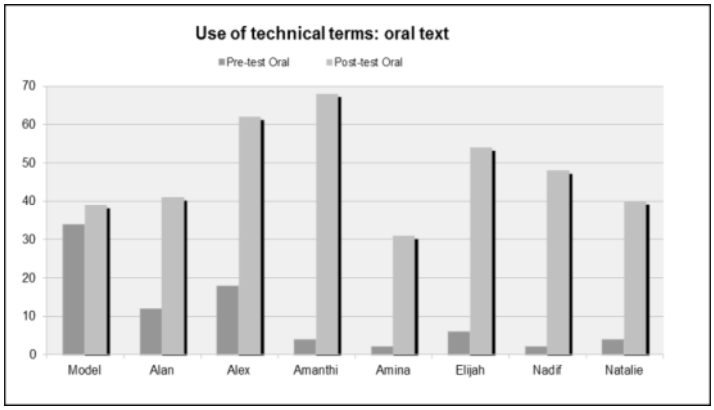
Figure 16. Use of passive voice: pre- cf post- oral test



Passive voice supports the Theme-Rheme, or given-new pattern within clauses, thereby supporting the cohesion of the text. It is a complex grammatical construct. For the purposes of the analysis, the more colloquial form of 'get…' was accepted as an example of passive voice. Only two of the seven students; Alan and Amanthi, used the passive voice in their *oral* pre-test. This was not a common grammatical resource for the students in this group. However, six of the seven students provided at least as many instances of the passive voice as the model text in their post-test, with Alex and Amanthi providing more instances than the model text, due to false starts and self-correcting. The exception was Amina, a refugee student, who produced one example of passive voice in the post-test: *They get washed and packed.*….

Indicators at word level: technical and scientific terms

Figure 17. Technical and scientific terms: pre- cf post- oral test



According to Halliday, technical terms have been developed for two purposes: one textual, to manage the flow of the discourse, and one ideational, to create *ordered taxonomies of abstract technical constructs* (Halliday, M.A.K. 1994:655) Within the focus text, a number of technical terms appear for the latter purpose, to describe technical constructs, terms which are not typical of student commonsense talk. These included

- a nominalisation of an adjective, for example *heat* from *hot*
- a nominalisation of a process: *light* used as a noun rather than a process, *the work of…*from the process *work*
- the employment of *the earth* to represent *the material world* in contrast to other planets
- *potential chemical energy* and *kinetic motion energy;* a noun group which includes classifiers of Latin and Greek origins, marking the text as belonging within scientific discourse. The employment of such terms renders the concepts more *exotic and highly valued* (Halliday, M.A.K. 1998:221).

When identifying the use of technical terms in the text, all terms were counted as they appeared, including repeated terms, as long as they were appropriately used in the context, and had not been suggested by the researcher in a prompt.

The use of technical terms showed the most dramatic increase of all language resources from the pre- to the post-test. For all students, the increase was ten-fold. For example, Nadif increased frequency from two to 48 technical terms, Natalie from two to 40 and Amina from two to 31 instances. With the exception of Amina, the students used more technical terms than the model text. This can be accounted for in part by the number of repetitions within the retell as students managed the demands of the task by reiterating parts of the sequence as they talked it through. Nevertheless, this phenomenon stands in stark contrast to the sparse use of technical terms in the students' oral pre-test.

In summary, most students showed an increase in all the targeted language resources from pre- to post-test. The language resources least evident in students' pre-tests were the passive voice and the use of technical terms. Both of these resources appeared in students' post-tests, with technical terms showing the most significant increase. This is understandable, requiring only renaming of things. The ability to put these new names into coherent explanations was more demanding.

The language development was not the same for all students. Amina and Natalie showed less development in many instances when compared with the other students. Natalie's use of circumstance and marked Theme, while present, was not as substantial as other students. Both girls showed significant increases in technical terms and both used passive voice for the first time in their post-test. Amina used elaborating clauses for the first time in her post-test.

Despite the fact that her performance was not as robust as other students, the development in Amina's language is clearly observable. Here is Amina's oral pre-test:

> *So the sun has like all the energy and it points down to the tree. And the tree when it's ready some person comes and collects it and then he takes it over here and then they come fresh and nice to eat and then they, when they ready a big truck comes and takes all the apples and all the fruit and he takes it all to the supermarket and then people buy it from the supermarket and then their kids start eating it and the kids get like energy and then they can go outside and play.*

Here is part of Amina's oral post-test:

> *When the… light and heat from the sun comes to the earth by rays to make the apples grow and the apple trees and then farmers come and put them in a big bin and then the farmers drive them to the shed and then they get washed, cleaned and packed in the shed and drive to the supermarket by a truck and then people come and buy it from the supermarket and then take it home and then kids eat the apples and it goes down into they muscles so they can ride their bike, jump around, swing and do all sorts of stuff.*

One obvious issue in Amina's oral pre-test was her use of exophoric, inconsistent and unattached reference items, which make her explanation hard to follow. For example, 'he takes *it* over here and then *they* come fresh and nice to eat', with both reference items inconsistently referring to apples, and leading away from the text to the illustrations. The second issue was her very 'oral' manner of cohesion; 'and then…and then' as well as colloquial continuatives such as 'like'. In her post-test, the unattached reference items had to a large extent disappeared, replaced by specific nouns.

These data provide evidence of the development of student oral language between the start and end of the topic on energy transformation in which the teacher had paid conscious and consistent attention to the language choices which she made and which she wanted the students to appropriate. The frequency of the target language resources in students' oral post-tests had increased, sometimes remarkably. Some language features such as circumstances of place, were already familiar to students, but increased in their use. Others, such as technical terms, were not evident in the students' pre-tests, but appeared in abundance in their post-tests. Most remarkable was the use of the passive voice, barely evident in the pre-tests, but used by six of the seven students in the post test.

The charts demonstrate how language resources were differentially appropriated. Interestingly, it was the resources that operated within the clause that became the most abundant in the post-test: the technical terms and the circumstances. Students seemed to take on these resources most easily. The resources which impacted on text cohesion, such as dependent clauses as marked Theme, and passive voice, were less frequent in the pre-tests, and were not the most strongly appropriated resources in the post-test. Two students, Amina, the refugee girl, and Natalie, the Aboriginal girl, particularly struggled with these more complex resources.

At the same time, student take-up of the new language shows what is possible when a teacher intentionally and consistently scaffolds specific language features selected, in this case, because they are typically found in sequential explanations. The student use of new language features appeared at the end of seven lessons of consistent work by the teacher in introducing and consolidating new language, scaffolding students through careful negotiation towards control.

4.2.2 Comparison of student post-test *oral* and *written* use of language resources

Oral and written performance each brought different challenges. On the one hand, oral performance allowed for immediate self-correction depending on feedback from the listener, and the task demands were less complex because there was no need to engage with the cipher system of the English language. On the other hand, the writing activity was staged over a number of days, allowing time for students to re-read and edit their work. At the same time, the

writing task required competence with encoding the English language, thereby increasing the cognitive load.

Differences between oral and written performance were evident. All students wrote more succinctly, without the superfluity of the oral performance. Some students showed evidence of editing their work. Some students who had performed well orally appeared to struggle with the increasing demands of writing. For some students, new resources observed in their oral performance disappeared when the same text was written.

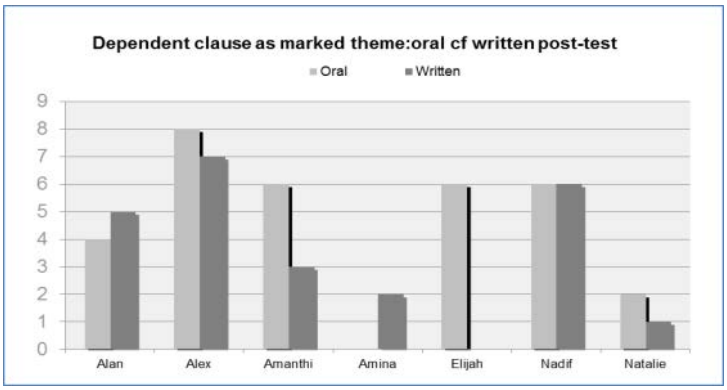
Coherent staging: oral versus written

Student post-topic written texts were unprompted. They were structurally organised with the aid of the images from the farm-to-table flow diagram, but not necessarily complete. They ranged from Nadif's seven staged explanation to Elijah's one stage. All but Natalie included at least one explanation phase in their written texts. Amina's text included one energy phase, despite her struggle with spelling:

> *…potential energy in the moare chea to kinic energy. to do the work of mareing* (Potential energy in the machine changed to kinetic energy to do the work of (?)).

Dependent clause as marked Theme

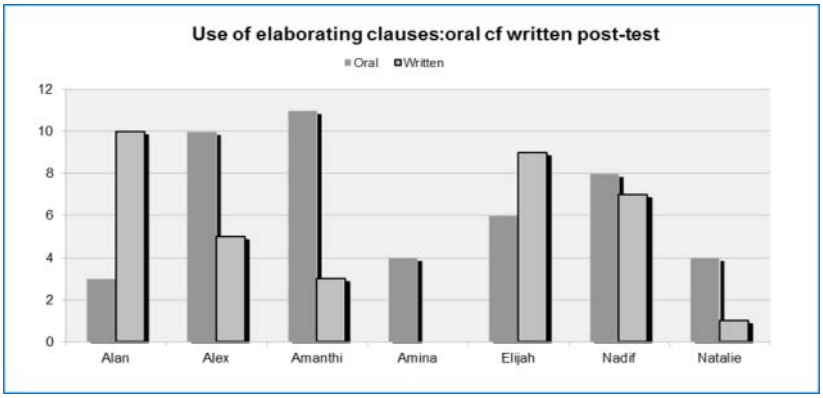
Figure 18. Dependent clause as marked Theme: oral cf written post-tests



Six of the seven students consistently staged their written explanations using a dependent clause of time as the marked Theme of the opening sentence of the stage. For five students, the frequency was close to that of their oral text. The exceptions were Amina, who had used no such clauses in her oral retell, but used this resource twice in her writing; and Elijah, whose written piece consisted of only the first stage which didn't require this clause. Natalie used one of these clauses in her second written stage, but shifted to the more oral 'then' in subsequent stages.

Extending non-finite clause

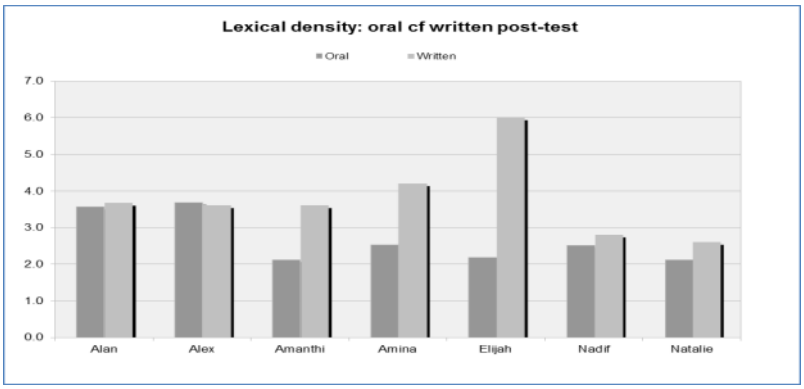
Figure 19. Extending non-finite clause: oral cf written post-tests



In the model text, the extending non-finite clauses were part of the energy phase. Six of the seven students used at least one non-finite clause in their written energy phases. Alex and Nadif produced approximately the same number as the model text. For four of the seven case study students the frequency of extending non-finite clauses in their written text was consistent with their oral texts. The first exception was Amanthi, whose frequency had decreased. This could be accounted for in that her oral use had been repetitive because of her self-correcting and retries. Elijah displayed no examples of this structure in his two sentence text, and Natalie used only one such clause in her opening written sentence, *to make them grow*.

Lexical density

Figure 20. Lexical density: oral cf written post-tests



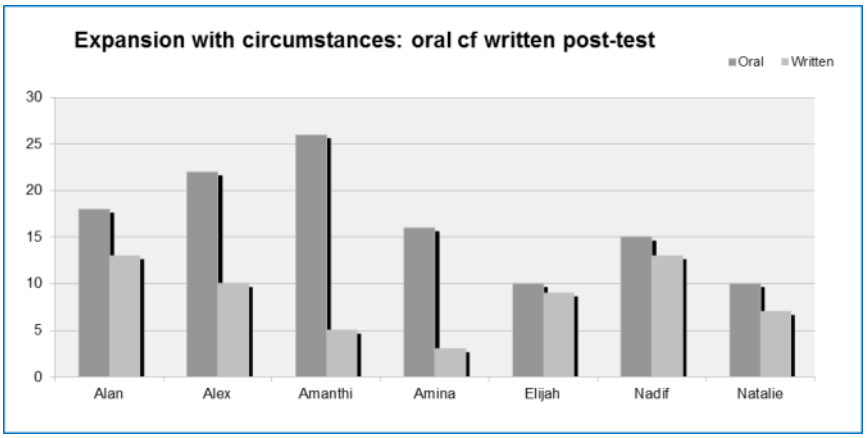
Five of the seven students increased the lexical density of their written text when compared with their oral text. The two most significant increases came from Elijah and Amina. Elijah's text consisted of only two sentences, but they were lexically very dense: the model text had a lexical density of 4.6, while Elijah's was 6.0. Amina's written text was 4.2, compared with her post-test oral text at 2.5. Here is Elijah's complete written text:

> *Light and heat comes from the sun by rays to the apple tree and macks the apples grow. heat and light kinetic energy changes to chemical potential energy.*

The increase in lexical density has to be balanced against the fact that neither student completed their text. Elijah wrote only one stage of the possible six, while Amina wrote three stages. On the positive side, the lexical density shows that even struggling students can engage in the production of more 'written-like' texts. The examples of Elijah and Amina suggest however, that the trade-off, at least in the short term, is that less is produced.

Expansion with circumstances of time, location and manner

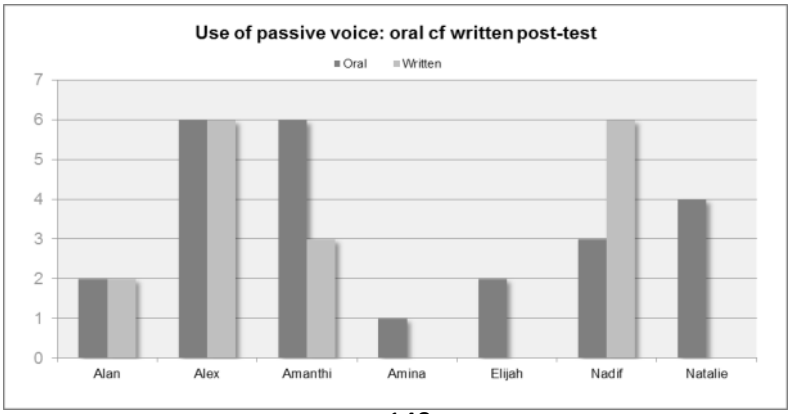
Figure 21. Expansions through circumstances of time, place and manner: oral cf written post-tests



No students used circumstances in their written texts with the same frequency as the oral text, but all students used them appropriately. Most were circumstances of location, and four students included a circumstance of manner. Amina's and Elijah's decrease can once again be accounted for because their texts were incomplete. Amanthi's text omitted the last of the six possible stages. This fact and the fact that her oral text was so repetitive help to explain the significant decrease in her use of circumstances.

Use of passive voice

Figure 22. Use of the passive voice: oral cf written post-tests



The passive voice was one of the language resources least evident in student texts before the topic was taught. While all students used this voice at least once in their oral post-retell, three students; Amina, Elijah and Natalie omitted passive voice completely in their written text. Amanthi was the student whose oral post-retell included a large number of repetitions and restarts, accounting for the large number of examples of passive voice. Although the frequency decreased in her written text, it was still greater than the model text. Alex and Nadif used the passive voice a great deal in their written texts. Here are some of Nadif's examples:

When the apples are taken to the shed…

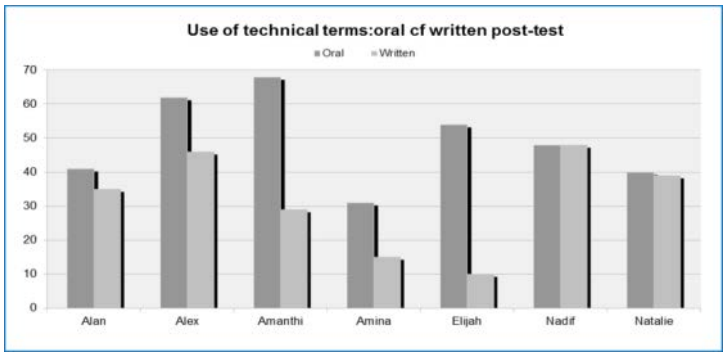
When the apples are wash pack and clean…

When the(y) are taken to the supermack (sic)…

This patterning of passive voice enabled Nadif to foreground the apples in Theme position and omit the human actor as less important in the explanation.

Use of technical terms

Figure 23. Technical and scientific terms: oral versus written post-tests



Technical terms were used frequently and appropriately by four of the seven case study students in their written texts. Although most students showed a reduction when compared with their oral text, particularly Amanthi, this can be explained by the repetition and repair evident in their oral texts. Elijah and Amina used the terms 'potential, kinetic, light, heat, energy' in their texts, but because the texts were very short, they did not display the frequency of the other students. Natalie used technical terms in her opening sentence: *Light and heat energy comes down from the sun in rays to the earth,* but from then on reverted to everyday vocabulary.

4.2.3 Conclusions about student oral and written performance

The case study data show that the persistent use of specific language by the teacher, and her work in handing over the language use to students seemed to have an influence on student language use. All students had shown language development around this topic across the seven weeks. That is not to say that the scaffolded pedagogy had equal effect on all students. The two

middle-class girls, Alex and Amanthi had greatest control of the language in both oral and written form. Nadif, the refugee boy, and Alan, a boy from a low socio-economic background, showed great improvement in their oral and written texts. Interestingly, Nadif and Alan had been previously identified as having learning difficulties but their significant language development raises questions about this label. Three students were of particular concern: Natalie, the Aboriginal girl, and Amina, the refugee girl, showed growth, but struggled with more complex grammatical resources. Faced with the challenge of writing independently, they, by and large, reverted to their spoken language patterns. Elijah, the Aboriginal boy, performed well in his oral post-test, but only partially completed his well-structured but very succinct written text. Both Natalie and Elijah had issues with attendance. Because the science lessons were held first thing in the morning, they often had to catch up on the beginning of the lesson.

Sociocultural theory works with the understanding that the zone of proximal development (ZPD) works beyond students' independent proficiency towards their next stage of development. The ZPD is not fixed: it is influenced not only by what a child has already internalised, but also the quality of the scaffold provided by the 'informed other'. As described below in Section 4.3.2, the teacher confronted some difficult issues in working out how to scaffold these students in this topic, in how to scaffold contingently for all. It is possible that students such as Amina and Natalie could have developed even further in their language use if some issues had been resolved earlier. This is speculation which cannot be tested. Nevertheless, the fact that the language of all students showed measurable and observable development supports the principle of bringing to a teacher's consciousness the language choices; both at the overall structural level through a focus on genre, and also at the level of text cohesion and clause, through a focus on grammatical resources. This explicit focus on language foregrounds these resources as important teaching and learning goals.

The students' final written performance produced some contrasting outcomes. Four students; Alex, Alan, Nadif and Amanthi, produced well-structured explanations that were more coherent than their oral post-tests. The frequency of use of the new language features was reduced but more controlled in their writing. The other three students; Amina, Natalie and Elijah, struggled in different ways. Neither Amina nor Natalie finished the text. Natalie omitted all phases that included new technical terms. It is difficult to know what happened with Elijah: did he miss some days of school and not finish? Was the task so onerous that he wrote one well-formed stage and gave up?

For these three students, it appears that the demands of such a written text were too great when required to write independently, even when the task was already paced out over a number of days. That is not to say the language demands of the explanation were too ambitious. In fact, the grammatical features of the text match closely those benchmarked for this age by Christie and

Derewianka (2008:233). Rather, that, if the final assessment had not been required for the study, the teacher would have settled with these students for a joint written construction of the text, rather than expecting an independent product.

Now that student language development has been established, the analysis moves to discussing how these outcomes were achieved. Section 4.3 examines the structure of the topic itself, describing the scope and sequence which supported the gradual handing over of new language and new learning.

4.3 The macrogeneric topic structure

The broad macrogeneric topic of energy transformation which was the focus of the study was divided into two sets of lessons: one set of four lessons focusing on explanations of a simple energy transformation observable in single objects such as a cotton-reel machine and a marble run, and the subsequent set of three lessons focusing on a more extended explanation of energy transformation in a farm-to-table chain. As explained in Section 36.2.2, p115ff, and following Christie (2005b), the unit of work is identified as a macrogenre, and each of the lessons is labeled as a genre.

The generic or topic structure is represented in Figure 24:

Figure 24. Macrogeneric structure of the topic of *Energy Transformation* showing

Macro-genre	**Topic:** Energy transformation						
Genres (lessons)	**Lesson 1** (77:30) Focus Text 1 Reiteration 1	**Lesson 2** (75:00) Focus Text 1 Reiteration 2	**Lesson 3** (75:30) Focus Text 1 Reiteration 3	**Lesson 4** (70:30) Focus Text 1 Reiteration 4	**Lesson 5** (96:00) Focus Text 2 Reiteration 1	**Lesson 6** (78:30) Focus Text 2 Reiteration 2	**Lesson 7** (82:00) Focus Text 2 Reiteration 3
	Set 1				**Set 2**		
	Focus Text 1: explanations of energy transformations found in similar demonstrations of four simple objects (marble run, chicken wing, cotton-reel toy and battery-operated propeller)				**Focus Text 2**: explanation of energy transformations found in farm-to-table chain		

Figure 24 shows the span of each set of lessons. The lessons in each set were reiterative, consisting of repeated activities over a number of days, and guided by a particular focus text. That is to say the four simple energy transformation activities guided by Focus Text 1 were revisited in each of four lessons, and the farm-to-table chain was the focus of attention in each of the three lessons in the second set, guided by Focus Text 2.

4.3.1 Structures to support the unfolding of the topic

The topic was planned to develop common content knowledge through expanded student use of decontextualised language, by staging the topic in a structured, logical and systematic way. Such a process is described by Halliday as 'logogenesis', the logical unfolding of meanings in a text (Halliday, M.A.K. & Matthiessen, C. 2004:530). Effective logogenesis, in contrast to a topic which consists of a collation of interesting activities, requires thoughtful planning, with

close attention to lesson coherence and language. In the planning for this study, the focus texts acted as a guide for the scope and sequencing of the topic, as well as for language choice. A further supporting structure was provided through the accompanying use of different types of artefacts, moving from concrete to three- and two-dimensional representations. These two aspects of the planning; the use of language and the use of artefacts, will now be elaborated upon.

4.3.1.1 Logogenesis: the logical unfolding of the topic

The topic introduced new scientific knowledge and language to students in a sequenced and logical manner. The unfolding of the macrogenre was given coherence through the systematic extension of content knowledge from the first to the second set of lessons, shifting from single energy transformation events to a chain of such events. The accompanying focus texts mirrored these extensions in meaning.

The first set of four lessons, grouped as Focus Text 1, included four activities, each of which was chosen to exemplify one simple form of energy transformation. (These activities were outlined in Chapter 3, Section 3.5.4, p107.)

- the marble run showing potential gravitational energy transformed into motion energy
- a chicken wing showing potential chemical energy transformed into motion energy
- a cotton-reel machine showing potential mechanical energy transformed into motion energy
- a battery and motor showing potential chemical energy transformed into motion energy.

The learning goal of each activity was for students to produce a sequential explanation which included energy transformation. The linguistic form of these explanations was guided by the teacher who was in turn guided by the focus text. The grammar and lexis of each text was very similar, providing a helpful common structure to support students in expressing the scientific meanings required for each activity.

Once students had grasped the grammar and lexis (vocabulary) required for the first set of explanations, the second set of three lessons, Focus Text 2, introduced further challenges for students: the setting of the activity shifted from the real-life situation of the classroom to a videoed farm-to-table chain including a number of new settings. It began with the apple orchard, and moved to the packing shed, supermarket and then home. The energy transformations expanded from one simple transformation per text in Focus Text 1 to a series of transformations as the apple moved along the chain. The accompanying explanations expanded from a simple explanation to a chain of events, with each event within the chain requiring its own explanation of energy transformation.

Despite the increased challenge, the logical sequence expressed in the grammatical structures and technical lexis from Focus Text 1 meant that the language required for Focus Text 2 would already be to some extent familiar to students, and provided the language resources they needed to successfully produce the more extended text required.

4.3.1.2 Gradual decontextualisation of activity

Section 2 2.3 in Chapter 2 introduced the work of functional linguists and their collaboration with educators in the field of science education. One aspect of this work was the description of the shift required of teacher and students along the Register continuum, from situated language to decontextualised language, from the concrete to the abstract, from 'spoken-like' to 'written-like' (Halliday, M.A.K. & Martin, J.R. 1993; Martin, J.R. & Veel, R. 1998). In moving to the written end of the Register continuum and its demand for decontextualised language, this language-driven pedagogy clashes with the enthusiasm in the science curriculum for 'hands-on' activity and group work. Language accompanying action resonates strongly with hands on activity. Language is not required to do all the meaning-making. The situated language assumes a shared common activity between listener and speaker. This means that the language can be abridged, because much of the meaning can be carried in the context and the shared action. Because the participants are all physically present, students can draw attention to objects in view through the use of reference items such as 'this', or 'it', or in fact by pointing without using language at all. A tension arises because the limited language use within a situated context carries the danger of restricting the establishment of conceptual understanding. This is because the development of abstract concepts such as energy transformation requires a recontextualisation of concrete materials and processes through specific language use so that they are viewed from an abstract scientific perspective.

The appropriation of new abstract language by students to represent meaning in a scientific way is not an optional extra, but fundamental to building academic intersubjectivity within the discourse of science (Halliday, M.A.K. 1993). It stands to reason that the continual use of hands-on activities so highly valued in primary science education might in fact be counter-productive for language development. This study argues that the continual use of concrete activities creates a structural impediment to students appropriating new language, reducing the opportunities for the teacher to mediate a scientific orientation to the activity, particularly in the early stages of a topic when novelty was high and intersubjectivity low. Instead of spending her time in explanation, the teacher was likely to spend a large proportion of her time managing groups, as pointed out by Galton et al (1980) and more recently by Martlew et al (2010). Consequently, the topic plan supported the decontextualisation of language by also establishing decontextualised activities: shifting students from hands-on engagement with concrete objects,

to more abstract two- and three-dimensional representations of various kinds, thus distancing the artefacts from students. Such a shift required language to do more work in the making of meaning: language as reflection, rather than language accompanying action. The range of two-dimensional artefacts included pictorial, photographic and video representations of real life experiences, scientific diagrams and text. For example, while Lesson 2 consisted of the same activities as Lesson 1, the students did not separate into groups and use the same concrete objects. Instead, the teacher had taken photographs and video of Lesson 1 activities which she used in the second lesson. Talk around the activities, represented at a distance in two dimensions on the interactive white-board, moved toward language for reflection, requiring more technical lexis and complex grammar.

Table 20 shows the range of artefacts employed across the seven lessons, demonstrating the gradual shift from situated activity towards decontextualisation.

Table 20. Two- and three-dimensional artefacts employed across the topic

Focus Text	Lesson	Three-dimensional artefacts			Two-dimensional artefacts				
		Real life objects	Scientific models	Students' own bodies	Videos	Photos	Other images	White board Diagram	Written text
Focus Text 1: simple energy transformations	1	■	■	■	■	■	■	■	
	2	■			■	■	■	■	
	3							■	■
	4	■							■
Focus Text 2: farm-to- table	5				■	■			
	6				■	■	■	■	
	7						■	■	■

Concrete Abstract

The shaded areas in Table 20 above represent lessons where a particular artefact was present. The double-headed arrows indicate the scope of each lesson. The arrow at the bottom of the table shows the gradual shift from concrete to abstract experience. Lessons 1and 2 began with began with a high level of 'hands-on' activity such as the use of concrete objects and the students' own bodies, along with a number of photographs and diagrams on the interactive white board. Lessons 3 and 4, at the end of Set 1 of lessons, show a reduced range of concrete objects and the introduction of writing. In Lesson 5 the farm-to-table chain began with video footage of the farm and sorting shed, the supermarket and home. No concrete objects or hands-

on activity were used in this lesson. Lesson 6 continued with the video, and introduced an abstract flow diagram of the energy chain on paper:

Figure 25. Farm-to-table flow diagram for Focus Text 2

The flow diagram was used as a prompt to help students jointly and individually construct the extended written explanation they produced in Lesson 7.

What is not readily apparent from Table 2 is the changing relationship between language and the classroom artefacts. For example, in Lesson 1, oral language accompanied the marble run demonstration. Language was an adjunct to the exciting activity which was the students' focus. By Lesson 4, language *was* the activity, with a formal oral and written presentation about the marble run the focus of student attention, and the marble run artefacts only acting as aids for the presentation.

The gradual shift in activity from concrete to abstract observed across lessons demonstrates the gradual re-orientation in the balance of meaning-making from physical activity to language. The study does not claim that students' use of more decontextualised language, both oral and written, was a direct and automatic result of the gradual removal of hands-on activity by itself. Rather, it proposes that a conscious shift in planning by the teacher from 'hands-on' activity requiring language to accompany action to more decontextualised activity requiring language as reflection created an imperative for more specific and technical language. This imperative in turn required the teacher to ensure that appropriate language resources were accessible for students to effectively engage in this more decontextualised situation. These appropriate language resources were found in the focus texts.

The progression of the lessons from single to extended instances of energy transformation served two purposes. Firstly, the gradual and systematic sequencing of knowledge expansion increased the chances for all students to internalise and consolidate this knowledge, thereby developing intersubjectivity within the instructional register and extending student understanding. Secondly, the predictable, reassuring sequencing helped students to understand where the topic was heading, thereby helping to maintain positive affect for all students.

Not only the broad topic scope, but also the lesson staging supported the development of both affective and academic intersubjectivity through the use of a pedagogic routine. The routine enabled teacher and students to *give their attention less to choreographing the activity and more to the academic content* (Cazden, C.B. 2001:101). Each lesson consisted of a number of regular stages.

4.3.2 Stages within the lesson

The topic of energy transformation consisted of a number of lessons, each a genre contributing to the macrogenre or topic. Each lesson was in turn divided into a number of stages. These lesson stages are identified by a change in register; that is through variations in one or more of the systems of meaning; Field, Tenor and Mode, and often accompanied by physical changes in setting as well.

As previously discussed in Chapter 3, the stages within a lesson are not generalisable to all teachers in all classrooms because they are contingent on a teacher's approach to teaching and learning (Section 3.2.7.2, p96). Because curriculum genres *occur as patterns of language choices arising out of particular educational assumptions and methodology* (Gray, B. 1998a: 131) their scope, purpose and patterns will change according those educational assumptions. For example, a science teacher who values student voice highly might only provide a short introduction to the whole class before moving to group activities. Such a teacher might prioritise group activity, following inquiry questions. A different teacher who values individual student effort might give as much time as possible to independent projects where students can record and display their individual research efforts for assessment.

For a socio-historically and language oriented teacher intent on her scaffolding her students to new knowledge, the imperative of contingent scaffolding guides the staging of the lesson. A scaffolding teacher has to spend whatever time is needed to build common knowledge amongst all participants in the classroom, aiming for a contingent level of scaffolding such that all students are appropriately supported in developing the cognitive and language resources needed to engage with the content. This requires the careful, and explicit building of field knowledge, checking for student handover, revisiting aspects not well understood, and carefully extending student proficiency from oral to written language.

In the data, three stages appeared within lessons. Each stage is identifiable in classroom dialogue as a shift in one aspect of the three semantic metafunctions; either Field, Tenor or Mode, with each functioning as a move towards student control of the topic. The three broad stages are Text expansion, Text handover and Mode shift. The functions of these stages can be described in the following way:

Table 21. Stages within the lessons expressed as changes in language register

Stage	Register Shift	Purpose
Text expansion	Field	To introduce new learning, to expand content knowledge (Teacher has major role, Mode is oral)
Text Handover	Tenor	To consolidate the knowledge and language covered in the previous lesson and to hand over control of the language from teacher to students. To gradually shift the role of speaker from teacher towards student (Field knowledge stays the same, Mode remains the same)
Mode Shift	Mode	To use the same knowledge and language from the previous lesson, and change the Mode e.g. from oral to written, from concrete to abstract activity, from informal conversation to formal presentation. (Roles are more shared between teacher and students, Field knowledge stays the same)

Rather than there being a consistent pattern and number of stages within each lesson, the stages progressed in a logical manner across the lessons and across the topic. In planning, the teacher used her understanding of contingent scaffolding and her judgement of student proficiency in the previous lesson to determine what stages should follow in the next lesson. The structure of stages in any lesson was determined by the teacher's assessment of student proficiency in the instructional register. If the teacher expected that the students would need more practice at what had already been introduced, the next stage would be another Handover stage. If she deemed that they were ready, Handover would be followed by Text Expansion or Mode Shift.

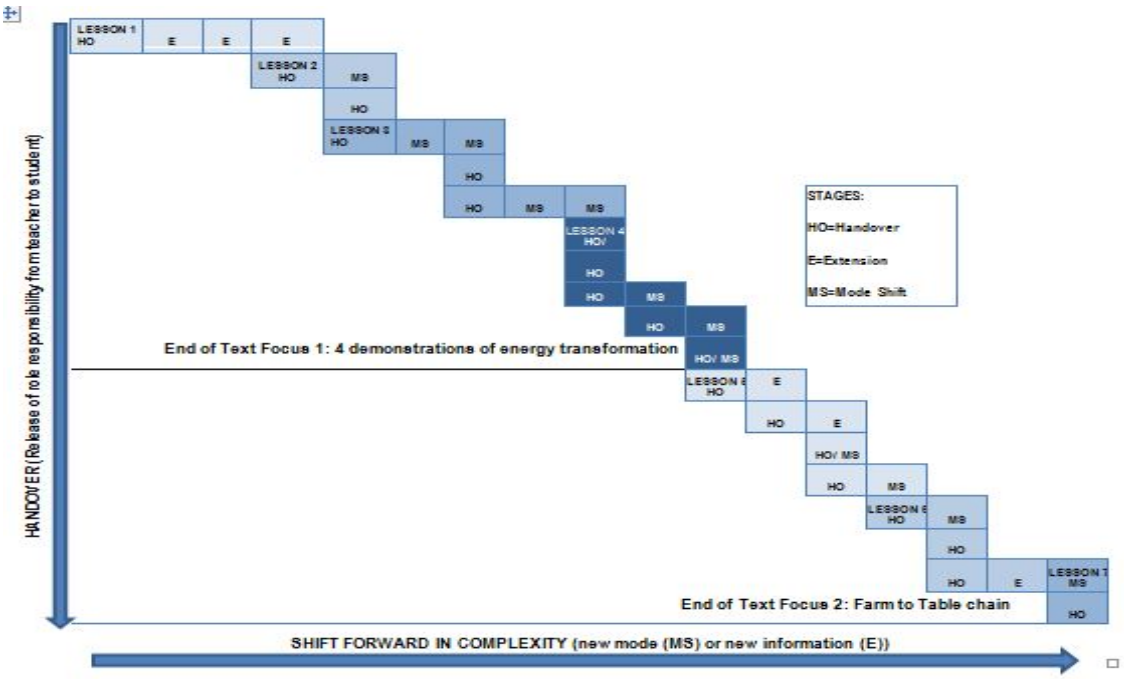
Text Expansion represented major expansions in the ideational meanings. There were only three Text Expansions in the topic: in Lesson 1, when the information about potential and kinetic energy and the four activities was introduced for the first time; and in Lessons 5 and 6, when new information related to the farm-to-energy chain was introduced in consecutive lessons. Text Expansion was a multi-modal stage, always oral, and accompanied by concrete and/or visual materials to help build the Field.

Text Handover occurred when the teacher, through classroom dialogue, checked to see what students remembered about the learning from the previous lesson or stage. The Field and the Mode remained constant. It focused on changes in the metafunction of Tenor. A Handover stage consisted of teacher questioning, and the students displaying what they knew through talk and action, with the teacher reconceptualising student answers as necessary, always working towards the establishment of common knowledge. The opening stage in each lesson was a Handover stage as the class reviewed what they had covered in the previous lesson. Handover stages also logically followed each Expansion or Mode Shift in order to monitor the take-up and control of new learning by the class, where the students would practise and gain greater control over previous learning. Text handover represented a change in interpersonal roles in the classroom. The trajectory moved towards greater student control, moving from whole class to groups or pairs and finally to individuals.

The Mode Shift was a change in textual meanings. It occurred when the teacher assessed that students had sufficient control over the oral text to begin to record it. This occurred in each lesson, following a Handover stage. Mode Shifts always began as whole class stages, with the shift from oral to written text being scaffolded through jointly negotiated text construction. On some occasions the joint construction was then followed with a similar independent written activity.

The logical progression of the topic is evident in Figure 26 below, when the three stages are plotted as they appeared across the seven lessons.

Figure 26. The staging of a topic: Handover, Extension and Mode Shifts



The three lesson stages are represented with a bi-directional shift along the two axes of the chart. On the vertical axis is Handover, which represents a shift in interpersonal relationships as the talk moves from teacher control to student control of consistent Field knowledge. The Handover stages are represented as moving from top to bottom towards increasing student control of the content. On the horizontal axis are the Extension stage and the Mode Shift. The Extension and Mode Shift stages move from left to right towards increasing complexity. To different degrees these two stages increase the complexity of knowledge, either because the content is new (ideational Extension stage), or because it is being represented in more 'written-like' ways (textual Shift).

The pattern evident in Figure 26 above demonstrates how the lessons moved from high teacher control of text, to independent student control of more complex text. The pattern is significant because it reflects and provides a real-life example of the familiar model first proposed by Pearson of the 'Gradual Release of Responsibility'(represented by arrows in Figure 27 below), moving from teacher control to student control (Pearson, P.D. & Gallagher, M.C. 1983:337):

Figure 27. Gradual release of responsibility (Pearson and Gallagher, 1983)

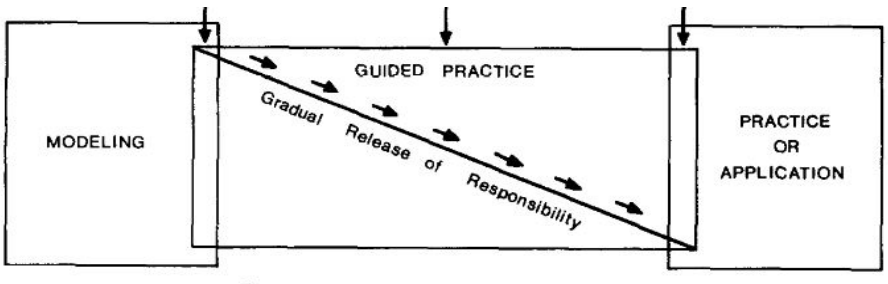


FIG. 1. A model of explicit instruction.

The mirroring of Pearson's gradual release trajectory evident in this topic suggests that the use of register changes in classroom dialogue to map the gradual shift of control from teacher to student might be a useful tool for assisting teachers to monitor their own pedagogic staging for its scaffolding potential.

What is evident from this pattern are the planned efforts of the teacher to systematically scaffold students towards control of the topic thereby developing academic intersubjectivity. The many repetitions of the Handover stage, particularly evident in earlier lessons, indicate her intent to contingently support the varied learners in her class, including the many refugee and EALD students with minimal English. She did not pursue new content each lesson, but spent time with students consolidating and handing over control of prior learning before increasing the cognitive load by shifting to a different Mode of communication, or by extending the topic.

4.3.3 Summary

To this point, Chapter 4 has analysed the topic of Energy Transformation at the broadest level, interpreting the unit of work as a macrogenre. The intention has been to demonstrate the logical progression of lessons centred on the two focus texts. It has demonstrated how the lesson stages, classified according to their shifts in Extension, Handover and Mode could be mapped to show intentional, systematic and gradual release of responsibility from the teacher to her students as intersubjectivity grew.

At each of these levels, the teacher made considered decisions about what strategies were most likely to provide contingent levels of support for students through the pedagogic structure. The purpose of these decisions in establishing class intersubjectivity is evident in the analysis so far. Ultimately though, it is the classroom dialogue which realised these intentions. Accordingly, classroom dialogue is the next and, for the study, the most important level of analysis because it enables close examination of the moment-by-moment negotiation of learning, identifying the effect at any point in time of the teacher's language choices in building intersubjectivity. As Alexander argues, *of all the tools for cultural and pedagogical intervention in human development and learning, talk is the most pervasive in its use and the most powerful in its possibilities* (Alexander, R. 2005:2).

4.4 Building intersubjectivity through classroom dialogue

The following analysis maps the teacher and student dialogue about the topic of energy transformation. It begins with the first set of lessons, Focus Text 1, looking at whole class and small group interactions around two of the demonstrations in the first set of lessons, namely the battery-operated propeller activity and the marble run activity. It then moves to observe how the language choices from Focus Text 1 were transferred and extended in the Focus Text 2 lessons

through classroom dialogue. The analysis shows how particular language choices from the focus texts were first used by the teacher, and were gradually appropriated by students as the topic developed. It provides examples of the scaffolding strategies used by the teacher to develop and maintain positive affect in the face of a difficult and unfamiliar topic. The study has previously argued that a teacher's regulative and instructional registers must change and adapt over time to facilitate student language development, and in response to student appropriation of language (Chapter 2, Section 2.4.2, p64). The study records this adaptive process in action, as the teacher makes moment-by-moment decisions about what language choices would provide contingent levels of scaffold. Each scaffolding strategy is explained in some detail the first time it is identified in an extract.

The topic was complex for both teacher and students. It required that they could distinguish between the notion of observable and concrete 'work', and the abstract notion of energy which enabled that work, from within the discipline of Physics. Such a distinction put a heavy load on language in classroom dialogue. The instances of 'interactive trouble' evident in the dialogue is some indication of the difficulty of this challenge. At the same time, these moments of interactive trouble also serve to strengthen the argument for thoughtful and persistent language choice, guided by a focus text, in developing new scientific concepts with students.

A total of ten extracts are provided from five of the seven lessons. As explained in Chapter 3, Section 3.6.2.3, p116, the extracts were selected to show the progression in language development across the topic, at the same time demonstrating scaffolding strategies used, and issues encountered. The scaffolding strategies were developed from the scaffolding principles outlined in Chapter 3 (Section 3.5.3, p104ff). The analysis of each extract is structured in the following way:

Introduction to scaffolding strategies and issues encountered

↓

Extract

↓

Discussion of scaffolding strategies and issues encountered

One useful measure of 'handover' is simply the changing quantity and purpose of student talk in each lesson. A quantitative analysis of the number of clauses of student talk in each lesson provides a complementary perspective on the changing role of students in classroom discussion.

The analysis begins with the extracts from Lesson 1.

4.4.1 Lesson 1: introduction to potential and kinetic energy

When Lesson 1 began, the class had already learned in the previous term where energy comes from, and what happens to it when it reaches the earth. They knew that *energy is the power to*

do work. However, this was the first time that they had been introduced to the concepts of potential and kinetic energy and energy transformation so there was little intersubjectivity, no common knowledge within the class about these new concepts.

The purpose of this lesson was threefold: to introduce the concepts of potential and kinetic energy and energy transformation to the class; to introduce four activities that demonstrated energy transformation of various kinds; and then to facilitate student rotation between each of these activities while the teacher moved from one group to the next, continuing to explain how the energy transformation was happening.

Three brief extracts are provided from Lesson 1. The extracts provide examples from two different settings: firstly the Extension stages conducted as a whole class event, when the teacher introduced the concept of kinetic energy, and also the practical process of the battery-operated propeller. These two extension stages are followed by an extract from the Handover stage, with an example of the group of three boys interacting on the topic of the battery-powered propeller during 'hands-on' activity.

Table 22. Stage, purpose and grouping arrangements of extracts from Lesson 1

Extract	Lesson Stage	Purpose	Grouping arrangements
1	Extension	The teacher introduces the concepts of potential and kinetic energy	Whole class
2	Extension	The teacher introduces the battery-powered propeller activity	Whole class
3	Handover	Students carry out the battery-powered propeller activity	Group of three

4.4.1.1 Student talk in Lesson 1

The principles of scaffolding and the gradual release of responsibility mean that, when intersubjectivity is low and knowledge is not shared, teacher talk is likely to dominate as new information is introduced. That is to be expected as the most likely contingent level of scaffold. Such is the case in Lesson 1, which consisted largely of teacher monologue, with minimal student contributions. This is evident in the small quantity of student talk in Table 23, which represents the clauses of student talk as a percentage of teacher and student dialogue evident in Lesson 1:

Table 23. Clauses of student talk as % of total clauses of classroom dialogue in Lesson 1

	Extension 1: Whole class intro to potential and kinetic energy	Extension 2: Whole class intro to the four activities	Handover: teacher-student dialogue as teacher rotated amongst groups during activities
Student initiations	5%	8%	7%
Student responses	16%	7%	9%
Joint constructions	3%	4%	1%
TOTAL STUDENT CONTRIBUTIONS	23%	19%	16%

Student contributions were of three kinds: initiations by the student, responses to teacher questions, and utterances jointly constructed by teacher and student, or by students together.

Student initiations are identified as a change in topic, or an extension of the teacher's topic initiated by the student without prompt. They require a level of confidence on the part of the student and can be a marker of increasing understanding. In this first lesson though, student initiations were rare, and when they did occur, they highlighted the low levels of scientific intersubjectivity in the group. They included simple spontaneous 'try-outs' of new technical terminology; e.g. *Kinetic, kinetic* and responses conceptualising the activity in commonsense terms; e.g. *Might be a windmill.* However, they were predominantly evaluative responses to the activity: *Awesome!, Do it again!, Ooooo!* or statements and questions involved with classroom regulation; e.g. *How come I never get a turn?* and *You have to move because there's not enough room.* In other words, student initiations were evidence of neither confidence nor familiarity with scientific discourse.

Responses to teacher questions by and large came from students' common-sense experience. For example, when the teacher put up on the white board a taxonomy of objects that used energy to move, students identified and named some of the objects; *bananas* and *car,* but did not expand on aspects of energy transformation. When students began to engage in scientific discussion, their answers were very brief; e.g. *It's a battery,* and sometimes incorrect. For example, when the teacher asked where energy came from, one student answered *water*.

Joint constructions are utterances composed jointly by the teacher and one or more students, or by a group of students together. Although students might only be able to contribute one part of the utterance, together with the teacher or another student they can produce a more extended coherent statement. Very few joint constructions were evident in Lesson 1, and those that appeared were hesitant, partial and brief. For example, Elijah and an unidentified student were able to construct the following sentence:

Turn	Speaker	Transcription
172	Elijah	Energy from the…//
173	Student	//the muscles//
174	Elijah	//the muscles makes you move.

In summary, student responses showed that students did not have a strong understanding of scientific content, or the language with which to express it. In fact, their contributions diminished as the lesson continued, from 23% in the first Extension stage to 16% in the Handover stage. The teacher's role was therefore crucial in providing language resources for students that would help them to contribute to the learning negotiation in a focused and purposeful way, in shifting their orientation from the commonsense to the scientific.

The analysis now proceeds to provide detail of how the teacher initially introduced the concept kinetic energy (Extract 1), and how she introduced and explained the battery-operated propeller activity (Extract 2). It then provides an example of a small group interaction with the teacher as the students were engaged in the hands-on battery-operated propeller activity (Extract 3).

4.4.1.2 Extract 1: introduction to potential and kinetic energy

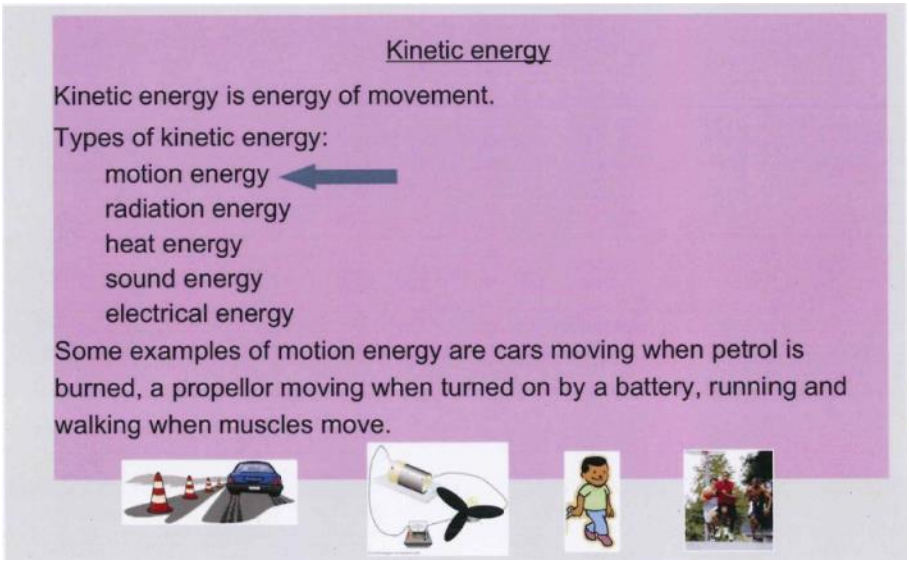
Extract 1 to follow demonstrates the teacher's scaffolding strategies used to introduce the topic of energy transformation. At this beginning point in the topic's unfolding, intersubjectivity was low.

While proficient in scaffolding strategies in the learning area of English, the teacher was taking on new content knowledge herself in the learning area of science, at the same time having to remain vigilant about language choices, a difficult challenge to meet at times. Extract 1 demonstrates the challenges faced as the teacher worked in a field with high cognitive demand: introducing new and abstract scientific concepts to young children and facilitating the crossing of the boundary between the commonsense and the scientific.

To begin this first lesson, the teacher reviewed the previous term's work on the earth's energy and its sources, before introducing the new concepts of potential and kinetic energy and energy transformation. The first extract comes from the first Expansion stage in that lesson (beginning at Lesson 1, Turn 120).

At this point in the lesson, the teacher had already introduced potential energy, and was moving to introduce kinetic energy. The talk that followed was accompanied by the following diagram on the interactive white board. This is the diagram to which the teacher refers in the extract:

Figure 28. Kinetic energy slide from interactive white board



Before the extract is presented, the scaffolding strategies employed in this extract are introduced.

Introduction to scaffolding strategies employed in Extract 1

The extract exemplifies the following pedagogic strategies deployed to share scientific knowledge, building a bridge from the commonsense to the scientific, and at the same time maintain positive affect in the class:

-Look back – look forward. This cuing strategy carries the purpose of keeping the students tracking where the lesson is going, and helps students to recall prior knowledge. Mercer calls these links 'recaps'(Mercer, N. 2008a:8). They allow the teacher to draw on a level of intersubjectivity established from earlier discussion, however tentative, and use this shared recall to logically continue the unfolding of the topic in the classroom.

-Careful choice of speech function: use of statements rather than questioning. Simply 'telling' students is the highest level of scaffold available to the classroom teacher. It occurs when the teacher expects that students will not have much knowledge about the topic, and are likely to be embarrassed or provide an incorrect answer if she asks a question.

-Use of first person plural in the regulative register signals learning as joint activity.

-Use of commonsense bridging terms to build understanding. Section 3.5.3 in Chapter 3, p104, proposed the use of bridging language as a way of making the boundary of science more permeable, more accessible to students. It was proposed that these commonsense terms would be used as long as necessary until it was evident that students had sufficient control of scientific language to leave them out.

-Reconceptualisation of student answers towards more scientific talk recasts student answers in a way which extends their answer, and models appropriate scientific language.

-Repetition. The role of imitation in learning and Wertsch's notion of ventriloquation were introduced in Chapter 2 (Section 2.3.1, p42). To ensure that many students had the chance to try out new language, the teacher did not just accept one answer, but encouraged students to repeat what other students had said. The opportunity to simply repeat new language and grammar is an important beginning step in appropriation.

-Oral cloze is a form of joint construction which the teacher uses to monitor student take-up of new information. In oral cloze, the teacher opens the statement, but then invites students to continue. If they can't, she will just complete the statement herself.

Introduction to issues in the development of intersubjectivity

Despite the conscious employment of contingent scaffolds, two issues in expressing conceptual understanding were noted in the teacher's language choices. The first was the problem of expressing relationships between the scientific phenomena being discussed. The second was the problem of language selection to effectively differentiate between concrete objects and abstractions. These issues demonstrate the vigilant and conscious attention needed to ensure that students are not simply developing a vague conceptual scientific understanding, but are also exposed persistently to appropriate language with which to develop these concepts.

Extract 1

In this and all subsequent extracts, each turn at talk is numbered with the speaker's name. Each clause within the extract is shown on a new line and numbered. The discussion to follow refers to Clauses, not Turns.

The underlining indicates the pedagogic register (Ref Chapter 3, Section 3.6.2.4, Table 17, p118): A single underline indicates the regulative register, while no underline indicates the instructional register. A dotted line indicates a clause or word which conflates both registers. Additional information about the context is included in brackets. Clauses not relevant to the discussion, such as treating a student's blood nose, have been omitted. All students' names are pseudonyms.

Turn	Speaker	Clause	Utterance
120	Teacher	1	We've talked about potential energy.
		2	This one's kinetic energy. (Shows kinetic energy slide, Figure 28 above.)
121	Students	3	Kinetic, kinetic.
122	Teacher	4	Good. Kinetic energy.
		5	And that's the energy of movement.
		6	That's when the work is going on.
		7	We're going to have a look at things moving. (Shifts arrow to 'motion energy'.)
			(Turns 8-14 omitted: visitor comes into room, teacher deals with her and resettles the class.)
		15	So we've learnt about potential energy (reveals relevant slide)
		16	because that's….
		17	what is it again Amina ?
123	Amina	18	/kumikl/ (ie attempted but mispronounced)//
124	Students	19	//chemical, chemical// (Students trying out new word)
125	Teacher	20	That's one kind of potential energy

		21	and it's all inside, stored, ready to be used.
		22	Now we're going to look at the energy that is making the work go on. (reveals kinetic energy slide)
		23	And we're going to have a look at the things that move, motion energy…..
		24	Jo? Tell us. (Points to board to indicate that students have to identify things moving)
			(Lines 25-27 omitted: teacher settles the class once again.)
125a	Jo	29	Car
		30	So the pot… the chemical potential energy has been stored in the tank and now it's making the car move, motion energy.
		31	(Hubub begins. Teacher moves around to back of group. Points to smart board.)
126	Alan	32	We're gunna move… (Sways body.)

Scaffolding strategies employed in Extract 1

-Look back – look forward. The teacher used this strategy at two points. She used it in the opening Clause 1: *We've talked about potential energy* and Clause 2: *This one's kinetic energy*, linking the new concept to the previously introduced concept. In other words, it was building this new information on a certain level of intersubjectivity developed from prior discussion about potential energy. Later, in Clause 15, the teacher looked back more extensively, reviewing the talk about potential energy for seven clauses (Clauses 15-21). The extended talk about potential energy allowed the teacher to re-establish this knowledge more thoroughly after an interruption from a visitor before she moved again to kinetic energy.

-Use of statements rather than questioning. The style of the teacher at this point would be described as didactic. She expected that students would not know have prior knowledge about energy transformation, so it was her responsibility to tell them. The first bidding question did not appear until Clause 17, *What is it again, Amina?* This was not a request for prior knowledge, but the first of her 'handover' questions, asking Amina to recall something that had just been shared with the whole class. It was the beginning of the development of common knowledge.

-Use of first person plural. The reference to 'us' and 'we' rather than 'you as a learner' was, for this teacher, the default reference in the regulative register. It appears in almost all clauses underlined as part of the regulative register (Clauses 1, 7, 15, 22, 23 and 24) and was a conscious choice to signal that learning was a joint endeavour, that everyone was responsible for contributing, and that the learning was a shared teacher and student process.

-Use of commonsense bridging terms to build understanding. Definitions of potential and kinetic energy using commonsense terms had been established by the research team when planning. *Potential energy is 'stored inside, waiting to be used'. Kinetic energy is the 'energy of movement' or motion energy.* The teacher introduced these bridging terms to explain kinetic energy (Clauses 5, 23, and 31) and reinforced them when talking about potential energy (Clause 21). The key words were *stored* and *waiting*, and *movement* or *motion* and began to appear in student talk.

-Reconceptualisation of student responses towards more scientific talk. The low level of intersubjectivity has already been identified. Student answers were brief. They came predominantly from student commonsense knowledge, or if scientific, were only partial. The teacher built on these partial responses, reframing them in scientific terms through her reconceptualisations (Refer Chapter 2, Section 2.5.3, p77). Two examples are provided: the first was when Amina was asked what potential energy was (Clause 17). She gave the answer of *chemical* (Clause 18) which was sufficiently correct that the teacher could affirm and extend it. The teacher reconceptualised this answer by replying *That's one kind of potential energy, and it's all inside, stored, ready to be used.* She used the reconceptualisation to 'refocus and extend the answer' (Gray, B. 2007:40), restating the definition she wanted students to use and giving them a chance to hear both the technical term and the bridging language again.

The second interaction that included a reconceptualisation began in Clause 24 when, pointing to the white board, the teacher asked students to identify something that could move. In Clause 29, Jo answered *Car*. His contribution was a simple one-word naming of a commonsense object. The teacher again shifted this towards the scientific in Clauses 30-31 by providing an explanation for energy transformation related to the car: *So the pot… the chemical potential energy has been stored in the tank and now it's making the car move, motion energy.* The reconceptualisation took the student's very concrete response, and extended the meaning into the abstract.

-Repetition of new language. The repetition of new language by students occurred throughout the topic. In Clauses 3 and 19, a number of students repeated words already used, without being prompted, trying them out. Students spontaneously repeated new terms without any apparent embarrassment or loss of face as described by Malcolm (1991:10). It appeared that this was an process already familiar to them because there was no regulative talk used by the teacher to prompt this.

-Oral cloze. The teacher's use of oral cloze in Clauses 15-18 monitored handover of new information without the risk to students of asking outright display questions, such as *What's potential energy, Amina?*. Instead, the teacher made the following utterance:

Turn	Speaker	Clause	Utterance
122	Teacher	15	So we've learnt about potential energy
		16	because that's….
		17	what is it again Amina ?

She began the statement about potential energy (Clause 15), but paused after *that's*. The pause opened up a chance for any student to complete the definition. No-one did, suggesting that the statement was not a sufficient prompt for this low level of intersubjectivity. She followed up with a low-risk prompting question. The question was not a typical display question. Rather it implied that the teacher had forgotten the answer: *What is it again, Amina?* By asking this more informal question, the implication was that Amina would be able to help the teacher out. Via this strategy the teacher maintained the message of mutual contribution to class learning.

Issues in the development of intersubjectivity

Two related issues in conceptual understanding began to appear in the teacher's talk. The first was the relationship between associated concepts: the teacher had difficulty in finding appropriate language to describe the relationship between the concepts of potential and kinetic energy and work. The second was the relationship and distinction between concrete objects that require energy to move, and the abstract notion of kinetic energy.

-Difficulties in conceptual relationships. Three phenomena sit in relationship in the topic of energy transformation. They are potential energy, kinetic energy, and work. The logical relationship between potential and kinetic energy is sequential and transformational: the latter follows the former and vice versa. The relationship between kinetic energy and work is causal: the former enables the latter. These relationships were not explicitly stated in the online science resources sourced to build content knowledge amongst the research team. Rather, the resources made assumptions about the level of scientific knowledge held by the reader. The relationships between types of energy and work were not sufficiently clear for the lay (not scientifically trained) science teacher. They had to be inferred, and only became apparent as the topic developed and language issues appeared.

Several examples of the confusion are evident in the extract. In Clause 15, the teacher opened her explanation with *So we've talked about potential energy*. She then expanded with the definition in Clauses 20 and 21: *That's one kind of potential energy and it's all inside, stored, ready to be used.* When she introduced kinetic energy in Clause 22, she again began her statement with the regulative register: *Now we're going to look at the energy that is making the work go on.*

Regulative register	Instructional register
So we've talked about	potential energy. That's one kind of potential energy and it's all inside, stored, read to be used.
Now we're going to look at	the energy that is making the work go on.

The relationship expressed between the two kinds of energy was not a scientific one; it did not reside in the instructional register. Instead the two types of energy were related only through a shared regulative register: they had a sequential relationship only in that the class had talked about them and looked at them in turn.

Not only is the relationship between potential and kinetic energy important, but the relationship between kinetic energy and work is central to understanding energy transformation. By means of a transducer, potential energy is changed into kinetic energy to enable particular types of work. As the kinetic energy increases, the potential energy decreases and work is enabled (e.g. CEC 2006; EIA 2008; NEED 2013; Wikipedia 2013a). The causal relationship between kinetic energy and the ability to do work was hazy and inconsistent in the extract above. Clause 6 suggested a simple temporal relationship; that kinetic energy and work happen simultaneously: *when the work is going on.* In contrast, Clause 22 suggested a causal relationship: *the energy that is making the work go on.* Furthermore, the scientific notion of 'work' differs from the commonsense: to a physicist, work is movement. At this point in the topic, there was no explicit redefinition of this concept.

Each of these messages about energy in the extract above was an attempt at using bridging terms that the students would understand. However, the terms were not sufficiently consistent or clear. While the research team had carefully developed definitions of potential and kinetic energy, no thought at this point had been given to describing the relationship between them, nor in sorting out in our minds the relationship between kinetic energy and work. This was evident in the lack of consistent language used in the explanation. These difficulties reinforce once again the need for conscious attention to teacher language and understanding while planning so that such confusions are less likely to arise.

-The distinction between concrete objects and abstract concepts. The second issue in the extract is the evident difficulty in distinguishing between concrete objects which used energy, and the abstract notion of energy. This proved to be a recurrent issue throughout the topic.

The first example is evident in Clause 23 with the statement *we're going to look at things that move, motion energy*. Transitivity analysis of the clause gives some indication of why this statement muddied the relationship between participants here. In the following and subsequent grammatical analyses, words in brackets are ellipsed and inferred.

Behaver	Pr:behavioural	Phenomenon
We	're going to look at	things that move, (that is) motion energy.

The nature of oral language means that ellipsis is common: language can be omitted when the meaning is expected to be evident to the listener from the context. Such is the case in this instance, when the first clause *We're going to look at things that move* was followed by one noun group on its own, *motion energy*. The question then arises about what words should have been inferred from the ellipsis. The most logical conclusion is *that is,* part of the same noun group, a rewording of the Phenomenon. This choice, however, presents a problem because *things that move* and *motion energy* are not the same phenomenon. There is a scientific relationship between the two, but they are not equivalent. The first phenomenon, *things that move*, is a concrete generalisation while the second, *motion energy* is an abstraction. This is the first of many instances of an ambiguous relationship between concrete objects, users of energy, and kinetic energy itself. The issue can be summarised as confusion about the relationship between energy, work and transducers, and a lack of attention by the research team to the specific language needed to explain this relationship.

The confusion between concrete and abstract participants was compounded as the explanation continued. The analysis of Clauses 30 and 31 is provided below. Together the clauses were a reconceptualisation of Jo's single word answer *Car* (Clause 29). The teacher took the student's response and elaborated and reframed it in scientific language. The analysis of her response points to how it both aided and hindered the target learning.

Clause 30	**So**	**the chemical potential energy**	**has**	**been stored**	**in the tank**
Transitivity		Goal		Pr:material	Circumstance
		MOOD		RESIDUE	
Mood	Adjunct: conjunction	Subject	Finite	Predicator	Adjunct: circ
Theme		THEME	RHEME		

Clause 31	**now**	**it**	**'s**	**making**	**the car**	**move,**	**motion energy**
Transitivity		Actor		Pr:material	Goal	Pr:material	Actor? Goal?
		MOOD		RESIDUE			?
Mood	Adjunct: conj	Subj.	Finite	Predicator	Complement	Predicator	Subject? Complement?
Theme	THEME		RHEME				?

Clause 30 supported the topic learning goals in that the teacher's language choice modelled the use of a verb in the passive voice, already identified as one of the language goals for the topic. The use of passive voice by the teacher meant that the Goal of the sentence, *chemical potential*

energy was also the Subject in Theme position, and the Actor, responsible for the action of storing was removed completely, thus appropriately depersonalising the clause. The use of passive voice was an important introduction to new grammar.

At the same time, the utterance caused confusion, with the first problem arising in Clause 30. When referring to the *chemical potential energy*, the teacher had in her mind fuel or petrol. However she overlooked making this link explicit. For the explanation provided in Clause 30 to make sense, the relationship between petrol and potential chemical energy and the (petrol) tank needed to be explicated. It was not always easy to anticipate where teacher assumptions might cause confusion. It was only after the event that the difficulties became evident. Such problematic assumptions became identified in research team discussions as 'leaps of faith'.

Further confusions between abstract and concrete participants in these clauses were caused by ambiguous pronoun reference. In Clause 31, the Actor *it* seemed to refer back to the Goal of the previous clause, namely *the chemical potential energy*. The reference was misleading, because potential energy, by definition, could not be an Actor in making a car move. An interim step in the transformation process was missing. Potential energy had first to be changed into kinetic energy. The reconceptualisation needed further expansion, explaining the energy transformation that enabled the work of running the motor and the wheels.

The final problem in teacher talk appeared when, in Clause 31, the teacher added *motion energy* to the end of her explanation. Its function was not clear. It may have been a correction of *it*, the Actor/Subject in the clause so that it now referred to kinetic rather than potential energy. It may alternatively have been a rewording of the Goal/Complement *the car*. Either way, this extension of the noun group did not help new learners understand the process of energy transformation.

In the complexity of teaching and learning and managing a class of young students, each of these language choices passed in a second, easily glossed over. However, the accumulative effect was unlikely to help student understanding of new complex and abstract new learning. Having analysed teacher talk turn by turn, clause by clause and almost word by word, it must be stressed that the pedagogic confusion made evident in this analysis is not aimed at discrediting the teacher. Rather, the extract serves to demonstrate just how vital premeditated and conscious language choices are in representing inter-related scientific concepts within the instructional register. Indeed, the lack of clarity in this lesson provided the impetus for more conscious attention to the focus texts in the following lessons. Particularly for the lay science teacher, when the scientific topic knowledge was not strong, careful attention to both the commonsense bridging language, the technical language and the causal relationships needed to be even clearer for the scaffolding strategy of reconceptualisation to achieve its goal.

4.4.1.3 Extract 2: introduction to potential chemical energy in the battery

In the second Extension stage, the four demonstration activities were introduced. The teacher introduced the battery-operated propeller, drawing on Focus Text 1 for the first time, and attempted to make links between the *process* of connecting an electric circuit with the *principle* of energy transformation.

To introduce the battery-operated propeller, the equipment, consisting of a battery, and a small propeller and a motor with wires attached, was on the carpet for all to see.

Figure 29. The teacher introduces the battery-operated propeller materials

By this stage in the lesson, the students had been sitting on the floor for 45 minutes, and were restless. They were also excited at the sight of the novel materials displayed in front of them, including chicken wings, a battery and propeller, a cotton-reel toy and the marble run. These circumstances created the imperative for the teacher to introduce the activities as quickly as possible, and organise the students into groups so that they were doing something active. At the same time, she attempted to briefly explain how the concepts of potential and kinetic energy introduced earlier in the lesson were relevant in each of these objects.

Introduction to scaffolding strategies employed in Extract 2

-Reconceptualisation of student answers. Once again the teacher responded to student questions in a manner that reframed and shared important knowledge and language choices with the whole class.

-Joint construction of a coherent piece of text. Joint construction becomes possible through the process of effective reconceptualisation which broadcasts for the students what is significant about the activity in which they have been participating. The ability for students to participate in joint construction of a text is both an indication of successful handover, as well as a useful strategy for maintaining positive affect in the classroom. It invites students into the discourse by

confirming that it is not only the teacher who can contribute to maintain meaningful conversation around the topic. Gray explains the process in the following way:

> *Joint construction of text is the next step from effective reconceptualisations. It enables students to share in the production of coherent and logical texts by contributing their partial knowledge to a group text. Joint constructions create the basis from which the teacher moves the students towards constructing monologic explanations and other elaborations. The students can move towards joint construction of the conversation if the teacher allows multiple responses by the students to questions and encourages students to elaborate and expand upon other students' responses.*(Gray, B. 2007:49)

-Introduction and reinforcement of language from the relevant focus text. Each of the activities was built around a focus text composed by the research team to guide the language development in the class. The teacher had the task of introducing language and grammar from this text as she introduced the activity. The focus text for the battery-operated propeller was introduced in Chapter 3 (Section 3.5.4, p107) and is repeated here:

> *When the wires aren't attached, the potential chemical energy is stored in the battery, waiting to be used. When the wires are attached to each end of the battery, the potential chemical energy in the battery changes to kinetic electrical energy to make the motor and the propeller move.*

Introduction to issues apparent in the development of intersubjectivity

Extract 2 to follow expands on the issues faced by the lay science teacher when trying to change her conscious focus from simple provision of activities to science activity embedded in language.

-Role of the regulative to orient to the scientific. Gray identifies the important role of the regulative register, not just to regulate classroom activity, but to orient students to the activity system to which they were being apprenticed (Ch 2, Section 2.4.2, p66). Following from this, one of the scaffolding principles established within the study was for the teacher to *use the regulative register to orient students to the role of the scientist* (Section 3.5.3, p104). Extract 2 demonstrates an attempt by the teacher to use the regulative register to extend student orientation beyond the behaviours expected in the classroom towards scientific behaviour through her deployment of the regulative register.

-Issues with contingent speech function choices. The importance of speech function choices was identified as an important scaffolding principle: the declarative, that is giving information, is a frequent choice when information is new and common knowledge scant. The next appropriate level of scaffolding is the interrogative, a preformulated question then accompanied

by a reconceptualisation. A less scaffolded choice is the command, when the teacher uses the imperative to elicit information from the students. To make contingent choices on the spot is not easy. Extract 2 highlights how the teacher's use of commands, questions and statements in this first lesson may not always have been the most appropriate when intersubjectivity was low, with students not likely to understand the purpose of these choices.

-Issues with exophoric reference items. This chapter has already described the paradox for teachers of trying to develop student language whilst they are at the same time engaged in hands-on activity. Extract 2 exemplifies this issue, particularly when the novelty of new materials created a sense of heightened anticipation and excitement in the class and the student attention was on concrete artefacts, not language.

The extract begins when the teacher placed the battery, a familiar object, on the floor in the middle of the circle (illustrated in Figure 29 above):

Turn	Speaker	Clause	Utterance
200	Teacher		(Puts battery on floor.)
		6	Tell me about this.
201	Students	7	It's a battery.
202	Teacher	8	And now being scientific,
		9	what can you tell me? Josh?
203	Josh	10	It holds the energy when you need it.
204	Teacher	11	Yes, so what kind of energy is that?
205	Nadif	12	Um, /ka/ //
206	Teacher	13	//Po…tential energy.
207	Nadif	14	//potential energy.
208	Teacher	15	Stored inside of it.
			I want to change that potential energy Elijah to movement energy, to kinetic energy.
			So what I want to move is the propeller.
209	Student	16	Yes!
210	Teacher	17	So I need to create a circuit around the battery
		18	so that the energy can flow through the wires
		19	and make the propeller work.
			(Clauses 20-22 omitted)
211	Students	23	Oooooh. (Sounds of admiration as propeller goes around.)
212	Elijah	24	Do it again.
213	Teacher	25	So energy in here making it work, okay?

Scaffolding strategies employed in Extract 2

-Reconceptualisation of student answers. In Clause 14, Nadif identified the energy in the battery as *potential energy.* The teacher reconceptualised in Clause 15 with the commonsense bridging terms which described potential energy, *stored inside of it.* The reconceptualisation provided yet another opportunity to broadcast the new information, thereby building common knowledge about the meaning of this technical term.

-Joint construction of a coherent piece of text. The example of joint oral text construction (Clauses 7-15) was prompted by the teacher, with contributions from three students. It began in Clause 7 when several students named the object: *it's a battery*. The teacher prompts in Clauses 8 and 9 led to further expansion by Josh in Clause 10: *it holds the energy when you need it.* A further prompting question *So what kind of energy is that?* (Clause 11) elicited a hesitant naming by Nadif of the type of energy, *potential energy*, further reconceptualised and concluded by the teacher with the bridging terms *stored inside of it.* Alexander identifies this kind of questioning used as part of joint construction as 'cumulative questioning', intended to *guide and prompt, reduce choices, minimise risk and error, and expedite the 'handover' of concepts and principles* (Alexander, R. 2005:12).

When contributions from all four contributors were combined, the joint text was something like *A battery holds potential energy when you need it, stored inside.* At this early stage in the topic, with low levels of intersubjectivity, the joint construction was strongly teacher-led. Nevertheless, it was a pedagogic strategy that allowed the teacher to monitor student handover, to affirm and build on student partial contributions, and to provide opportunities for students to try out new vocabulary.

-Introduction and reinforcement of language from the relevant focus text. Several relevant technical terms were used by the teacher during this first brief introduction to the battery-operated propeller. *Potential energy* and *kinetic energy* were re-used, while *battery, propeller, wires,* and the verb group *make (the propeller) work* were introduced.

Issues in the development of intersubjectivity

--The role of the regulative register in orienting to the scientific. The inclusion of Clause 9 *being scientific* provides an example of the teacher's efforts to use the regulative register to orient students to what it means to behave 'scientifically'. The clause *being scientific* was a preformulation; a prompting statement intended to orient students to how to approach the question to follow. It was an attempt to shift the focus from the commonsense identification of the battery to its scientifically understood purpose, to mark the boundary into science, an

intention Bernstein would have supported (1990:206). An analysis of this preformulation and the following question provides the following information:

Clauses 8-9	Being	scientific,		what (about this battery)	can	you	tell	me?
Transitivity	Pr:relational	Attribute		Circumstance: Manner		Actor	Pr:verbal	Goal
	RESIDUE			RESIDUE	MOOD		RESIDUE	
Mood	Predicator	Subject		Wh/ complement	Finite	Subject	Predicator	Complement
Theme	THEME	RHEME		THEME	RHEME			
	THEME			RHEME				

Doubt must be cast on the effectiveness of two aspects of this question at this early stage of the topic when intersubjectivity was low. The first is the dependent non-finite clause (Clause 8), foregrounded in Theme position, requiring a particular 'state of being'. What attributes did 'scientific' imply? The second is that, through these two clauses combined, students were being called on to 'tell scientifically'. How might this differ from previous telling? The lack of explication of the meaning of 'scientific' in this context meant that such a cue would not provide useful guidance about a scientific state of being.

-Issues with contingent speech function choices. The trouble in the question above was compounded by the absence of additional scaffolding in the second clause *what can you tell me?* (Clause 9). In Theme position was the interrogative what, conflating both the regulative and instructional registers. In its regulative role, 'what' required a response from students, rather than inviting a response. 'What' also had a role in the instructional register, acting as a marker for information about the energy in the battery. It was part of a circumstance of manner, with the remainder of the circumstance ellipsed: *what (about potential chemical energy in the battery)…* However, in this low intersubjective context, with the abstraction of potential chemical energy only recently introduced, no further clues were provided about exactly what response was appropriate for this question. Beyond the exhortation to be scientific, the intention of the question was assumed.

Both preformulation and question were non-specific, and in this early phase in the topic, further orientation was needed. Both clauses were likely to create difficulties for the students least oriented towards this scientific activity. Surprisingly then, the question elicited a coherent answer from one student who seemed to have some prior knowledge on the subject: *It holds the energy when you need it.* The answer enabled the teacher to continue with the joint construction already described above despite the absence of shared knowledge about the content.

-Language restricted through exophoric reference items. It was proposed earlier in this chapter that 'hands-on' activity created risk for teachers committed to teaching language as an intrinsic part of the science curriculum, because situated language shared the meaning-making demands of the context with other contextual features. One example of that difficulty was

evident in this extract. At this point, the teacher had joined the wires to create a circuit, and the motor had driven the propeller as expected. The teacher summarised the process in the following manner in Clause 25:

Clause 25	so	energy in here	(is)	making	it	work.
Transitivity		Actor		Pr:material	Goal	Pr:material
		MOOD		RESIDUE		
Mood	Adjunct: conj	Subject	Finite	Predicator	Complement	Predicator
Theme	THEME		RHEME			

The Actor in this summary was *energy in here*. When compared with the focus text presented above, important information had been ellipsed. *Energy* needed to be expanded to *potential chemical energy* and the term *here* was exophoric; that is, it pointed outside the text to the context. By using this pronoun, the teacher missed the opportunity to reinforce the name of the battery and link it with *potential chemical energy*. The second example is the Goal *it*, a singular third person pronoun. The referent of this pronoun was unclear: did *it* refer to the propeller which all students were watching, or did *it* refer to the phenomenon of energy transformation in the battery, the motor and the propeller? While choosing such exophoric reference items in that hands-on context was the natural thing to do, it had adverse consequences. When the appropriation of new language is an important learning goal, both of these examples, although making sense in the context, reduced the number of exposures for students to hear the new target language and begin to understand the distinction between the observable processes and the abstract concept of energy.

It must be pointed out that, given the excitement of the students and the time pressures previously mentioned, what the teacher had said at this point would probably have made little difference! The teacher was trying to explain just enough that students could successfully manage the activities and have a rudimentary understanding of the energy transformations taking place. Nevertheless, the issues identified once again underline just how the teacher's language choices in the moment either supported or worked against her intentions. Interactive trouble not only caused confusion that had to be repaired, but it also threatened the positive affect in the classroom. It was not efficient. The analysis provided so far demonstrates how careful and conscious attention to language choices in both the regulative and instructional registers might have reduced the likelihood of interactive trouble which would need to be repaired at a later date.

The final extract from this first lesson comes from the third Extension stage, where the students rotated in groups of three to try out each of the four demonstrations of energy transformation. This extract introduces three boys participating in the battery and propeller demonstration. The

extract provides insight into their use of language during the first attempt at these hands-on demonstrations previously introduced to the whole class on the floor.

4.4.1.4 Extract 3: small group battery-operated propeller activity

The purpose of including the following extract is twofold: firstly to demonstrate the low level of understanding about this activity from a scientific perspective, evident in the ways the three boys in this extract interacted with the artefacts. Secondly, the extract shows how the teacher responded to the lack of common knowledge in an inclusive manner that patiently continued to work towards developing intersubjectivity.

Introduction to scaffolding strategies employed in Extract 3

-Deflecting the social agenda. Educationally marginalised students engagement with school is often social, or, in Tomasello's terms, dyadic (Tomasello, M. & Malinda, C. 2007). One of the ways in which they are marginalised is that they don't share academic goals with the education system. As already explained in Chapter 2, the lack of shared educational goals makes the interpersonal relationship between teacher and students fundamental to students being willing to engage in the unfamiliar. But positive relationships are not sufficient for the move to academic intersubjectivity. The challenge for the teacher was to maintain positive affect while redirecting and extending student engagement into the academic. This is achieved significantly through language, but in this case the teacher also used non-verbal means to consolidate the same message.

-Use of specific questioning techniques checked for handover and reconceptualised, elaborating on student answers.

-Respectful invitation into the discourse through acknowledgement of student contributions. As common knowledge was established, students began to make relevant contributions to the class dialogue. Along with the use of first person plural, 'we', the teacher's affirmation of these contributions was important for building a learning community within the class.

Introduction to issues in the development of intersubjectivity

-Confusion caused by the well-intentioned distinction between procedure and principle. The research team had been discussing Edwards and Mercer's caution about progressivist classrooms attending to ritualistic procedural knowledge about scientific activity, rather than extending classroom talk to the principles demonstrated by the activity (Edwards, D. & Mercer, N. 1987: Ch 6). The teacher was conscious of making sure the students were not just talking about what they had done and what had happened, but about the energy transformation that enabled the movement to happen. The distinction between process and principle, and the confusion caused by this distinction, is evident in Extract 3.

-Use of unpreformulated non-specific questions. The contingency of particular speech function choices was once again a point of concern.

Immediately prior to this extract, the boys had been working in a group without the teacher, trying to get the wires attached to the battery and the propeller working. They used 'trial and error', physical activity, and were completely silent with no language at all to mediate the activity. One of the boys had given up and had sat down, while two boys were finally successful. The first response to this success was an exclamation *You're doing it*, along with some propeller sounding noises, followed by *Cut my T-shirt* and *Do it to me!* These responses were not the ones that would immediately come to mind if the boys had been operating within the discourse of science. The teacher arrived to the scene shown in Figure 30 below:

Figure 30. Cut my T-shirt

Turn	Speaker	Clause	Transcription
13	Teacher	1	What's going on?
		2	Oh, let's start again
		3	and tell us what's happening (looking at battery and propeller).
			(Turns 14-20 omitted.)
21	Nadif	4	When we put it together
		5	you put both of them on both sides and (?).
22	Teacher	6	But where do we get this movement from?
23	Alan	7	Inside the…//
24	Elijah	8	//Energy//
25	Alan	9	//Inside the um…//
26	Nadif	10	//Inside the.. (looks at battery)

27	Teacher	11	Ah (looking at Elijah), so what kind of energy is that? (Elijah shrugs.)
28	Nadif	12	Pot… (smiles, can't remember rest of word.)
29	Teacher	13	(Nods). Nadif was a really good listener down there on the floor, wasn't he?
		14	Potential. (Elijah fiddles with battery.)
		15	It has the potential to do some work.
		16	And so what does potential energy mean? (Takes battery out of Elijah's hands.)
33	Nadif	17	It can do work that (?)
34	Teacher	18	So it's stored inside of it.
		19	Chemical energy is stored inside of here (points to battery)
		20	and we can change it by what you're saying Nadif (hands battery back to Elijah)
		21	to connect the wires
		22	and make a circuit. (Elijah and Nadif together get the propeller working again.)

Scaffolding strategies employed in Extract 3

-Deflecting the social agenda. The teacher understood the imperative to build and maintain strong and positive relationships between her and students. At the same time, she wanted to convey the important message that 'We're here for the learning'. She did not waste time in the classroom on minor misdemeanours that side-tracked the learning conversation. Clauses 1-3 provide an example of this strategy. When the teacher arrived, Alan was busy trying to cut up Elijah's shirt. The teacher opened the conversation with *What's going on?* The teacher's ambiguous question served two purposes: firstly, as part of the regulative register, it suggested that the boys might have been up to something they shouldn't. In the instructional register, it requested information about the activity. That one ambiguous question was the end of the behaviour management. She did not probe to find out who had done what, she did not reprimand. Instead, in Clause 2 she dismissed any issue with *Oh, let's start again* and in Clause 3 drew their attention back to the activity with *Tell us what's happening.*

The teacher's eye movement also conveyed the strong message that there was work to be done. Accompanying Clause 3, her eyes were drawn, not to the boys, but to the battery and propeller. Her attention was on the work at hand. Later in the extract, Elijah was fiddling with the battery and wires while the teacher tried to focus on energy matters (Clause 17). Elijah had at this point not contributed to the discussion except for a shrug. Without any sort of verbal reprimand or eye contact, the teacher took the battery out of Elijah's hands, conveying the message that his

attention should be on the conversation. She handed the battery back once the discussion had finished. When scientific engagement and boundary crossing into scientific discourse are so tenuous in a class of marginalised students, the avoidance of wasted time on behaviour management, and the persistent drawing of attention to learning activity have an accumulative effect which helps to shift the focus of attention to academic learning.

Use of questioning to check for handover. In Clauses 7-10, the three boys together identified energy in the battery as the source of the propeller's movement (although none of them could name the battery, identifying it only by their gaze). The teacher responded with an extending question to expand on their answer: *So what kind of energy is that?* She got a partial response from Nadif, *pot…* (Clause 12). What followed in Clauses 14 and 15 was a reconceptualisation, where she once again provided the definition *It has the potential to do some work.*

The teacher didn't stop there however. The fact that Nadif could provide one syllable of *potential* was not evidence of strong handover. So in Clause 16, she asked the boys once again for the definition of potential energy. In some classrooms this would be unexpected. After all, the teacher had just provided this answer. However, this was a common strategy used by the teacher. It provided the opportunity to extend the use of new language to other students.

Nadif's hesitant answer in Clause 17, *It can do work that…* showed that his understanding was still not strong, so in Clauses 18-22, the teacher once again patiently reconceptualised, expanding on potential energy, using the term chemical energy, and explaining how it was changed by connecting the wires. The scaffolding sequence outlined above followed the guidelines proposed by Wood: if the child succeeds, offer less help, if the child doesn't succeed, offer more help (Wood, D. & Wood, H. 1996:396). There was no acrimony because the boys could not answer; no frustration on the part of the teacher. She just chose once again what she thought was the contingent level of scaffold, and that was to once more provide the information.

Respectful invitation into the discourse through acknowledgement of student contributions. One of the reasons that students and teacher persevered through the evident interactive trouble (to be discussed below) was the capacity to capitalise on the previously established goodwill in this class. While she was grappling with the teaching of these new concepts, the teacher still managed to continue the conversation in a way that was respectful of students and their contributions.

One simple example was her response to Elijah's first and only contribution of *Energy* in Clause 8. In Clause 11 she responded with *Ah!,* sounding both interested and excited at this answer. Elijah was on the right track. Her positive response served to encourage continued participation, rather than dismiss the answer because it was only partial or reprimand Elijah because he had not engaged sufficiently in the discussion to that point.

The second example of her respectful inclusion was the way the teacher incorporated partial student answers into her expanded reconceptualisations. In Clauses 4 and 5, Nadif had tried to explain the process of creating a circuit. While the meaning was evident from the context, he had very little language to help: *When we put it* (the circuit) *together you put both of them* (the wires) *on both sides* (the battery terminals) *and (?).* The teacher was able to include Nadif's attempted explanation later in the discussion (Clauses 21-22), and expanded it with her own: *Chemical energy is stored inside of here (points to battery) and we can change it by what you're saying Nadif, to connect the wires and make a circuit.* In this instance she attributed the information about connecting wires to Nadif, reconceptualising at the same time to provide the language to name the objects. The effect of these strategies was to acknowledge and validate some very partial answers and their contributors as part of the growing body of common knowledge in the class.

Issues in the development of intersubjectivity

-Confusion caused by the well-intentioned distinction between procedure and principle. One of the principles of questioning in this study was that the teacher's level of preformulation should be such that she could always affirm the student's answer, at least partially. Hence the unusual appearance in Clause 6, a response question, of the conjunction of exception *but*, signaling a rejection of the answer. The response arose because the teacher had in mind the imperative to avoid talking about procedure, which was easy to describe, and focus on the energy transformation principles behind the procedure. Hence, Nadif's explanation in Clauses 4-5 didn't match with what was in her head. He described the procedure, not the principle: *When we put it* (the circuit) *together you put both of them* (the wires) *on both sides* (the battery terminals) *and (?).* The teacher wanted to discuss energy, hence the question in Clause 6 *But where do we get this movement from?* This counterproductive response had the effect of rejecting Nadif's answer and working against her intentions of positive affect. The issue of finding language to distinguish between procedure and explanation of principle continued to be a challenge throughout the topic.

If Nadif's answer was wrong, then the teacher's level of preformulation needed to be reviewed, because it wasn't providing sufficient cueing to 'what was in the teacher's head'. This is the next issue to be discussed.

Use of unpreformulated non-specific commands. The teacher turn which prompted Nadif's procedural talk was an unpreformulated command in Clause 2-3: *Tell us what's happening.* It didn't provide sufficient information about the teacher's intentions: did she want to know what was happening with the battery and the wires and the propeller, or did she want to know what was happening with the potential chemical energy? Either would have seemed a reasonable

assumption. In Bernstein's terms, the question was an example of a weak frame (2000:13), giving the students too much autonomy at this early stage of the topic. Such an open-ended, unpreformulated command might have been sufficient for a group of students with a high level of intersubjectivity around energy transformation, but in this situation it didn't meet the teacher's goal and required repair.

They boys were obviously enjoying themselves in this and subsequent activities. However, their engagement with pseudo-scientific artefacts belonged within horizontal, social discourse. The need to manage the whole class in this rotational hands-on group activity meant that the teacher was not there to contingently mediate the shift from the horizontal to the vertical, from common-sense to academic. She wasn't there to support with new language.

The small group Handover stage from which this extract was taken had high energy and engagement, lots of hands-on activity and children talking in an animated way; it was very child-centred. From a Vygotskian activity theory perspective however, the students were engaged in activity, but it could not be counted as science, even with the presence of scientific artefacts. As one observer said 'They might as well be at the circus'. Three important elements of discourse activity; motivations, goals and means (language and thinking) were not aligned with the world of science. In the instance of the battery-operated propeller, the boys' motivations were to have fun, the goal was to cut up each other's shirts, and the means were unprincipled trial and error. For the boys, the purpose was at odds with that intended by the teacher. The activity had a social, rather than an academic purpose. Engeström calls an activity devoid of shared goals a 'task' (Engeström, Y. 1987:28). In other words, it was not clearly aligned with any shared activity system.

Lesson 1 summary

By the end of Lesson 1, intersubjectivity around energy transformation was still low. The teacher had begun the move from the highest scaffold of providing information, that is 'telling', to asking questions, and the students had begun to answer. There were instances where, under the stress of managing an excited class, the teacher had reduced the scaffolding too quickly. She shifted from making statements to commanding, while still struggling with the language of energy transformation. The hands-on activities had been very popular, producing a high level of energy in the class, and lots of student talk. This stood in contrast to the previous stages of the lesson where the teacher had dominated. A progressivist teacher would have been proud of the last stage of the lesson. However, to the scaffolding teacher, the language used by the students was commonsense, not scientific. Students were approaching the activities as entertainment, not science. It signaled that there was a way to go to cross the boundary into scientific discourse.

When reflecting later, the teacher suggested that we would have to wait until the novelty of these new materials wore off before real language learning could take place.

4.4.2 Lesson 2: reviewing energy transformation in the battery-operated propeller

Lesson 2 took place seven days after the previous lesson. The purpose of Lesson 2 was handover. Lesson 1 had introduced a considerable amount of new content, and student understanding needed to be monitored and consolidated. No new content was introduced in the second lesson.

Two extracts are provided from Lesson 2, both focusing on the battery-operated propeller activity. The first, Extract 4, is part of the first Handover stage, revising potential and kinetic energy. The second extract, Extract 5, comes from the second Handover stage. While the rest of the class worked on simple worksheets, the teacher took groups of three students at a time onto the carpet to revise the four energy transformation activities and accompanying language from the previous week. The same group of three boys from Extract 3 is the focus of this extract.

Table 24. Stage, purpose and grouping arrangements of extracts from Lesson 2

Extract	Lesson Stage	Purpose	Grouping arrangements
4	Handover 1	The teacher revises the concepts of potential and kinetic energy	Whole class
5	Handover 2	Students revise the battery-powered propeller activity	Group of three

4.4.2.1 Student talk in Lesson 2

The principles of contingent scaffolding require that the teacher reduces support when less is required. If pedagogic strategies are to be constituted as scaffolding rather than other dependent forms of help, then a change in the proportions of teacher and student talk should be observable as the locus of control gradually moves from teacher to student.

The increasing contribution from students is observable across the stages of Lesson 2. The clauses of student talk increased from 25% in the initial whole class Handover stage to 53% in the small group Handover stage, the final stage of Lesson 2.

Table 25. Clauses of student talk as % of total clauses of classroom dialogue in Lesson 2

	Handover 1 Whole class	Mode Shift Whole class	Handover 2 In group
Student initiations	8%	8%	7%
Student responses	14%	16%	17%
Joint constructions	2%	15%	29%
TOTAL STUDENT CONTRIBUTIONS	25%	39%	53%

The table shows that there was almost no change in the quantity of student initiations across stages. However, the quality of student initiations was beginning to change. Some socially oriented initiations still appeared: *Mei Ling, come and sit here,* as well as comments that demonstrated the commonsense, rather than scientific orientation of students: *You're hotwiring it, you're hotwiring it.* However, when compared with the initiations in Lesson 1, many more were focused on the scientific activity in front of them: comments such as *It's moving on its own;* hypothesising such as *but what if you…;* and explanations: *If you move your muscles, that's making your muscles work.*

Teacher questions and student responses remained at approximately the same percentages throughout the lesson. The responses demonstrated the beginnings of students attempting to appropriate new technical language, although they struggled with the grammar at this stage. For example: *Potential energy is when energy is going to rest and ready to use* and *It was using energy what was inside of the thing.*

While the percentage of teacher questions and student responses remained the same across the stages of the lesson, teacher statements from the first to the final stage decreased from 58% to 31%. This change is an interesting phenomenon. Teacher statements appeared in two roles. Many were opening statements, but they were also responses; that is reconceptualisations of student answers, broadcasting important information to develop common knowledge. Teacher reconceptualising statements in the first stage of the lesson re-emerged in the final stage of the lesson as part of joint constructions by students and teacher. The percentage of joint constructions increased from 2% in the first stage of the lesson to 29% in the final, small group stage, in inverse proportion to the decrease in teacher statements.

The growing contribution of students is even more apparent when comparisons are made across a longer span of time. Table 26 below compares student participation in the small group Handover stage in Lesson 1 with the small group Handover stage in Lesson 2.

Table 26. Clauses of student talk as % of total clauses of teacher and student dialogue in small group Handover stages, Lesson 1 and Lesson 2

	Lesson 1 Handover Group of 3	Lesson 2 Handover 2 Group of 3
Student initiations	7%	7%
Student responses	9%	17%
Joint constructions	1%	29%
TOTAL STUDENT CONTRIBUTIONS	16%	53%

The percentage of student initiations in small group Handover stage in Lessons 1 and 2 was still very small; 7%. In contrast, student responses to teacher questions in Lesson 2 were almost double that in Lesson 1, even though this was not matched by a doubling of teacher questions.

The percentage of teacher questioning remained the same. The increase can be explained because students were able to say more. Their responses were expanded, using more than one clause, or providing more than one word answers.

Their increasing capacity is shown most significantly when the percentage of joint constructions between lessons is compared. While the students could not produce monologic 'long turns', they could, with the teacher's cumulative questioning, contribute to coherent utterances relevant to the topic. That is not to say that the quality of their contributions was at this stage always consistent with the target language, but they were beginning to contribute to the meaning making process.

The analysis of Lesson 2 now looks more closely at the changes in classroom dialogue through two extracts. It begins with the whole class Handover stage, when student knowledge about potential and kinetic energy was consolidated.

4.4.2.2 Extract 4: revision of potential and kinetic energy

In the following extract the teacher continued to review the taxonomy introduced the previous week. She was checking for handover of the concepts of potential energy. Figure 31 shows the slide that was displayed on the white board. With the exception of the label 'potential energy', all boxes in the taxonomy were at this point masked.

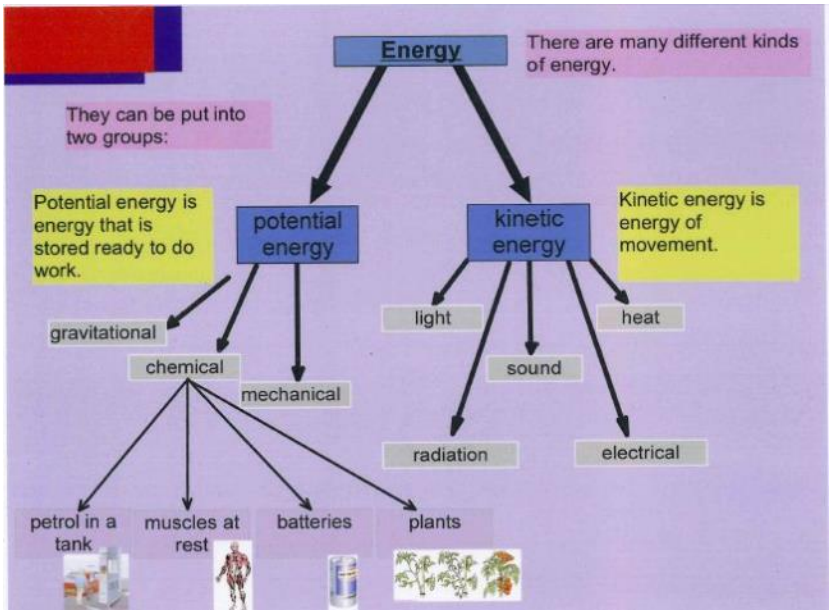


Figure 31. Lesson 2 slide from white board showing the energy taxonomy

The teacher expected some common knowledge amongst the class about potential and kinetic energy as a result of the previous lesson. The 'telling' of the previous week was no longer the predominant scaffold. Instead, the teacher checked for common knowledge by using questions, some of them preformulated, to monitor student handover. She then reconceptualised student

answers as necessary to fill in gaps, to model the appropriate language and orient students further into the topic.

Introduction to scaffolding strategies employed in Extract 4

-Use of non-specific nominations. The use of non-specific participants, e.g. *anyone, someone* rather than naming a specific student takes the pressure off students when intersubjectivity is low. Non-specific nominations mean that the less confident students are invited, but at this stage not required to answer a teacher's question.

Couching demand for information as request for service. Chapter 2 (Section 2.4.1.2, p55ff) explained why 'display' questions are often perilous for marginalised students who have difficulty inferring teacher intent. While the answering of wh- display questions might be a long-term goal of teaching and learning negotiation, their inclusion when intersubjectivity is low serves to further marginalise some students, potentially leading to exclusion and loss of confidence. At the same time, the teacher has to monitor student understanding of the content. Extract 4 includes an example of how the teacher does this in a risk-reducing way. The speech function is a command: the teacher expects information from students. However, the command is made in an incongruent way: rather than being an exchange of information, the question and answer became an exchange of service, couched as the students doing the class a favour by helping. It invited responses rather than expected them and offered agency to students in a way that meant they could pass up the invitation without losing face.

-Reconceptualisations that move students towards stronger classification in the instructional register. Once again, the teacher affirmed student partial answers, and continued to reconceptualise in a way that was more closely aligned with the target language.

-Use of question tags to include students as discourse members. The question tag is an interrogative clause added to the end of a statement which tempers or introduces an element of doubt in the statement (Eggins, S. 1994:155). One consequence of the use of a question tag is that it weakens a statement's impact, seeking backup authorisation from others by inviting affirmation from the listener (Eggins, S. & Slade, D. 1997:86; Jackson, R. & Hogg, M. 2010:2). Affirmation from the listener is evident in the use of Continuatives such as 'yeah' which affirm that the hearer is following and agreeing with what the speaker is saying (Gray, B. 1998:192). The use of the question tag implies that listeners, in this case students, have the authority and entitlement to comment and evaluate on the speaker's utterance. At the same time, in using the question tag, the speaker expects that the listener's evaluation will be aligned with and confirm that of the speaker.

The use of the question tag is an important strategy at levels of low intersubjectivity to guide the direction of the discussion. It has three important effects: firstly it gives the teacher another

chance to tell students something when she suspects that they might not yet be able to volunteer the information as an answer. Secondly, it creates positive affect within the classroom because it implies shared and mutual understanding; that the students will be able to affirm the teacher's statement, and thirdly, the balance of power in the classroom changes in that the use of question tags implies that students have the authority to make the evaluation.

Introduction to issues in the development of intersubjectivity

-Lack of specificity in the instructional register. As with Lesson 1, this extract provides an example of small confusions caused by overgeneralised language evident in the hurley burley of classroom discussion, particularly when the content is new to teacher as well as students.

Turn	Speaker	Clause	Transcription
51	Teacher	1	Yes, so who can help to explain
		2	or describe what potential energy is a bit more?
		3	Mei Ling?
52	Mei Ling	4	Potential energy is when energy is going to rest and ready to use.
53	Teacher	5	Ah, ready to do some work, isn't it? (Reveals definition of potential energy on white board.)
		6	So yes, we know that energy has something to do with power to do work,
		7	and so this kind of energy is just stored ready to do that work.
		8	Did you want to say something else about this one? (Pointing to potential energy definition. Nigel has his hand up and shakes his head.)
54		9	Alright, does anyone want to say something else about this one? (Teacher continues to point to potential energy definition on board and looks at Tammy.)
59	Tammy	10	Potential energy is energy stored ready to do work. (Reads off board.)
60	Teacher	11	Good reading.
		13	Amina?
61	Amina	14	Energy comes from the sun
		15	because by rayses to the earth.
62	Teacher	16	Yes, and now we're talking about the different, Amina,
		17	we're talking about the different kinds of energy
		18	and how we can put them into two groups.
63	Tammy	19	Potential energy and…// (Struggles with kinetic.)
64	Teacher	20	//And yes… Nigel?
65	Nigel	21	Kinetic energy.
66	Tammy	22	Potential energy and kinetic energy.
67	Teacher	23	Kinetic, yes, well done.

Scaffolding strategies employed in Extract 4

-Use of non-specific nominations. Clauses 1 and 9 are examples of the non-specific nature of teacher nominations in this early stage of the topic. In Clause 1 she asked an open 'Who can

help to explain…', and in Clause 9, 'Does anyone want to say something…'. In both cases the role of Sayer was general, available to all students. The effect is that no student was put on the spot, being required to respond if they didn't know the answer.

Couching demand for information as request for service. As the lesson began, the teacher began to cautiously test what students could recall from the previous lesson. Because she was checking for handover, she didn't begin with a high level of scaffold such as a question preformulation. At the same time, direct asking of an outright display question such as *What is potential energy?* would have been a high risk strategy for students just beginning their second lesson on the topic. The grammatical structure of such a hypothetical display question is as follows:

Pedagogic register	Instructional/regulative	Instructional	
Clause 1	What	is	potential energy?
Transitivity		Pr: rel attributive intensive	Carrier
	RESIDUE	MOOD	
Mood	Wh/ complement	Finite	Subject
Theme	THEME	RHEME	
	Topical Theme		

At the level of discourse semantics, this question is a command, incongruently masked as a question. It requires information from participants. It is almost entirely in the instructional register. The exception is *what*, which conflates the instructional and the regulative registers, as it flags the need for information and at the same time regulates the hearer by requiring an answer. The complement, that is the part of the sentence that specifies the knowledge requirement, is foregrounded in Theme position and carries no additional clues for students about exactly what information is required. It is the type of question that is frequently part of knowledge construction in vertical, academic discourse.

The teacher in this instance did not ask such a display question. Instead, she asked non-specific questions such as this one, Clause 1:

Pedagogic register	Regulative				Instructional / regulative	Regulative	Instructional
Clause 1	Yes	So	who	can	help to explain	(a bit more?)	what potential energy is
Transitivity					Pr: mental	Circ: extent	Phenomenon
			MOOD		RESIDUE		
Mood	Adjunct: cont	Adj: conj.	Wh/ subj	Finite: modal	Predicator	Adj: Mood	Complement
Theme	THEME			RHEME			
	Textual	Textual	Topical				

In contrast to the demand for information of the previous wh- display question above, this question was a modulated interrogative. Rather than being part of knowledge construction, it was incongruently presented as part of a service transaction. The verb *help* marks the question as a request for assistance. Instead of the instructional register being foregrounded in Theme, the regulative register, that is the underlined parts to do with student behaviour, was foregrounded in Theme. The instructional register, that is the information about potential energy, was relegated to Rheme, packaged as the phenomenon for which help was required.

The effect of situating the regulative register as Theme changed the intent of the question. It shifted the purpose from demanding a display of information to an invitation to participate in the joint construction of a phenomenon. The choice of *help to explain* rather than *explain* served to maintain the teacher's message that this work was communal. It also suggested that the volunteer answerer did not have to do it all by themselves, just help with the construction. The modality of the verb supported this argument: the choice of *can* rather than *will* implied ability and assumed cooperation. The use of the circumstance of extent *a bit more* modified the required answer. It emphasised that a partial answer was acceptable. Students were only required to help as they could, not provide a complete coherent answer.

While the ability of students to display new scientific knowledge is the end goal of the teaching and learning, it is through these carefully modalised invitations such as this clause that that positive affect is maintained, and students develop trust to offer their first tentative contributions to the class's learning. When intersubjectivity is low, use of the regulative register to invite students into participation, as is exemplified here, carries an important transitional function.

-Reconceptualisations that orient towards tighter classification in the instructional register.

In Clause 4, Mei Ling volunteered the first sign of handover, her definition of potential energy: *Potential energy is when energy is going to rest and ready to use.* She used several new lexical items: *potential, energy, rest, ready, use*. However, she had difficulty with the grammar: *going to rest* instead of *at rest*, and *ready to use* instead of the passive voice *ready to be used.* Nevertheless, the answer was congruent, and the teacher was able to build on this response. She reconceptualised Mei Ling's answer in three clauses (Clauses 5-7), using the interactive white board as support. Her reconceptualisation had two purposes: firstly it extended Mei Ling's answer to include additional information about work. She used the phrases *ready to do some work, something to do with power to do work*, and *ready to do that work.* In addition, she reworded Mei Ling's definition to include passive voice: *this kind of energy is just stored…* These extensions and rewordings served to incrementally strengthen the instructional register, once again signaling to students not just what needed to be said, but also how to say it.

While the reconceptualisation was largely in the instructional register, the teacher used various language resources in the regulative register to maintain positive affect. Her intonation in the clause beginning with *Ah* sounded excited and pleased. She followed that with an emphatic *yes*, and once again used the first person plural *we* to remind students that this was common knowledge.

-Use of question tags to include students as discourse members. The reconceptualisation just described included the following clause: *Ah, ready to do some work, isn't it?* The teacher used this clause to restate and expand the student's definition of potential energy. At the same time, the question tag attached to the end provided a way of including students in the discussion. It affirmed partially formed shared perceptions. The use of the question tag conveyed a sense of belonging. In essence, it implied intersubjectivity on the topic, that *not only do I know, but you know, and I know that you know…* (Sperber, D. & Wilson, D. 1986:18).

Issues in the development of intersubjectivity

-Lack of specificity in the instructional register. While the speech function choices in the regulative register supported the goodwill in the classroom, some aspects of the instructional register did not work so well. Although the regulative register was doing important work in maintaining positive affect and encouraging students to participate, the instructional register was struggling to find a contingent degree of scaffold. For example, in Clause 6, the teacher said that *energy 'has something to do' with power to do work*,. This was a change from the established definition used to introduce energy to the class; *energy 'is' the power to do work*. A transitivity analysis shows the effect of the changes:

The original definition established in the previous term:

Energy	is	the power to do work.
Token	Pr:intensive	Value

The new description used for the first time in this lesson:

Energy	has	something to do with the power to do work.
Carrier/possessor	Pr:possessive	Attribute/possessed

The choice made by the teacher in the midst of classroom activity did not help to tighten the instructional register. While *is* is an intensive verb that defines, *has* is a possessive verb that denotes ownership. In this instance, the specific defining value of *the power to do work* has become less defined, now just one attribute, a description of *something to do with the power to do work.*

The final extract for Lesson 2 comes from the second Handover stage. The teacher was on the floor with the same boys introduced from Lesson 1: Nadif, Alan and Elijah. The group had just

finished talking about the potential chemical energy in their muscles, and the teacher had brought out the battery-operated propeller once again.

4.4.2.3 Extract 5: review of the battery-operated propeller

With the development of common knowledge from previous handover stages, the teacher's and students' talk in this small group setting had begun to change. The extract exemplifies how, still guided by the teacher, the students had begun to take control of the language of the focus text. Together they jointly constructed a relatively coherent oral explanation.

Chapter 2 argued (Section 2.4.2, p65), using Bernstein's terms, that pedagogic framing and classification should have an inverse correlation as meaning and language become shared: as framing moves from strong to apparently weaker (because it is shared and has become inferred), classification becomes stronger (as the language resource becomes internalised and refined). The framing in this stage of the lesson was apparently weaker: the teacher reduced the level of scaffolding in her questioning. At the same time, classification became tighter, as the teacher guided students towards a more aligned use of language from the focus text.

Introduction to scaffolding strategies employed in Extract 5

-Reduced scaffolding in the question structure. A principle developed by Gray is *never to ask a preformulated question when the common knowledge established between teacher and students is such that the students could answer appropriately without it* (Gray, B. 2007:40). The success of students in appropriately answering a number of un-preformulated display questions was evidence of growing alignment between students and teacher.

-Inclusion of an extended jointly-constructed text. Two joint constructions were evident in the extract. In preparation for the activity in which the group was about participate, the teacher first rehearsed the text about energy transformation in the battery and propeller. After getting the battery and propeller to work, the group jointly constructed a second, tighter version of the same explanation, aligned more closely to the focus text.

-Student initiations had become discourse-relevant and followed on from other students unprompted.

-The teacher's reconceptualisations re-appeared further into the extract as part of a student utterance, evidence of student appropriation of language.

Introduction to issues with the development of intersubjectivity

-The use of non-specific generalisations that didn't provide sufficient scaffold. The use of non-specific referents such as 'what's going on' exemplifies, in Bernstein's terms, a 'weak frame'. It leaves the question too open to interpretation for students whose scientific orientation

is still tentative. This was particularly problematic when the referent could be a concrete process, an abstract concept, or perhaps both.

-Difficulties with exophoric reference items exacerbated by hands-on activity. Once again student involvement in hands-on activity demonstrated its influence in truncating language, with meaning generated from the context.

Turn	Speaker	Clause	Transcription
34	Teacher	1	What about if we had this as our example? (Takes out propeller and battery.)
35	Alan	2	It's resting now.
36	Teacher	3	What's resting?
37	Elijah	4	The energy.
38	Nadif	5	The energy is at rest
		6	and it's inside,
		7	it's storing.
39	Teacher	8	Where?
40	Alan	9	In the battery
41	Elijah	10	And it's waiting to be used.
42	Teacher	11	Ah, ready to do that work.
		12	What work can we make it do?
43	Elijah	13	Make it move//
44	Alan	14	// Spin.
45	Teacher	15	Let's see if we can.
46			(Students work together to connect the propeller to the engine and the battery.)
47	Teacher	16	Now can we explain that, what's going on?
48	Alan	17	It's moving
		18	because you're putting the string here.
49	Nadif	19	You're putting the wire in here.
50	Teacher	20	So you're explaining what you're doing really well.
51	Alan	21	And the energy is coming through there, up there, in there
		22	so it can spin.
52	Teacher	23	Okay, now can you explain scientifically what was going on?
53	Nadif	24	When we putted the wires//
54	Teacher	25	So before we had the wires on,
		26	when the battery...
55	Elijah	27	Was at rest (Teacher nods)
56	Teacher	28	Yes, so when the battery didn't have wires on it,...
57	Alan	29	It was making more energy
		30	so it can go faster.
58	Teacher	31	Well what's going on with the battery here first, without the wires on.
59	Nadif	32	It's at rest

60	Elijah	33	Waiting to be used.
61	Teacher	34	What's waiting to be used?
62	Students	35	The energy.
63	Teacher	36	So we can call that...
64	Students	37	Po..tential
65	Teacher	38	Potential chemical energy,
		39	and when we put the wires on...
66	Nadif	40	They start working together
		41	and trying to make it move faster
67	Teacher	42	And that means that the energy, potential chemical energy has changed...
68	Nadif	43	To kinetic energy.
69	Teacher	44	Good, good explanation.

Scaffolding strategies employed in Extract 5

-Reduced scaffolding in the question structure. *What's resting?* (Clause 3); *Where?* (Clause 8); and *What work can we make it do?* (Clause 12) are examples of unpreformulated display questions used by the teacher in this extract. Concerns have been raised in the discussion of previous extracts about the premature use of unpreformulated display questions. Open-ended examples discussed previously, such as *Tell me what's going on…* required as an answer an unspecified extended utterance, requiring considerable control over scientific processes and the language resources with which they were expressed. In contrast, the questions in Extract 5 received successful answers, showing that the level of scaffold was appropriate. The success of these questions can be explained by their tight focus. These cumulative display questions cued students in sequence to specific parts of the clause that the teacher wanted them to construct: an abstract noun, a circumstance of place, and a material process. Together these parts of the clause contributed to a jointly constructed extended utterance which will be identified below.

A more scaffolded form of question appeared when the question was more demanding. In Clause 16, the teacher asked: *Now can we explain that, what's going on?* Overlooking the issues with the non-specific instructional register *what's going on* which will be discussed later, the question used first person plural *we* to share responsibility for the answer, and modalised the verb with *can*, in other words, *is this possible?* The effect of this form of question reduced the risk of a wrong answer by opening it up to all participants.

-Inclusion of an extended jointly-constructed text. Extract 5 exemplifies how the teacher's questioning changed as she prepared students for more extended 'long turns'. Instead of the expected Initiation-Response-Evaluation pattern so prevalent in classrooms, most of the evaluative responses at the end of a questioning sequence disappeared. Only two evaluative clauses appear in the extract: the first in Clause 20: *So you're explaining what you're doing really well.,* and the second at the end of the joint construction in Clause 44: *Good, good*

explanation. Instead, the authoritative roles changed. The teacher still initiated most often, using less preformulated questions. However, the student responses were often followed by the contributions and extensions by other students, rather than by teacher evaluation or reconceptualisation. For example:

Turn	Speaker	Clause	Transcription
35	Alan	2	It's resting now.
36	Teacher	3	What's resting?
37	Elijah	4	The energy.
38	Nadif	5	The energy is at rest
		6	and it's inside,
		7	it's storing.

In the example above, the teacher asked a clarifying question of Alan in Clause 3. This was responded to by Elijah in Clause 4 with *The energy* and further extended by Nadif in Clauses 5-7; *The energy is at rest and it's inside, it's storing*. At this point, the teacher had reduced her scaffold. The boys had taken over more of the language work.

The change in teacher and student roles, enabled by a growth in intersubjectivity, had two effects: firstly it provided the opportunity for students to display their appropriated language, and secondly it changed the power relationships within the group. From the perspective of Pearson's gradual release of responsibility, the group was moving away from teacher control and towards more student control. The reduction in teacher evaluation and the increase in the boys' ability to extend on other's talk was evidence of the change in power. Authority was more shared. Although it was never in doubt that the teacher led the group, the participants behaved more like equal members of scientific discourse. Their focus was on knowledge construction, not on managing relationships or transacting services.

Two 'long turns' or jointly constructed texts appear in this Extract 5. The first (Clauses 2-14), prepared the students for the battery-powered propeller demonstration. When the text is tracked across speakers, it looks something like this:

The energy is at rest/resting and it's storing inside in the battery, waiting to be used, and ready to do the work of moving/spinning.

Colour key: purple: students in chorus; Green: Nadif; Blue: Elijah; Maroon: Alan; Black: the teacher.

In contrast to the teacher monologue of the first lesson, all participants in the group contributed in some way to the construction of this text.

When the group had attached the wires and the propeller was working, the teacher once again led a joint construction. This time, the text needed a dependent clause of time in Theme position. Interestingly, it was Nadif who initiated this in Clause 24: *When we putted the wires//*.

He got stuck at this point, and the teacher stepped in. With some prompting, and cumulative questioning from the teacher, the following text was jointly constructed:

> *When the battery was at rest, when the battery didn't have wires on it, the energy is at rest, waiting to be used. We can call that potential chemical energy. When we put the wires on, they start working together and trying to make it move faster so it can spin. That means that the potential chemical energy has changed to kinetic energy.*

Colour key: purple: students in chorus; Green: Nadif; Blue: Elijah; Maroon: Alan; Black: the teacher..

The joint construction was beginning to approximate more closely the structure of the focus text. It had two phases: process and explanation. It included three dependent clauses of time. There was some appropriate technical language, and one instance of passive voice, *waiting to be used.*

-Student initiations are discourse-relevant. While the percentage of student initiations remained consistent across these first lessons, the content of student initiations changed. Alan, for example, initiated three utterances in this extract: Clauses 3, 7, and 22. In each case the initiations were relevant to the scientific field under discussion, although still needing refinement in language choices. There were no further mentions of hot-wiring or cutting shirts. Students' growing intersubjectivity around language include not only what to say, but also what *not* to say in this increasingly scientific context.

-The teacher's reconceptualisations re-appear as student utterances. One instance in this extract demonstrates clearly how the teacher's words could be appropriated and re-used by students. In the joint construction discussed earlier (Clauses 2-14), the teacher's contribution was an elaboration which introduced the notion of movement as work: *ready to do that work.* She further consolidated the notion of work with an extending question: *What work can we make it do?*

In the subsequent jointly constructed explanation, it was not the teacher but Nadif who extended the explanation with the notion of work. In Clause 40, he said: *They start working together and trying to make it move faster*. Nadif's usage was not entirely consistent with the teacher's: while she had nominalised *work*, Nadif converted it to a verb. Nevertheless, this key word, initially provided by the teacher, had re-appeared, appropriated by a novice speaker.

Issues in the development of intersubjectivity

-The use of non-specific referents. Once again, the teacher's use of generalised non-specific noun groups led to confusion. This is exemplified in the following preformulation and question (Clauses 20-21). The preformulation was an attempt at the 'look back – look forward' scaffold. In the teacher's mind, supported by Edwards and Mercer's argument (1987) that scientific principles should be addressed, not just processes, she was distinguishing between the

observable *process* of making the propeller work (Clause 20) and the abstract *principle* of energy explanation behind the process (Clause 21). This distinction was attempted with only a minor difference in language choice.

Looking back:

Preformulation: look back (*process* of getting the propeller to work)					
Clause 20	So	you	're explaining	what you're doing	really well.
		Sayer	Pr:verbal	Verbiage	Circ: Manner

Looking forward:

Question: look forward (*principle* of energy transformation)							
Clause 23	Okay	now	can	you	explain	scientifically	what was going on
		Circ: time		Sayer	Pr:verbal	Circ: Manner	Verbiage

The distinction between the concrete process and the abstract principle was made through the verbiage and the circumstances of manner. In Clause 20 the concrete process was realised as *what you're doing*, while the abstract *scientific principle* in Clause 21 was *what was going on.* The circumstances of manner added to the confusion: the use of *scientifically* in Clause 23 suggested that explaining the concrete process was not scientific activity, while explaining the abstract principle was. In fact, concrete processes can be explained more or less scientifically, depending on the grammar and word choice used. Such a distinction was likely to mislead and confuse.

The sequence was well intended. Indeed, the guideline of attending to both process and principle as proposed by Edwards and Mercer is one which should be further pursued. This preliminary attempt demonstrates that further work needs to be done to find the right word choices for achieving an effective outcome.

-Difficulties with exophoric reference exacerbated by hands-on activity. Once again the extract demonstrated how student involvement in hands-on activity could truncate language, with its reliance on the context rather than language for creating meaning.

Alan's language choices best exemplify this phenomenon. One extended utterance in Clauses 17-22 included the following, with the exophoric reference items underlined: *<u>It</u>'s moving because you're putting the string <u>here</u>. You're putting the wire in <u>here</u>. And the energy is coming through <u>there</u>, up <u>there</u>, in <u>there</u> so <u>it</u> can spin.* The meaning is evident through his actions. However, without the development of specific vocabulary such as *terminal*, *motor*, and *propeller*, Alan had only exophoric reference to call on. He was reliant at this point on reference to concrete activity and pointing to material objects to assist with meaning making.

Alan's utterances demonstrate how intuitive and sensible it is to abridge language when situated in real-life activity. However, his choices were not going to be effective or help him to

decontextualise when he moved to writing, without concrete materials for reference. To shift along the Register continuum, he had to move from exophoric to endophoric reference where the decontextualised meanings are in the text. The responsibility of the science teacher is to find pedagogic strategies that support that shift. One strategy suggested in this study is to move as quickly as possible from hands-on activity to decontextualised talk about activity, viewing it at arm's length.

The issues evident in the interactive trouble stemmed largely from issues with the instructional register: difficulties in finding the right language with which to distinguish between observable and abstract phenomena. Despite these problems, it is evident that students were beginning to appropriate the target language. They were not always correct, and not yet able to produce extended utterances independently, but nevertheless, willing and able to participate in joint text construction with others.

Lesson 3 continued this work. The next extracts come from Lesson 4, the final of the set of lessons around Focus Text 1. This time the attention had shifted from the battery-operated propeller to the marble run. The three boys from previous extracts were given the responsibility of developing a report on the marble run demonstration.

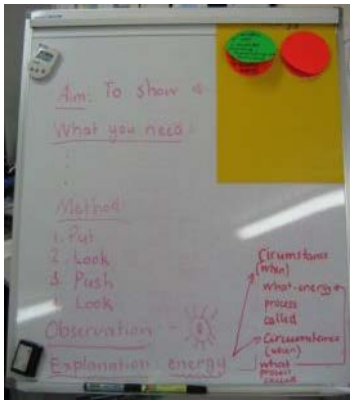
4.4.3 Lesson 4: the master class

The teacher continued to work with the demonstrations of energy transformations and the focus texts across Lessons 3 and 4. Although extracts from Lesson 3 are not included here, it is relevant to note that in Lesson 3, the class began to jointly construct a written scientific procedure concerned with the Chicken Wing demonstration. Significant for the extracts to follow, the procedure included the headings Aim, What you Need, Method, Observations, and Explanation.

In Lesson 4 the structure and headings of the Chicken Wing scientific procedure were revised in a Handover stage. A Mode Shift stage followed, with an experimental class structure: the teacher set the class to work on a simple worksheet while she worked with the same group of three boys; Nadif, Alan and Elijah, to jointly construct a scientific procedure for the marble run demonstration, using the headings introduced in the previous lesson. The purpose was to trial modelling text production with just a small group of students, who would then present their new text to the rest of the class. While not usual in Western societies with their focus on individual performance, the role of 'collective representative' was identified by Alexander in his observations of classrooms in Russia where the student *is in a sense a representative of that class as much as an individual* and where fewer students get to speak each lesson, but produce more extended texts in the presence of their peers (Alexander, R. 2005:9).

The level of scaffold in this part of the lesson had been significantly reduced. The teacher negotiated with the group of boys the headings they needed. These were gradually recorded on the white board:

Figure 32. Scaffolded text structure for Marble Run scientific procedure



The boys were then allocated particular headings on which to expand. Some stages of the procedure were familiar to students from previous genre work. They already knew about What you need and Method. The newly introduced sections were Observation and Explanation. The boys wrote their sections largely independently, while the teacher monitored and supported as needed, particularly for Nadif and Elijah who had the more difficult new sections.

The final written outcomes from the three boys were as follows:

Figure 33. Writing sample 1: Alan's part of the scientific procedure: *Aim,What you Need* and *Method*

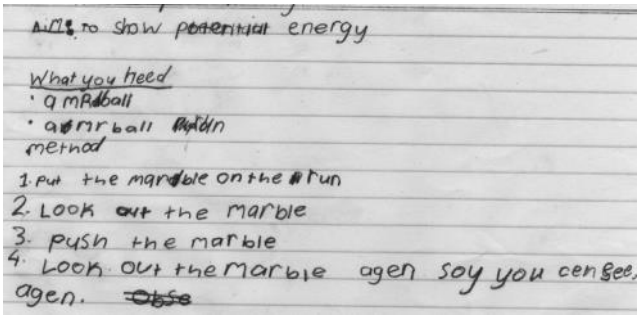


Figure 34. Writing sample 2: Nadif's part of the scientific procedure: *Aim* and *Observation*

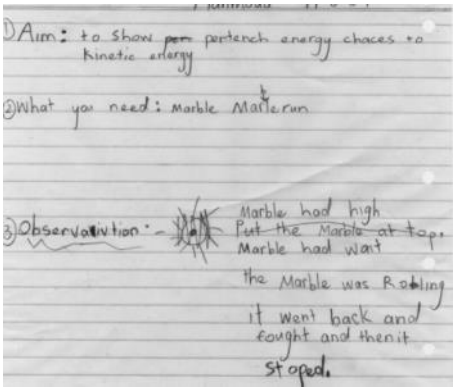
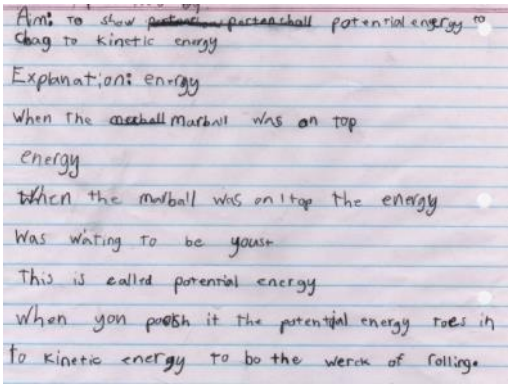


Figure 35. Writing sample 3: Elijah's part of the scientific procedure: *Explanation*



Once the text was complete, a further Mode Shift took place. This time it moved back along the Register continuum, from more decontextualised to more situated. However, as a formal oral presentation, using the written text as prompts, the shift did not return to the most oral end of the continuum. The class was called back to the floor, and the lesson became a type of 'master class'. The boys were introduced as 'three visiting scientists'. Remarkable to the observer was the change in demeanour of these three boys when compared with the first lesson. Figure 36 illustrates their contrasting participation in the Marble Run activity in Lesson 1 and Lesson 4:

Figure 36. Participation from three boys: Lesson 1 cf Lesson 4: Three visiting scientists

In the first lesson, the boys' attention was on the marble. In the fourth lesson, their attention was on the text. The marble and marble run had become adjunct to the centre of the activity which was language production. The photographs in Figure 36 demonstrate a transition from their previous demeanor which belonged in the playground to one appropriate for a scientific presentation.

When Wertsch's activity system elements (1998:32) are compared across lessons in Table 27 below, it becomes clear that while the setting and artefacts are the same, the activities do not belong to the same activity system.

Table 27. Lesson 1 cf Lesson 4: Comparision of activity elements of the marble run activity

Activity elements	Lesson 1	Lesson 4
Action	Largely physical: flick, catch and stamp on the marble	Language: scientific procedure accompanied by some physical demonstration of process
Agent	Three boys	Three boys as presenters, rest of the class as audience, teacher as mediator
Mediational means	Marble, marble run, scant commonsense oral language	Marble, marble run, desk, fomal written text, formal oral language
Setting	Classroom floor	Classroom at desk
Motivation	Entertainment	Information provision
Goals	Stop the marble	Make a coherent presentation, impress their class mates

The setting and concrete artefacts remained largely the same, but the action, mediational means and motivations had changed significantly. Agency too has expanded, with not only the boys themselves, but the teacher and the other students playing important roles in the activity of formal presentation. It is, in Alexander's terms, no longer individualistic but collective (Alexander, R. 2005:5).

The two extracts from Lesson 4 are from the final stage of the lesson, during the master class. Extract 6 shows the interactions around the boys' presentation: the language used by the boys in their presentation, and the role of the teacher in mediating the shift from written text to formal oral presentation.

Extract 7 demonstrates a significant change in teacher talk. Gone were the preformulations and reconceptualisations of previous lessons. At the end of the boys' presentation, the teacher interrogated the class, asking outright display questions to gauge their recall from the presentation.

Table 28. Stage, purpose and grouping arrangements of extracts from Lesson 4

Extract	Stage	Purpose	Class structure
6	Mode Shift	Three boys present their findings about energy transformation in the marble run	Small group presenting to class
7	Handover	The teacher interrogates the class	Whole class

4.4.3.1 Student talk in Lesson 4

It could be anticipated that the amount of teacher talk would diminish at this end of the four lessons: the gradual release of responsibility should have been well underway, and students should have been taking more control. However, when the data are compared across the three

lessons included so far in the analysis, they show a different picture. Table 29 below compares the student participation in this lesson with those that had preceded it.

Table 29. Percentage of student talk in Lesson 4 Mode Shift stage compared with previous lessons

	Lesson 1 Handover Group of 3	Lesson 2 Handover 2 Group of 3	Lesson 4 Mode Shift 2 Group of 3
Student initiations	7%	7%	27%
Student responses	9%	17%	7%
Joint constructions	1%	29%	10%
TOTAL STUDENT CONTRIBUTIONS	16%	53%	44%

While still high when compared with Lesson 1, student participation had decreased from 53% in Lesson 2 to 44% in this lesson.

Student initiations had increased significantly, from 7% to 27% so it is evident that students were more confident and taking more control. Such a shift is necessary for students to successfully produce an independent oral performance. All initiations but one were in the instructional register and appropriate. The increase in student initiations was matched by a decrease in joint constructions. The students were not so reliant on each other or the teacher to help with text production. They were moving towards independence.

The apparent anomaly of a reduction in student participation and the increase in teacher talk in this stage of Lesson 4 can be explained by the teacher's ongoing attention to pedagogic contingency. Although the students were now able to describe energy transformation with some confidence and needed less support in text construction, a formal presentation constituted an increase in challenge: a Mode shift. Students were no longer talking in a small group to each other, or writing for themselves, but making a formal oral presentation to the class. The format was unfamiliar for both presenters and audience. Scaffolding was necessary so that presenters knew how to engage the audience with the use of aids, and so that the audience knew what their role was. Once again the teacher stepped up the support, guiding students in how to behave: for example, to the audience: *Listen to their observation;* and to the speakers: *try and not read it out.*

4.4.3.2 Extract 6: three visiting scientists

Extract 6 spans the boys' presentation of the marble run demonstration.

Introduction to scaffolding strategies employed in Extract 6

-Use of the regulative register by the teacher to orient students to the world of science. Gray argued that the regulative register should be used, not just for managing behaviour and the

scope and sequence of the lesson, but also as to effect the 'mental engagement' of students, orienting them to the goals, roles and intent of the target discourse, in this case science.

In this extract, the teacher began by formally marking the discourse boundary, using the regulative register to signify the scientific importance of this presentation and give the boys authority to present.

-Orientation by the teacher to the process of formal presentations. In earlier iterations of this study, the teacher retreated to the back of the room when students present to the class, sending the message that the students were on their own, that the performance was expected to be independent. This was a dangerous pedagogic strategy, leaving marginalised students abandoned in a high risk setting. In contrast, the teacher in this instance knelt right by the desk, monitoring student performance, and continuing to scaffold both presenters and audience when needed. This was the appropriate organisation for a master class, with the 'expert', that is the teacher, acting as mediator between presenters and audience. She supported the presenters as required, and directed the audience to salient points.

-Elijah's Explanation. The Explanation stage of the boys' text, written by Elijah, and then delivered by him as a formal oral presentation, is of particular interest to the study, because it was the text stage most closely aligned with the focus text. Elijah's presentation is analysed to see which features of the focus text were now appearing in his written/formal oral text.

Turn	Speaker	Clause	Transcription
439	Teacher	1	Three visiting scientists to our classroom today.
		2	Now I can call these people scientists
		3	because they have worked as scientists,
		4	they've recorded as scientists;
		5	they're going to demonstrate to you how they observed and can explain as scientists.
441		6	Over to you scientists. (Nadif reaches for marble run.)
442		7	Before you even pick anything up,
		8	you need to give them some kind of focus of what you're going to be doing, which is called your... Aim.
443		9	So we're looking at the scientists. (Scientists are silent)
444		10	So 'our aim today...'
445	Students	11	Our aim today is *to show potential energy changes to kinetic energy* (reading).
446	Elijah	12	(to Alan) You go first.
447	Alan	13	*What you need.*

			A marble,
448	Teacher	14	And you might hold it up as part of your demonstration.
449	Alan	15	(Holds up marble) *A marble and a marble run.*
			(Alan's presentation continues here, turns 450-461.)
462	Teacher	16	Now… do some observation
		17	and listen to their scientific observation
		18	and see if it's the same thing that you observed.
		19	How accurate are you?
		20	So we'll do it one more time.
		21	Okay, got it in your head?
		22	Now listen to our scientists' observation.
			(Nadif's presentation continues here, turns 463-476)
477	Teacher	23	So can you hear how clear their observation was.
		24	Was your observation like that (to rest of class)?
		25	Okay, and then they need to explain...
478	Elijah	26	*Explanation: energy.*
		27	*When the marble was on top*
		28	*the energy was waiting to be used.*
		29	*This is called potential energy.*
		30a	*When ....* (Teacher points).
		30b	*When you pushed it,*
		31	*the potential energy turns into kinetic energy*
		32	*to do the work of rolling.*

Scaffolding strategies employed in Extract 6

-Use of the regulative register by the teacher to orient students to the world of science. Clauses 1-5 constitute the teacher's orientation to the event. She began by introducing the boys, not as classroom members, but as *three visiting scientists* (Clause 1) thereby giving them authority as members of the scientific community. She expanded on this by identifying a number of processes in which the boys had shown capability as scientists: *work, record, demonstrate, observe* and *explain as scientists.* There is no way of knowing whether any of the students understood the significance of those processes, or knew what it meant to do any of those things 'as scientists'. What is worthy of note is that the teacher attempted to do what Bernstein argued was important for student development, and that was to use the regulative register to mark the boundary between discourses as a tension point *opening possible futures*

(Bernstein, B. 2000:xx). The opening statement set the tone for the presentation, with both presenters and the audience quite solemn.

-Orientation by the teacher to the processes of formal presentations. The principle of providing help when, and only when it is needed is fundamental to scaffolding. It is not always easy to judge when the help is likely to be needed. Extract 6 provides an example of how the teacher modified her scaffolding three times in one instance before she found the contingent level of support for this formal presentation..

The first intervention included no scaffold. The teacher's introduction of the three scientists finished with *Over to you scientists* (Clause 6) with no further prompts. She handed responsibility entirely over to the boys. After a brief hesitation, Nadif reached to pick up the materials but didn't seem sure of what to do. At this point came the second intervention. She provided a scaffold by suggesting, in Clauses 7 and 8, that they needed to tell their audience the *aim* of the demonstration. The word 'Aim' was the first heading in their written text. This should have been a sufficient cue to get the boys started, but was met with silence from the visiting scientists. The third intervention in Clause 9 gave them the words to start their presentation: *So our aim today….* This high level of scaffold was finally successful, and all three boys launched into jointly reading out the aim of their presentation.

The successful outcome of this episode does not mean that the teacher's spontaneous and intuitive choice of scaffolds was the most efficient way of getting the boys' presentation started. She might have pre-empted their lack of confidence if she had anticipated more accurately the level of support required, preformulating with something like *Now remember, the first thing you have to do is tell your audience what you want to show, your aim. And you already have that at the top of your paper, don't you?* She might have pointed to the correct place from which to read. However, she did not. The point here, though, is that the teacher was monitoring student performance moment by moment. When they faltered, she stepped in with a higher level of scaffold, and when that didn't work, she had a third level on which to call. It is not possible to always choose the most contingent level of scaffold on each occasion, but control of these strategies, and understanding of the possible levels of support mean that refinement of teacher talk towards a more contingent choice is often possible.

Now that she realised how much support was needed, the teacher maintained a higher level of scaffold. The presentation began to take on the form of a master class, with the teacher behaving as the expert commentator, mediating between performers and audience. Through the role of mediator she scaffolded both presenters and audience. She played this role by engaging in evaluative commentary. The commentary was addressed to the audience, rather than the speakers. In Clauses 16-21 she prepared the audience for the ensuing observation with a

preformulation, asking the students *to do some observation and listen to their (the boys') scientific observation and see if it's the same thing that you observed.*

Once Nadif had finished his observation (turns 463-476, not included in extract), she followed up her earlier preformulation with a semi-rhetorical question:

Clause 23	So	can	you	hear	how clear	their observation	was?
Transitivity			Actor	Pr:material	Goal		
					Attribute	Carrier	Pr:relational
	MOOD			RESIDUE			
Mood	Adj:conj	Finite	Subject	Predicate	Complement		
Theme	THEME			RHEME			

Clause 23 drew the audience's attention to the text type and its quality through its Goal *how clear their observation was*. As in the case of question tags, this question expected a positive answer, and implied alignment between the teacher and the audience about the clarity of the presentation. At the same time, the question served to provide positive but indirect feedback to the presenters. It also helped to stage the presentation by summing up and marking the end of the observation that had just been completed.

Clause 24 shifted the subject from *their observation* to *your observation*, from speaker performance to audience performance:

Clause 24	Was	your observation	like that?
Transitivity	Pr:relational	Carrier	Circ:manner
	MOOD		RESIDUE
Mood	Finite	Subject	Adj:circ
Theme	THEME		RHEME

The teacher's questions alerted the audience to their own role in the presentation, that of reflective and critical listener.

Continuing to address the audience rather than the speakers, the teacher continued with a comment which cued Elijah in to his turn, the Explanation stage:

Clause 25	Okay	and	then	they	need	to explain.
Transitivity			Circ:time	Senser	Pr:mental	Pr:verbal
				MOOD		RESIDUE
Mood	Adj:cont	Adj:conj	Adj:conj	Subject	Finite	Complement
Theme			THEME		RHEME	

Clause 25 marked the next step in the performance with a continuative adjunct, *Okay* but the teacher continued to address the audience. Referring to the presenters as third person plural *they* rather than directly as *you* was a useful strategy. Instead of a command, it became part of the commentary. It acted as a preformulation, an indirect cue to prepare the presenters, giving them

greater autonomy. While the earlier cue of 'Aim' had not been effective, there was now some common knowledge about how to proceed, and this cue of *explain* was a sufficient level of scaffold for Elijah to begin his explanation.

-Elijah's Explanation. Elijah had written most of his explanation independently under some time pressure. It showed a high level of congruence with the target language forms identified in Chapter 3 (Section 3.5.4, p106ff).

Table 30. Examples of Elijah's use of target language forms

Target language form	Example in Elijah's writing
Coherent staging of text	Two stages structured through dependent clauses of time.
Dependent clause of time in Theme position	*When the marble was on top…* *When you pushed it…*
Dependent non-finite clause at end of sentence	*…to do the work of rolling.*
Use of technical terms	*energy, potential, kinetic, work*
Extension through circumstances of time and place	*on top*
Use of passive voice	*is called*

The endemic issues for teacher and students in distinguishing between abstract and concrete concepts that appeared throughout the topic so far have been thoroughly discussed. There is no claim that Elijah's ability to write and present such a text is evidence that this confusion had been overcome. The study proposes that Elijah had at this time appropriated not just technical language, but grammatical resources to coherently structure that language. This appropriation now enabled him, as Halliday and Matthiessen argued, to move from being stuck in concrete operations, to using language for ongoing consolidation of his understanding (1999:618). The concepts of energy and energy transformation appear repeatedly in the Australian Curriculum, and Elijah now had expanded mediational means rather than simple exophoric reference items and physical pointing with which to negotiate future meaning.

4.4.3.3 Extract 7: class interrogation

Following Elijah's presentation, the teacher once again turned to the audience. The teacher's language choices in Extract 7 provide an example of appropriate pedagogic choices when intersubjectivity between participants has increased. When compared with the mediation of the presentation that had just occurred, a significant change in this extract was the reduction in regulative register. The teacher was no longer using the regulative register to scaffold the class in how to behave as an audience. She was evaluating their performance as an audience by asking questions to display what they had heard.

There was no longer any preformulation to make explicit the purpose of the teacher questions. The purpose was now implicit, making the framing apparently weak, in the form of unadorned

wh- questions. The strong classificatory expectations were evident in both the teacher's questions and the successful, accurately phrased answers.

Turn	Speaker	Clause	Transcription
479	Teacher	1	So what work was it doing?
480	Student	2	The work of rolling.
481	Teacher	3	Excellent listening.
		4	When did , when was there potential energy?
482	Richard	5	When the marble was sitting on the top.
483	Teacher	6	Good listening.
		7	What was that called? Mei Ling?
484	Mei Ling	8	Potential energy.
485	Teacher	9	Good.
		10	When did the potential energy change to kinetic energy? Alex?
486	Alex	11	When you push the marble.
487	Teacher	12	Good,
		13	and what happened to the potential energy
		14	when you pushed the marble? Donisia? Tammy?
488	Tammy	15	It changed to kinetic energy.
489	Teacher	16	Very good. Yes

This extract demonstrates the typical I-R-E pattern so prevalent in Western pedagogy. No scaffolding strategies were evident. There were no preformulations to cue students in, no reconceptualisations to follow up, only wh- questions, student answers and positive teacher evaluations. Their purpose was no longer joint construction but assessment with the criterion for assessment being *good listening* as evidenced through student ability to correctly answer the questions.

Of course, the students' displayed knowledge was not simply evidence of good listening. The content of Elijah's presentation had been covered previously by the whole class. The students' ability to successfully answer these display questions was evidence of the growth of intersubjectivity from dyadic; that is social engagement in class activity, to triadic; that is the academic engagement in specifically scientific activity. That is not to say that the release of responsibility was at an end, but that the process had made an observable shift from teacher control towards student control.

This extract marks the end of the first set of lessons dedicated to the four demonstrations of energy transformation. The topic then shifted to the new focus text, explaining energy transformations in the farm-to-table chain. The final extracts in the analysis come from Lessons 5 and 6, the first two sessions in the Farm-to-Table set. These extracts demonstrate the

scaffolding techniques used by the teacher to encourage students to use some of the grammatical structures and language already introduced as part of the first set of lessons.

4.4.4 Lesson 5: tracking language in the farm-to-table chain

Analysis of the previous extracts spanned the lessons concerned with the first set of focus texts and the energy transformation demonstrations. It provided examples of the scaffolding strategies used by the teacher, modified over time to both prepare and respond to language appropriation by students. It demonstrated the challenges of the instructional register: finding the right language with which to distinguish between concrete and abstract concepts and their relationship. It also showed how ongoing involvement in hands-on activity could undermine the expressed learning goal of language development.

Instead of single energy transformations in the four demonstrations, the farm-to-table chain required an extended string of energy transformations to be sequenced across time. The purpose of analysis in the final lessons of the topic is to show how the language features from Focus Text 1 were consolidated in the new context, and how the teacher worked to make sure that all students had a chance to practice this new language, working towards fluency.

In the opening stage of Lesson 5, the teacher and students were together on the floor. They were viewing a video of the farm-to-table chain, following an apple as it moved from farm to home. After the difficulties in the previous activities of distinguishing between the observable process and the underlying principle, the teacher had decided to clearly separate the two. In this first lesson of the farm-to-table chain, she focused only on the observable concrete process, reconceptualising each step in the process as 'work', as the apple moved from farm to table.

Extracts 8 and 9 from Lesson 5 highlight the teacher's introduction of two grammatical structures important to this phase of the explanation: passive voice in the verb, and a dependent clause of time in Theme position. Both of these structures helped to stage the explanation through the control of Theme: passive voice enabled the foregrounding of the apple rather than human agents, and the dependent clause in Theme position staged each step of the process as a consequence of the previous step. The extracts show how the teacher continued her work on these structures orally, and in the joint construction of a written text.

The extract stages and their purpose are outlined in Table 31 below:

Table 31. Stage, purpose and grouping arrangements of extracts from Lesson 5

Extract	Stage	Purpose	Class structure
8	Extension	The teacher introduces the farm-to-table process	Whole class
9	Mode shift	Class jointly constructs parts of the written text of the farm-to-table process	Whole class

4.4.4.1 Student talk in Lesson 5

The move from the four demonstrations to the farm-to-table chain marked a new Field, a significant change in the context. While the quantitative analysis of student talk in the final stage of Lesson 4 demonstrated a relatively high level of student participation (Section 4.4.3.1, p201ff), the first Extension stage of Lesson 5 stood in contrast.

Lesson 5 began with an Extension stage: the introduction of the new field of farm-to-table. As discussed in Section 4.3.2, p156, the degree of scaffold would be expected to increase with new Field knowledge; when common knowledge about the Field is low. Although some aspects of the farm to table process may have been familiar to students, it was evident that the language to express the Field was not familiar to all. The change in intersubjectivity is evident when the percentage of student talk from Lesson 4 is compared with Lesson 5 below. It dropped from 44% to 16%.

Table 32. Clauses of student talk as % of total clauses of teacher and student dialogue in Lesson 5

	Lesson 4 Mode Shift 2 Group of 3	Lesson 5 Extension Whole class
Student initiations	27%	12%
Student responses	7%	0%
Joint constructions	10%	4%
TOTAL STUDENT CONTRIBUTIONS	44%	16%

The Extension stage of Lesson 5 introduced new content for only the second time in the topic. (The first was in Lesson 1.) Consequently, the speech function choice reverted from questions to making statements, as the teacher explained what was happening in the video. In fact, teacher statements constituted 84% of clauses. There were no teacher questions to which students could respond. The only example of a joint construction was the definition of energy with which the students were very familiar: *Energy is the power to do work* .

A number of student initiations in Lesson 5 were evident, but in contrast to those in the previous lesson, which were scientific in nature (Section 4.4.3.1, p202), these were evaluative comments from students' every-day experience: *Ugh, look at that water!* and *I like the ones from Central Market.* As was evident in Lesson 1 when the Field was new, student language was situated in the commonsense. It was the teacher's role to once again orient them to perceiving the farm-to-table chain through scientific eyes.

Extracts 8 and 9 from Lesson 5 show the particular scaffolding strategies used by the teacher to consolidate the new grammars and vocabulary she had already introduced in Focus Text 1. In particular, they demonstrate the persistence with which she first introduced the passive voice

and the dependent clause in Theme position, as well as her use of reconceptualisation to continually move students towards the focus language.

4.4.4.2 Extract 8: introducing passive voice

Extract 8 is part of the teacher's introduction to the farm-to-table chain. The explanation below accompanied the video of the process. It demonstrates the manner in which the teacher consolidated the passive voice through her introduction. This was one aspect of grammar with which some of the case study students struggled (Section 4.2.3, p142 and 148). (Passive voice is shown below in bold.).

Turn	Speaker	Clause	Utterance
13	Teacher	1	Okay, so here are the apples in the apple shed.
		2	So they've been taken out of those bins,
		3	and there's lots of machines in the shed that need to wash the apples, ….
15	Teacher	4	And they've got to be sorted out…
		5	and packed
		6	so maybe any apples that have marks on them, or a little bit rotten, they need to be taken
		7	out
		8	and then sorted,
		9	perhaps sorting them by size
		10	so they're ready to be packed into boxes.
16		11	And here they are being packed into boxes.

Significant features of the extract

The backgrounding of human agency to the point of invisibility through the use of passive voice is an important and sometimes difficult shift along the Register continuum for students used to operating in socially organising horizontal discourses. The struggle was evident in the case study analyses at the beginning of this chapter. The important feature of Extract 8 is the number of times the teacher concealed the Actor in the sentence by using a verb in the passive voice. In eleven clauses, she included seven examples of the passive voice. This meant that she could regularly place 'the apples' or their referent in Theme position in the sentence. The Actor; that is human agency, was absent. Her repetitions provided students with many opportunities to hear this language form.

Also noticeable is the absence of dependent clauses of time in Theme position to stage the explanation, despite this being an identified grammatical structure in the focus text. Instead, the teacher used the more spoken-like conjunctions *and* (Clauses 3,4 5 and 11) and *so* (Clauses 1, 2, 6 and 10) to stage the sequence. Because the talk accompanied a video that was moving from scene to scene, the staging of the sequence was clear as the scenes changed. The meaning was evident in the context, and the foregrounding of a 'when' clause was not essential to express the

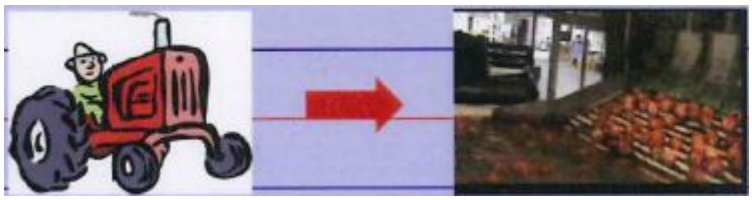
logical unfolding of the process. This is not to say that the teacher made a conscious choice to omit the clause, merely to point out that because the visual context shared the meaning with the language that accompanied it, the context reduced the need to use such a clause.

4.4.4.3 Extract 9: introducing dependent clause in Theme position

Extract 9 is taken from the Mode Shift which followed the viewing of the video. The Mode shift consisted of teacher and students together negotiating the written text of the opening stages of the farm-to-table process.

The shift was accompanied by a change in artefacts from video to segments of the farm-to-table flow diagram on the white board (Figure 37).

Figure 37. Farm to table images accompanying Extract 9



Each image now encapsulated one of the stages of the farm-to-table process, and all the language used to describe it. The arrow represented the sequential relationship between each step of the process.

Introduction to scaffolding strategies employed in Extract 9

-Use of gestures to scaffold. The teacher reinforced the sequential nature of the explanation by pointing between images.

-Reconceptualisations to refine grammatical forms. The teacher used her reconceptualisation of student answers to more closely approximate the grammatical forms of the focus text.

-Text marking of the written text. Text marking is a strategy used in both Accelerated Literacy pedagogy (Gray, B. 2007:23), and in the Reading to Learn program (Rose, D. 2005:22). It is loosely a form of transitivity analysis, and functions in those programs to break up text into smaller units of grammar as a reading support and comprehension strategy.

Turn	Speaker	Clause	Transcription
475	Teacher	1	So when this has happened (pointing back to image of tractor in the sequence),
		2	this can happen (pointing forward to image of packing shed).
		3	So what was going on here? Nigel?
476	Nigel	4	When the farmers have picked the apples
		5	and taken them to the shed,
		6	they went through a washing machine.

477	Teacher	7	Okay, so *when the apples,…*
		8	Can we just shorten that a little bit?
		9	*When the apples are taken to the shed…* (writing)

Scaffolding strategies employed in Extract 9

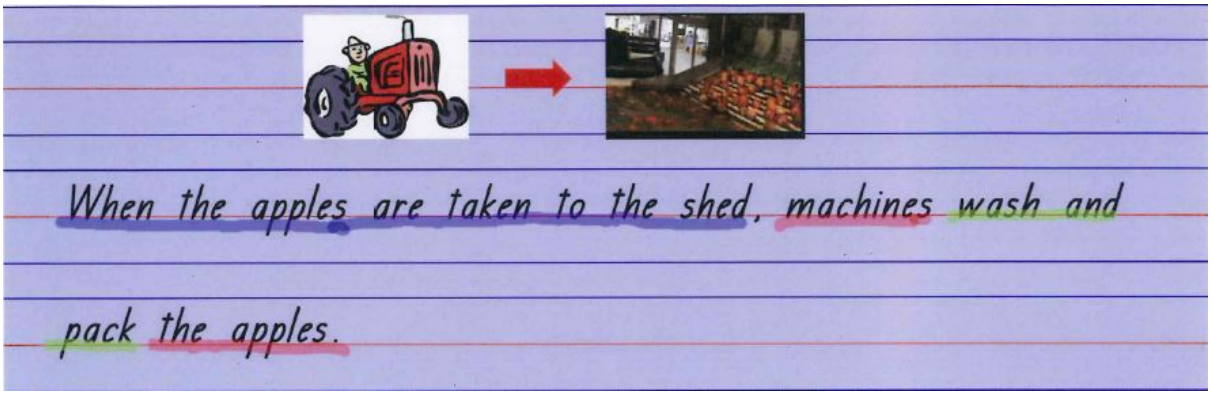
Use of gestures with the flow diagram. Using the images shown in Figure 37 above, which were displayed on the board, the teacher reinforced the foregrounding of the dependent clause by pointing first back to the image of the tractor and using the conjunction *when* (Clause 1) before pointing forward to the packing shed (Clause 2). The gestures were a physical reminder that the ideational meanings of the first image preceded those of the second.

Reframing of student talk through reconceptualisation. The second scaffolding technique was the teacher's reframing of student text to approximate more closely the focus text. Nigel's proposed sentence (Clauses 4-6) appropriately included the dependent clause in Theme position. At the same time, he used the active voice, placing *the farmers* in Theme position in the clause, rather than *the apples.* The teacher accepted his proposal, but asked permission to *shorten that a little bit,* and provided a sentence that more closely approximated the focus text. Her strategy converted the verb into passive voice for the text construction, without diminishing positive affect (Clauses 7-9).

Text marking.

The end product of this text negotiation was one jointly-constructed stage of the farm-to-table explanation, recorded on the board. With prompts from the teacher, the students proceeded to underline the text in groups of words that functioned grammatically together. Students were familiar with this process. The end product is shown in Figure 38.

Figure 38. Text marking to reinforce the dependent clause in Theme position



The dependent clause was underlined in blue as one 'chunk', clearly distinguishable from the rest of the sentence. When students proceeded to write additional stages of the sequence independently, they marked their own texts in a similar manner to check that they had foregrounded the dependent clause.

In contrast to its use as a reading strategy in the *Accelerated Literacy* and *Reading to Learn* programs, text marking in this study had a different purpose. Because the students had already rehearsed their written texts orally, and participated in the joint construction, they were all able to read it proficiently. The purpose of text marking in this instance was to bring to consciousness and consolidate the grammatical structures that they teacher had previously introduced. It was an editing strategy for student writing.

4.4.5 Lesson 6: putting it all together one step at a time

Lesson 6 was the point at which the process of the farm-to-table chain and the energy transformations embedded in the process were combined into one explanation. This took place in the third and final Extension stage from which Extract 10 was selected.

Table 33. Stage, purpose and grouping arrangements of extracts from Lesson 6

Extract	Stage	Purpose	Class structure
10	Extension	Students add energy transformation phase to their procedure	Whole class

4.4.5.1 Student talk in Lesson 6

There was a distinct change in student participation in talk between Lesson 5, strongly guided by the teacher and Lesson 6. In the final stage of Lesson 6, teacher talk of any kind amounted to less than 50% of all talk, with teacher statements decreasing to 31%. Both joint constructions and student initiations had more than doubled in number, and student initiations were no longer evaluative comments but independent constructions of parts of the farm-to-table chain such as *The children eat them and get energy by them when they're in the fruit bowl.*

Table 34. Clauses of student talk as % of total clauses of classroom dialogue, Lesson 5 cf Lesson 6

	Lesson 5 Extension Whole class	Lesson 6 Handover Groups of 3
Student initiations	12%	26%
Student responses	0%	9%
Joint constructions	4%	16%
TOTAL STUDENT CONTRIBUTIONS	16%	51%

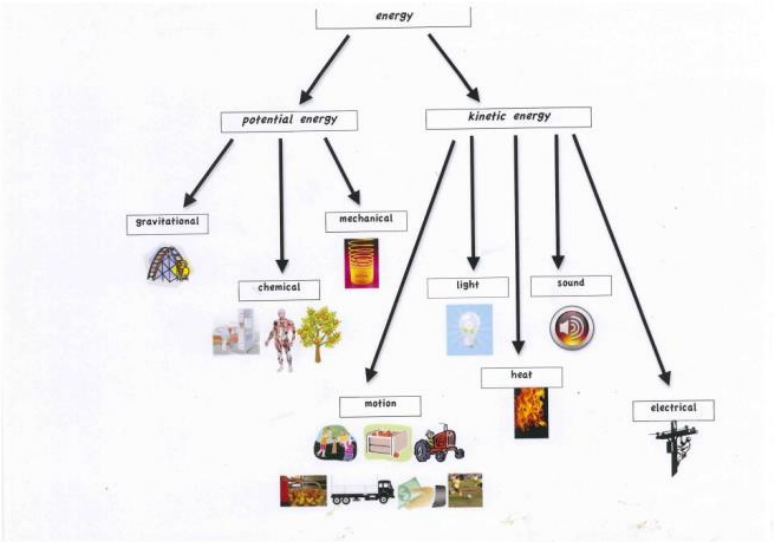
It is proposed that there were two important factors in the rapid increase in handover of language by students. Firstly, the Field knowledge around the farm-to-table processes was not completely unfamiliar to many students, even if they struggled with the vocabulary and grammar with which it was represented. If they didn't know about farms and packing sheds, they could nevertheless talk about trucks and the supermarket and the fruit bowl. In particular, students were proficient in talking about the work which was part of their world: *and when they eat it they can play, they can swing, they can kick, they can climb, they can do all sorts of stuff.* Secondly, the process of language acquisition is cumulative: the language about energy

transformation already appropriated during the small demonstrations in the previous set of lessons was to some degree internalised by students, able to be called on in this new context. The teacher was not starting from the beginning in building this language.

4.4.5.3 Extract 10: Adding energy and non-finite clause

In this final extract, the teacher and students viewed the video of the farm-to-table sequence once more. At each step of the sequence, the teacher stopped the video, and the class jointly constructed an oral explanation of that step. This time the teacher and class added the energy transformation phase. In other words, the explanation was extended with the abstract principle added to the observable concrete process. When needed, the teacher switched from the video to the taxonomy of energy transformation (Figure 39 below), to help students track the transformation. This is the diagram referred to in Extract 10, Clause 2.

Figure 39. Diagram on interactive white board to accompany extract 10.



Introduction to scaffolding strategies employed in Extract 10

Extract 10 will demonstrate two final scaffolding techniques, both important for encouraging students to use target language. The first is the reframing of student talk so that the jointly constructed text more closely resembles the focus text. The second is the teacher's use of elaborating questions which extended the number of student turns and enabled several students at a time to try out new language.

Issues in the development of intersubjectivity

The extract demonstrates, through student language use, that their appropriation of new language was not complete, but in process. Their language use was tentative at this point as students and teacher tried to incorporate not only the process phase but the energy explanation phase, and within that, technical language, the dependent clause and passive voice.

Turn	Speaker	Clause	Transcription
	Nigel	1	When the truck isn't moving at all,
		2	it's using potential mechanical energy (Teacher switches to taxonomy, points to petrol tank), potential chemical energy in the tank.
		4	And when it's moving,
236		5	it uses...//
237	Teacher	6a	// And so can you say 'the potential chemical energy changes...
238	Nigel	6b	…to kinetic motion energy.
239	Teacher	7	Good, to do the work of....
240	Nigel	8	Of running the apples to the shop.
	Teacher	9	Excellent. Did you hear how he did that?
		10	Who else can do that?
241		11	Who else can tell us? Despina?
242	Despina	12	When... the....
243	Teacher	13	So there was potential...
244	Despina	15	Chemical energy.
	Teacher	16	In the... petrol tank,
245		17a	and it changed to....
246	Students	17b	…kinetic / movement / energy
247	Teacher	18	Yep, to do the work of... what was the truck doing?
248	Students	19	Movement.
	Teacher	20	Taking the... apples.... to the? shop.
249		21	Who else can do that? Elijah.

Scaffolding strategies employed in Extract 10

-Reframing leading to joint construction

The first point of interest is the oral joint construction between Nigel and the teacher. Nigel initiated the explanation (Clauses 1-5). He used appropriately two dependent clauses in Theme position to stage his text (Clauses 1 and 4) but did not use passive voice. In Clause 5 the *truck* was subject rather than *energy* being the subject. Consequently the teacher interrupted, reconceptualising with *and so you can say 'the potential energy…'* (Clause 6a). This was a simple scaffolding strategy that reframed student talk in a respectful way, affirming Nigel's contribution, and at the same time enabling a closer approximation of the text to the focus text.

However, the teacher did not reframe the whole explanation phase. She had steered Nigel in the right direction but did not want to over-scaffold. She paused after the first clause, enabling Nigel to continue the sentence in Clause 6b. Once again she responded, this time launching him into the extending non-finite clause: …*to do the work of*..(Clause 7), which Nigel completed: *of running the apples to the shop* (Clause 8).

Through joint construction and the use of cumulative questioning and reconceptualisation, Nigel and the teacher had closely approximated the target language.

-Use of elaboration prompts. In Clause 9, the teacher initiated three questions, inviting other students to use the language of the text that had just been constructed by Nigel and the teacher: *Did you hear how he did that? Who else can do that? Who else can tell us?* In other words, the teacher was facilitating a retell of the same text. The teacher wanted as many students as possible to 'ventriloquate' this new, well-formed utterance. Her prompting questions extended the role of successful speaker to other students through repetition.

The teacher then nominated two other students to repeat the same sentences: to Despina and Elijah she asked *Who else can do that? Who else can tell us?* The clear message from this process was that the teacher would help, but learning this language was everyone's responsibility.

4.4.6 Summary of classroom discourse analysis

Chapter 4 has explored the way in which the study enacted the scaffolding principles listed in Chapter 3 (Section 3.5.3, p104). After demonstrating the language development of a number of marginalised case study students, the chapter began the analysis of the topic of energy transformation at the macro-level. It showed how the topic was planned logically to develop student language around the topic of energy transformation. It identified the lesson stages which appeared across the topic, explaining that the patterns of the appearance of each stage were logical and sequenced, but not consistently present for each lesson. Rather, the pattern depended on teacher judgment of what would provide a contingent level of support. Importantly, the analysis demonstrated how these patterned stages came to resemble the gradual release of responsibility model introduced by Pearson, showing clearly the considered scaffolding intent of the teacher.

Chapter 4 continued at the micro-level with an analysis of teacher-student talk across a number of lessons in the topic. It showed how the proportions and function of teacher and student talk varied as common knowledge and confidence grew. At the same time, the data suggested that the trajectory towards student control was not one-directional, with the teacher taking back some control whenever she thought it contingent to do so.

The extracts demonstrated a range of scaffolding strategies used intentionally by the teacher to support the appropriation of language by the students at the same as she maintained a sense of trust, security and respect within the class. They showed the extensive use of the regulative register in the early lessons of the topic to respectfully encourage students to participate when intersubjectivity was low.

The role of scaffolding was not only to maintain student engagement, but to support their appropriation of language. The teacher's control of important scaffolds was exemplified throughout the extracts. These included her ability to reconceptualise in order to elaborate, extend or enhance meanings; her ability to monitor for handover, and adjust her talk so that reconceptualisations became joint constructions; and her use of probing and cuing questions that extended and elaborated student talk, involving many students in the closer approximation of the target language.

The extracts demonstrated the inverse relationship between framing and classification. The contrast was most evident between Lesson 1 and 4. In Lesson 1, framing was strong as the teacher worked to explicitly introduce new abstract concepts. Classification was relatively weak, as she affirmed even one-word student contributions in a way that maintained participation and a willingness to persevere. By the end of Lesson 4, with higher levels of intersubjectivity, the students were able to successfully answer the teacher's scaffold-free display questions in a manner that belonged strongly within the discourse of science.

At the same time, the analysis demonstrated the difficulties in a lay teacher taking on a complex topic like energy transformation. It required the instructional register to do complex work, explaining logical relationships between abstract concepts, and clearly distinguishing between concrete objects and abstractions. The confusions were exacerbated by the imperative in primary science classrooms for 'hands-on' activity which worked against the expressed goals of language development.

This completes the classroom discourse analysis. The final chapter will now summarise the learning from the study, and make recommendations for further investigation.

CHAPTER 5

The future of scaffolded pedagogy in science education

5.1 Summary of the study and its intentions

This study, *Scaffolding science*, was a project that began with a political and social imperative: to improve access to effective science education for educationally marginalised students. Being scientifically literate is fundamental to participatory citizenship in contemporary Australia.

While the goals of post-compulsory education and future employment may seem a long way from working with 7-8 year olds, the cumulative work of building common knowledge and language around science cannot begin with secondary education. Early science education for marginalised students has to be more than just enjoyable for those involved. It has also to begin the work of providing an orientation to the activity system of science, including its values, processes, goals and language.

Chapter 1 described the competing pedagogic paradigms that currently pervade Australian science education: the 'hands-on', highly engaging progressivist model popular in primary schools and the traditional 'transmission' model, more common in secondary education (Goodrum, D. *et al* 2000; Tytler, R. 2007).

Harnessing key understandings from psychology, sociology and linguistics, the study proposed to work within a third pedagogic paradigm, a visible, scaffolding pedagogy, labelled by Bernstein as *a radical realisation of an apparently conservative practice* (Bernstein, B. 1990:xx).

Although many have investigated how the notion of scaffolding might be enacted in the classroom (Gibbons, P. 2002; Maybin, J., Mercer, N. & Stierer, B. 1994; Renshaw, P. 2013; Sharpe, T. 2006; Tharp, R. & Gallimore, R. 1991; van de Pol, J. & Elbers, E. 2013; Wells, G. 1999a), further work is needed to investigate how the three theories together can assist teachers in scaffolding systematically for best effect.

To this end, the current study was undertaken, investigating the teaching and learning processes around one topic of energy transformation in a Year 2-3 classroom, with close attention to student language acquisition. The choice of physics was ambitious, especially as it is an area of science which is often avoided in the primary classroom (Goodrum, D. *et al* 2000). However, the suggested correlation between the coverage of physics in the classroom and student long-

term success in science education (Ainley, J. & Thomson, S. 2006:16) provided the motivation for taking on a challenging topic. The choice of topic was at the same time fortuitous, because it brought into sharp relief the pedagogic challenges confronted when young children are taught about abstract concepts for the first time.

The effective scaffolding of a science topic required detailed knowledge by the teacher of the language demands of the activity system of science. The resources developed in systemic functional linguistics were central here (Halliday, M.A.K. & Martin, J.R. 1993; Korner, H. *et al* 2007; Lemke, J.L. 1993; Martin, J.R. & Veel, R. 1998). Topic implementation also required a nuanced understanding of scaffolding and contingent pedagogy; the strategies and language choices available, and how they could be systematically selected so as to effect the gradual handover of language from teacher to student. This aspect of pedagogy was strongly influenced by the work of Bruner and Wood (1976; 1996), and importantly, in developing a systematic routine and in controlling teacher questioning, by the work of Gray (2007, 1998).

The enactment of these theories was complex and challenging. The teacher was required to work with new scientific knowledge and language beyond her level of comfort, while at the same time systematically employing her knowledge of scaffolding techniques in a new learning area.

The classroom discourse analysis drew on Christie for its analysis of the structural integrity of the topic and lessons (Christie, F. 2005a). Christie and Gray provided the tools for the analysis of the classroom dialogue, enabling an examination of the changes in the regulative and instructional registers as the topic progressed (Christie, F. 2005a; Gray, B. 1998). In addition, the notion of 'interactive trouble' (Freebody, P. *et al* 1995) was used to identify points in the dialogue which created discomfort for the observer, thereby demanding further investigation. The work of the functional linguists framed the analysis of student language appropriation from the beginning to the end of the topic.

The analysis of these lessons has provided significant insights in scaffolding marginalised students in a way that both maintains support and helps them cross the boundary into science. It has also demonstrated several issues encountered in the topic which provide useful lessons for future study. The learning from this study will be summarised in the remainder of this chapter.

Since the study began, new developments arising from collaboration between sociology and systemic functional linguistics have been proposed by Maton and others within Legitimation Code Theory (LCT) (Freebody, P. 2013a, 2013b; Martin, J.R. 2013a, 2013b; Martin, J.R. & Maton, K. 2013; Maton, K. 2013). LCT enables the plotting of meaning in language along two axes; semantic gravity and semantic density. High gravity meaning is situated, grounded in the concrete and specific, while high density meaning is decontextualised, generalised, transferable

and abstract. LCT proposes that disciplines have their own particular patterns of logogenesis, of shifting from the situated to the abstract and back again, which are pertinent to the pedagogic instructional register. While the publicly available work so far is concerned with secondary education, LCT provokes important questions about appropriate instructional register choices in primary classrooms. The implications of LCT in relation to the findings of this study will be discussed where relevant.

The logical planning of the topic of energy transformation in the study supported the systematic handover of knowledge and language. Ultimately, though, it is teacher control of the classroom dialogue which determines whether talk is simply conversation or intentional and timely negotiation of teaching and learning. There is a danger that lists of scaffolding techniques become a 'grab bag' from which teachers randomly select without a principled understanding (e.g. Sharpe, T. 2006; Smit, J. & van Eerde, D. 2013; Van de Pol, J., Volman, M. & Beishuizen, J. 2011). This study has shown the effect of contingent selection of scaffolding strategies by the teacher according to the levels of intersubjectivity in the class.

If left to teacher intuition, the understanding and selection of contingent pedagogic processes is likely to remain elusive for teachers who lack the foundation and guidance of consistent socio-historic and linguistic principles from their training. Consequently, the final reflection on this study poses further questions. What are the affordances and constraints evident in this one enactment of scaffolded pedagogy with marginalised students, and what are the implications of these findings for future research with teachers? The remainder of this chapter, Section 5.2 responds to these questions. Section 5.2.1 summarises the learning from the case studies of individual students. Section 5.2.2 summarises the learning from the structural planning of the topic. Section 5.2.3 addresses the learning from the classroom discourse analysis across the seven lessons. Section 5.2.4 discusses briefly the range of class grouping arrangements used in the study.

5.2 Findings of the study: affordances and constraints in enacting scaffolded pedagogy

5.2.1 Learning from the case studies of individual students

The analysis of student oral and written texts in Chapter 4 demonstrated the apparent development in student language performance before and after the scaffolding processes used in this study. Significantly, the language learning goals in the study included not simply student acquisition of vocabulary, but also student competency in the construction of coherent texts. Two recent studies in scaffolding in the early years have, similarly to this study, identified

language acquisition as an appropriate measure of scaffolding success. However, neither has used extended text as a criterion for evaluation.

The first, a recent study by Thwaite et al, set the criterion as technical naming rather than explaining:

> *As these children are very young, the emphasis is on terminology rather than the more scientific processes of description and classification, although these do occur* (Thwaite, A. 2014:7).

The second study was an investigation into the efficacy of scaffolding in early years mathematics (Smit, J. & van Eerde, D. 2013). It isolated three key language elements as proof of effectiveness: the use of graph-related labels, the use of the adverb 'gradually' and the accurate use of prepositions (ibid: 25). The data from the current study, *Scaffolding science,* show that student appropriation of scientific labels was relatively easy (Figure 17, p143) when compared with the more important grammatical challenge of using marked Theme (Figure 12, p140) and passive voice (Figure 16, p142) as part of an explanation. For this reason, student use of extended text remains an important educational goal and evaluation tool if marginalised students are to become active participants in scientific activity.

The final performance of the case study students, both oral and written, under test conditions, was tentative rather than accomplished. They were fledgling users of scientific language. There is no claim that they had 'arrived' at some final point of knowledge creation. Rather, the point reached in this study was only part way to the goal of understanding energy transformation. Vygotsky and Wertsch help to explain the tentative nature of first language use, and its relationship to concept development (Section 2.3.1, p37). Nevertheless, students had a rich new transferable language resource. The language they had acquired to explain the processes of energy change and work had relatively high semantic density and relatively low semantic gravity. With this new language, they had resources through which they could continue to build meaning, and apply it in new contexts. It was through use and application in new contexts, again with teacher guidance, that meaning would be consolidated.

The recognition and valuing by teachers of goal-oriented imitation, often misinterpreted as rote performance, requires a paradigm shift in understanding of child development, from Piagetian to Vygotskian. To be comfortable with students' imperfect use of new language, teachers will need to understand the role of imitation and ventriloquation as a valued, valid and necessary part of language development (Daniels, H. 2001:81). In the current western educational climate, where individuality and student voice are valorised, the Bakhtinian notion that our voice first belongs to someone else (Wertsch, J.V. 1991:51) can be difficult to accept.

5.2.2 Learning from topic planning

5.2.2.1 Understanding science as an activity system

Science education is an apprenticeship into the activity system of science, which as outlined in Chapter 2 (Section 2.2.1, p14ff), contains its own particular motivations, intentions, purposes, goals, and means including concrete artefacts and language. Without some shared orientation in the classroom to these scientific foundations, it is difficult to make science activities purposeful, and easy to reduce them to entertaining tasks. The challenge to orient young children to the motivations and purposes of the activity system of science created a dilemma for the research team. There was no simple resource that explained to the lay teacher what scientists do and why. Eventually the internet provided some enlightenment through websites which described the nature of science (e.g. AAS 2008).

More recently, the Australian Science Curriculum has provided some support in this challenge (ACARA 2011). To begin with, it includes a strand of S*cience as Human Endeavour* in each year level, which can help teachers to see the relationship between science activities and the activity system to which they belong. The comprehensive curriculum introduction (ibid: 4-18) provides insights into its scientific intentions and goals. Unlike the previous South Australian science curriculum, SACSA, which was restricted to the use of commonsense terms, the national science curriculum classifies the content according to specific disciplines: Biological sciences, Physical sciences and so on. This small change helps teachers to contextualise primary school science activity as part of broader disciplines.

The New Zealand science Curriculum provides further information. It includes *Nature of science* as an *overarching and unifying strand* (University_of_Waikato 2007), and the resources on its website, accessible internationally, provide useful support for teachers.

However, searching websites and determining their authority and accuracy is extremely time consuming and unreliable. The experience of this study suggests that a nationally authorised source of information on the nature of science, understandable to the primary lay science teacher, would be an immensely useful addition to the Australian science curriculum for teachers who work from a socio-cultural theory of learning.

5.2.2.2 Selecting activities

Armed with an understanding of the nature of science, the research team began to plan the topic; deciding on the content, the scope and sequence of activities which will introduce the content, the learning goals, and the language with which to realise those learning goals.

When it comes to activity selection, the curriculum documents reduce their support. In an endeavour to provide *flexibility and choice for teachers and students*, the science Shaping Paper states that selection of activities will depend *on local science learning opportunities, historical perspectives, contemporary and local issues and available learning resources* (ACARA 2009:10). What this means for the lay science teacher is uncertainty about what activities will be effective in achieving the curriculum goals, and a great deal of work in selecting and preparing those activities. In the case of this study, the teacher used children's science webpages on the internet to select the four demonstrations of energy transformation which she used in Lessons 1-4. When the teacher's scientific knowledge is tentative, these choices can be fraught. For example, the *chicken wing* activity in the study was intended to show how potential chemical energy in the chicken's muscles changed to kinetic energy to do the work of flying. Some assumptions made the activity difficult to engage in as intended. For a start, the wing didn't look much like a wing: it was featherless, stripped of skin and no longer attached to the energy source of the chicken. Secondly, because the wing was no longer alive, the potential chemical energy being transformed into potential movement energy was in the muscles of students rather than the bird, as they held the wing at each end and made it flap.

This example is not a criticism of the teacher. It demonstrates the constraints of a system which provides inadequate scaffolding to classroom teachers who need to be proficient in eight separate learning areas, each of them attached to a different discipline. A Google search for *energy transformation activities for students* revealed 99,500,000 results in 0.35 seconds. Expecting each teacher to do their own research and make considered and well-informed selections is inefficient, as well as carrying a high risk of unreliable activities.

Two federal initiatives have the potential to ameliorate the issue of activity selection. The first is *Primary Connections* (AAS 2007a).This series is comprised of teacher resources for a number of age-appropriate science topics. The activities are finite, sequenced and manageable, and have been selected with care by the research team, so teachers can have some confidence that they reliably achieve what they set out to achieve. Although they precede the Australian science Curriculum, many activities have been matched against current science learning outcomes (AAS 2013). Furthermore, schools can buy kits and consumables ready to use with the activities, saving the teacher preparation time.

The second initiative is the CSIRO *Scientist in Schools* program (CSIRO 2011). Classes are matched up with volunteer scientists, who can answer the difficult questions with which the lay science teacher might struggle, and provide an orientation to scientific activity that helps to shift student perspectives.

5.2.2.3 Understanding the language demands of science

Scaffolding science holds as its foundation that language is central to learning, that doing science is necessarily also talking, reading and writing scientifically. The planning included careful choice of language learning goals, moving students along the Register continuum from situated to decontextualised language. Guidance for the language resources which became the focus of learning in the study came from a number of sources (DECD 2004; Eggins, S. 1994; Halliday, M.A.K. & Martin, J.R. 1993; Korner, H. *et al* 2007; Martin, J.R. & Veel, R. 1998).

While such resources are productive at the research level, they provide a level of information which is daunting for the classroom teacher. Fortunately new resources have appeared to support teachers in understanding the written language demands of science for their year levels. *School Discourse* (Christie, F. & Derewianka, B. 2008) plots the writing development of different aged students in different learning areas. The developmental trajectory provided in the text (ibid: 232-37) suggests that the language goals identified in this study were largely consistent with those typical of a child at these year levels.

Significantly, the Australian Curriculum now provides a Language and Literacy scope and sequence to guide teachers in establishing written language goals. With systemic functional linguistic foundations, the Language and Literacy Continuum (ACARA 2013), part of the Literacy Capability, attends to Text, Grammar, Word, and Visual Knowledge for each year level and mandates the genres to be taught at each year level in each learning area. The ACARA Literacy Continuum and the Australian Curriculum English have been supplemented by the South Australian produced, comprehensive *Language and Literacy Levels* (DECD 2013) which provide examples of student language use at each year level.

It must be stressed that the developmental stages identified in Christie and Derewianka and the Language and Literacy Levels are not intended to be regarded as 'natural'. They are levels of performance which are required, or expected, if students are to move gradually towards the abstract 'uncommonsense' lexico-grammar required to express knowledge in the senior years of schooling. These levels assist with establishing learning goals and assessing student performance but for most students, development will only be reached with the support of quality teaching:

> *The teaching of writing… is a fundamental responsibility of schooling, and what teachers do is very important in ensuring that children learn to write, as well as read… There are developmental phases in mastering the written mode, and though these are not be understood as functioning in some 'lock step' fashion, they do apply, having consequences for the kinds of writing children should produce at different stages of their lives* (Christie, F. & Derewianka, B. 2008:214).

Finally, a new text *Apprenticing students into science* (Polias, J.:forthcoming) provides detail on science genres and their place on the Register continuum. Together, the four resources listed above provide an accessible, coherent approach and analysis of age-appropriate language features which are reassuringly consistent for a classroom teacher who is interested in learning more about the language demands of the science curriculum.

Legitimation Code Theory (LCT) sheds further light on the language demands of science. Research so far introduces the notion of semantic waves: shifts in strength of semantic gravity and density within written texts; as well as patterns of gravity and density within teacher talk as meaning is constructed in the classroom (Maton, C. 2014). The notion of semantic waves demonstrates how text moves from the abstract to the concrete and back again in systematic ways within disciplines.

Doing science in the early years of primary school begins, from the perspective of LCT, with text demonstrating high semantic gravity, describing the concrete and observable in nature. The curriculum requires students to observe and identify patterns and relationships between things and phenomena, in other words requiring a a shift from the specific to generalisation, moving from high gravity to higher density through abstract language. In the light of LCT, *Primary Connections* is seen to have three significant language issues which need to be overcome in order for the scaffolding teacher to use it as an effective resource, its previous recommendation as a reliable source of activities notwithstanding.

The issues all stem from the lack of understanding evident in the resource of the role of language in scientific knowledge production. The first issue is the limitation of the staged pedagogy known as the '5 Es': Engage, Explore, Explain, Elaborate and Evaluate, to move students away from engaging at a level of high semantic gravity to engaging in language of higher semantic density. Although some new language is introduced in a piecemeal fashion in the early stages, it is only the third of five stages, *Explain*, that has the expressed aim *to introduce current scientific views…and support students to explain…* (e.g. AAS 2007b:1). Until this stage is reached, the orientation to scientific thinking is haphazard and confused by the imperative to capture students' interest. For marginalised students, this leaves an important period of study where they are potentially engaged at a superficial level with scientific artefacts, without a clear idea of the intention of the activities and without systematic support to access new language.

Scaffolding Science shows the effort required by the teacher to move students from concrete to abstract language. The study proposes that a logical language development sequence requires the scientific language orientation to begin in the first lesson, at the same time that students are

engaged with hands-on activities, giving marginalised students as many chances as possible to hear, understand and appropriate language.

The second issue is the lack of scientific language and coherent text expected of students. On principle, the activities begin strongly embedded in common sense. For example, the Stage 1 Energy and Change topic on force is called *Push-Pull* and the activities are concerned with toys, and sinking and floating. Some new vocabulary is introduced, but rather than a conscious re-orientation to science being the focus of the lesson, the plan is to *provide hands-on, shared experiences of pushes and pulls...* (ibid). The language choices here render the boundary between science and the everyday invisible. Although *Primary Connections* expects students to explain the processes in which they are involved, the language resources to achieve that aim are not foregrounded in the materials.

In fact, there are some very useful language resources in *Primary Connections*. They are identified as *Teacher background information*, found as an introduction to every activity, and intended to help with teacher understanding. These explanations and descriptions are detailed, and could be mined by the scaffolding teacher for more scientifically appropriate topic language.

The third issue is that the language and literacy guidelines provided in *Primary Connections* reflect poorly the text types and language resources necessary for effective participation in science. The use of word walls is strongly promoted (e.g. AAS 2007b:52), and popular with teachers because it is easily accomplished. The issue with a focus on listing technical language is that, as Martin points out, science is more than *logocentric* (Martin, J.R. 2013b); that is it does not focus primarily on individual words, or 'vocabulary' as it is often termed. The texts of a discipline are more than *word salad* (ibid). For Martin, words are place markers for the classificatory, compositional and sequential relations with the discipline (ibid). Pasting labels on a word wall is not sufficient to represent discipline specific meaning.

The understanding of literacy in *Primary Connections* is limited to an eclectic list of formats and text types. The identification of 'flow charts' as a literacy focus in Stage 4 is one example. A flow chart is a particular multimodal format of a sequential explanation. Each arrow in a flow chart represents a temporal, causal or factorial relationship between one part of the diagram and the next. The teacher's work is not done until the student is able produce a coherent oral or written text, to turn the arrows into words that represent the logical relationship. Fortunately the understanding of literacy in this resource has been superseded by the current guidelines of the Literacy Capability in the Australian Curriculum (ACARA 2013).

The language demands of science are complex. Teachers need to have a thorough understanding of the topic content, and which text types function to express the learning of the content

descriptors. They have to understand not only the structure of the genres (Text Knowledge), but the language choices inside them (Grammar and Word Knowledge) (ACARA 2013). The control of Theme and Rheme to organise and logically develop the text, the function and manner of nominalisations, and the use of conjunctions to express the logical relationships between parts of text are key. Because science often uses multimodal and multigeneric texts, teachers also have to understand the function of flow charts and diagrams, and the language which these images represent (Visual knowledge).

The explicit and detailed language descriptions within the Australian Curriculum have the potential to make a significant difference to the teaching of language and literacy embedded within the learning areas. However, at this point, the wealth of the language description in the curriculum documents can create a great deal of stress for teachers who, because of their own histories, may find the language challenging. The stress is exacerbated when combined with renewed expectations to regularly teach unfamiliar science content knowledge (Goodrum, D. *et al* 2000). Such stress was evident at times in this study. The conclusion drawn in this final chapter is that planning a focus text or series of focus texts prior to teaching the topic provides strong support and reduces the moment by moment stress for teachers. At the same time it increases the likelihood that students will be consistently exposed to the important language features they need to appropriate this new knowledge.

5.2.2.4 Using a focus text

The value of the teacher developing a focus text was first proposed by Gray (1998). Its purpose was to establish parameters for the instructional register, ensuring that teacher had given thought to, and was conscious of the text types and language choices which were to be important learning goals for the topic.

The development of focus texts before the teaching and learning take place demonstrated a number of advantages for the study. When the research team, in planning, had to articulate what we wanted to come out of students' mouths and to be written on paper by the end of the topic, we were forced to shift from vague conceptual understandings of the topic to specific language choices. The process alerted us to hazy understandings that needed further urgent investigation. It made us shift our thinking from isolated 'vocabulary' to attempt to articulate the relationship between concepts through coherent text.

Establishing a focus text meant that we could cross check its language elements against those expected in the early years of schooling, and refine the grammar as needed. One example was the inclusion of the Theme-Rheme pattern in the second focus text that staged the sequence of events (e.g. *When the apples have been taken to the shed.*…).

The structure of the focus text reflected the scope of the topic. In other words, the focus texts were clearly aligned with the curriculum goals and every curriculum goal was realised somewhere in a focus text.

The focus texts provided both coherence, that is a logical relationship between classroom activities, and cohesion between the two sets of activities (Eggins, S. 1994:87). Whether the students were rolling a marble down a chute, winding up a cotton-reel, or watching a video of the farm, the consistent and repeated talk about energy transformation provided coherence to otherwise unassociated activity. Each activity was another orienting iteration of the concept of energy transformation, with language as the cohesive element.

The focus text provided a clear trajectory from classroom dialogue to assessment. Each text accompanying activity was initially constructed orally, jointly and individually as part of classroom discussions, before students recorded it, jointly and individually. The words came first from the teacher, and eventually from students. They were assessed on their production of oral and written texts that had already been rehearsed through talk.

Such a highly scaffolded approach to assessment might sit uncomfortably with teachers whose pedagogy belongs in what Bernstein has labelled as the *competence* model (Bernstein, B. 2000). Whether progressivist or transmission, the competence model keeps the recognition and realisation rules for legitimate texts implicit. It emphasises *the realisation of competences that acquirers already possess, or are thought to possess* (ibid: 45). In contrast, the pedagogic model used in this study was a *performance* model. The recognition rules for legitimate texts were explicit and realised in the focus text. Classification was strong. The expectations of the assessment tasks were clear. The tasks assessed what a student had appropriated and could therefore display, rather than assessing any innate or prior knowledge. The use of the focus text guided this explicit process.

It goes without saying that there are risks in the use of a focus text. From the perspective of the progressivist 'discovery' pedagogic paradigm, its use is restrictive. From a socio-cultural perspective, that is its strength. The use of focus texts helps to keep classification strong, guiding the teacher in the use of scientifically appropriate language when she may not be sure of what to say. It makes sure the class is hearing and using language resources appropriate for their year level. It helps with the accuracy of the science content. Instances in the study, particularly in small group activity, demonstrated what happened when the teacher lost sight of the focus text. Classroom talk didn't become richer. It moved along the Register continuum towards situated, everyday talk. The instances of interactive trouble arising in those situations provide a strong argument for the value of focus texts in anchoring classroom dialogue. Talk using the

language from the focus text was efficient because it had already been thought through, and was reliable.

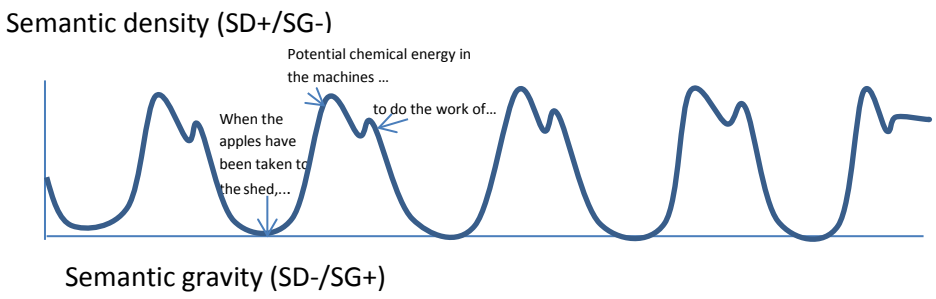
The scaffolding processes outlined in Chapter 4 demonstrated the many ways in which the teacher gradually handed over language and meaning to students, moving from imitation towards control. There is a danger, however, that instead of goal–oriented imitation, the process of students appropriating the focus text becomes rote repetition. The intention of incorporating focus texts into scaffolding processes is to support meaning development in the activity system of science. Rote repetition does not work towards that purpose. Rather than meaning development, it serves more aptly as artefact accumulation, a collection of texts that students will struggle to put to use.

A third potential issue is that the focus texts created by teachers are only as reliable as teacher knowledge about the topic, and also knowledge about language. Martin describes discourse meanings as composed of compositional, classificatory and sequential relations (Martin, J.R. 2013b). Relevant aspects of these relationships, not just a list of technical terms, should somehow be expressed in the text. Thorough knowledge of such relations is a struggle for the lay primary teacher. This is where a resource like *Primary Connections* can be drawn on, with focus texts developed from the Teacher Background Information as a trustworthy source of content and language.

Explanations, such as the focus texts developed for this study, are a central language resource in the activity system of science. Whilst Legitimation Code Theory has begun to describe semantic wave patterns for science explanations and has attempted to map semantic waves in secondary science texts (e.g. Matruglio, E., Maton, K. & Martin, J.R. 2013), the pattern for early primary science texts has not yet been investigated. Nominalisation, so important in structuring the texts of mature writers, is not yet expected at this age (Christie, F. & Derewianka, B. 2008:233). How does that change the semantic wave patterns of texts?

The semantic waves evident in the final focus text look something like this (extrapolated from Maton, K. 2013):

Figure 40. Semantic wave pattern of the farm-to-table chain text



Each stage in the text began with a phase describing the observable process (high semantic gravity). The next phase shifted to explaining the energy transformation (relatively high semantic density, lower gravity). Each stage finished with a clause of purpose explaining the work being done (slightly lower density, higher gravity). Further work in LCT is required to determine whether such a pattern is appropriate in the early years of schooling, or whether it could be improved to align with future language learning goals in science education.

The study proposes that building high density language is important, even in the early years, for establishing a scientific orientation and apprenticing students into science. It also proposes that the development of focus texts prior to teaching a topic supports this conscious effort by teachers. The question is how can this be achieved? How does the language-aware, scaffolding teacher find the appropriate, coherent language resources when developing these focus texts for any topic? There is a great deal of value in classroom teachers planning a topic together, including planning the accompanying focus texts, deciding on which genres will be used, and the language features within them, and matching the texts to curriculum documents to justify their choice. The rich conversations bring about immense learning. At the same time, the process can be highly frustrating and inefficient. Reliable and easily understood sources of scientific information are not readily available for the lay science teacher, and it takes considerable time to think through a topic to its conclusion and to determine the focus language. These two effects, of rich conversations and an increased workload for the teacher must be held in balance. There is value in providing teachers with exemplars of focus texts for particular Australian science Curriculum topics to begin the process of consciously aligning language with content. The *Primary Connections* activities provide a reliable source of sequenced activities on which language could be built.

5.2.2.5 Gradual release of responsibility and teacher register choices

One of the most interesting outcomes of the study is the idea that the gradual release of responsibility from teacher to student can be tracked through the changes in language use apparent in classroom dialogue, using the three metafunctions of the Ideational, Interpersonal and Textual. It means that it is possible to plot the logogenesis of a topic in two dimensions. Not only can the logical unfolding of the topic content be understood through the changes in ideational and textual meanings, but student control of language can also be mapped through changes in interpersonal roles, as the teacher hands over responsibility.

The use of the three metafunctions to track gradual release is a useful response to one of the limitations of semantic wave theory as it is currently presented. Semantic wave theory attends to logogenesis; that is the manner in which meaning is developed across a topic. Current work has

mapped teacher talk to show how concepts are unpacked and repacked to build semantic density. Martin talks about the need to move from high stakes reading to high stakes writing. He describes teachers 'powering up' and 'powering down' as they interpret and explain written texts (Martin, J.R. 2013b). Currently though, the pedagogic mechanism through which students are supported to appropriate high density language from their reading, and are able to apply it with control in high density writing is not apparent. How does the locus of control change? What happens in the classroom to enable the teacher to handover of control of high density language to students?

The plotting of handover and language development through language changes in classroom discourse was one way in which the study tracked the teacher's intended trajectory. It broadly established both the logical movement of classroom teaching and learning negotiation, as well as the changes in roles as students appropriated language. The study proposes that mapping language changes in this way could be a useful evaluation and self-monitoring tool for teachers developing their scaffolding techniques, and warrants further investigation.

5.2.2.6 The gradual abstraction of artefacts

As intended, the conscious shift from concrete to abstract representations within lessons proved to be a useful aid in shifting classroom dialogue to more decontextualised language. That is not to say that planning such a shift will automatically change teacher and student talk. It simply serves as a reminder to the teacher to remain conscious of decontextualising her language and supporting students to do the same.

Two additional strategies proposed by Polias, in his forthcoming text, *Apprenticing into science* may complement the strategy of artefact choice. The first is that that teachers support a shift along the Register continuum with the use of a 'meso-scaffold': by changing one aspect of register at a time; people, space or time:

> *Increasing each of these three variables changes the register so that it either shifts to the left, towards the spoken end of the continuum, or it shifts to the right, towards the written end of the continuum. In other words, increasing the number of people involved in the communication, or the space between the people involved in the communication, or the time between when something happened and when it is talked about moves the language closer to written language* (Polias, J. Forthcoming:88).

Each of the proposed shifts potentially increases the meaning-making load on language. Polias also suggests the gradual development of genres from the 'doing' genres, such as a recount to the 'arguing' genres, such as an argument and discussion (ibid: 10). His recommendations support the shift in artefacts proposed here from the concrete to the abstract. Both these

strategies are worthy of further investigation as future principles for guiding the shift from the concrete to abstract, and from situated to decontextualised student language.

5.2.3 Learning from classroom dialogue

5.2.3.1 Scaffolding strategies

Scaffolding science demonstrated the many principled scaffolding strategies available to the classroom teacher to support teaching and learning. Most importantly, the strategies are not a 'grab-bag' of resources, but carefully selected in response to the levels of intersubjectivity already established. They build common knowledge, while at the same time maintaining positive affect in the classroom.

The principles established to guide the study were outlined in Chapter 3. Several principles were aimed at 'respectful invitation into the discourse'; to encourage participation whenever intersubjectivity was low. These included the use of the inclusive 'we', question tags to share authority and infer intersubjectivity, and non-specific nominations such as 'anyone'. Other strategies worked towards academic intersubjectivity, building common knowledge. These included the contingent use of preformulation and reconceptualisations in the questioning sequence, the gradual change in questioning strategies to shift student lexis from commonsense to technical language, and the shift from reconceptualisations to joint construction as an important first step in student appropriation of language.

One insight gained from the study is the change in speech function as the topic progressed. When intersubjectivity was low, the teacher made statements; she used the declarative to share new information. That was the highest level of scaffold, requiring no active participation from students. As she progressed, the teacher introduced question tags at the end of her statements as an inclusion strategy. She moved from statements to questions, cued with a preformulation to orient students to 'what was in the teacher's head', followed with a reconceptualisation to broadcast the significance of the answer and develop common understandings. Importantly, early questions were couched as transactions of services, as students doing the teacher and class a favour by helping them with an answer. Later, when intersubjectivity was higher, question and answer sequences changed to become part of a knowledge exchange. Teacher reconceptualisations became teacher questions, with the purpose of checking for handover, at about the same time that joint construction of texts began.

Chapter 4 provided examples of the range of questioning modifications available as scaffolds. They were not always used contingently in the study. Instances of interactive trouble in the study were the result of inappropriate choices of speech function, or insufficient preformulation in a question such that students were still guessing what was in the teacher's head.

The challenge of contingent questioning as a scaffold still relies a great deal on teacher intuition. How does the teacher determine when and how to preformulate, and what to say as reconceptualisations? When and how does she reduce the scaffold, turning statements and reconceptualisations into questions? When are question tags appropriate? When do service exchanges shift to knowledge exchanges? What type of questions assist with joint construction of text and with students producing more extended texts? The work of Gray (2007), Cowey (2007), Harper (2008)and Rose (Martin, J. R. & Rose, D. 2007) in articulating the purpose and structure of scaffolding questions is acknowledged. There is still scope for further work in mapping the relationship between types of questions and levels of scaffolding to further support intentional and contingent teaching.

5.2.3.2 The role of the regulative and instructional registers

One of the most important findings of the discourse analysis presented in the study was the inverse and changing relationship of the regulative and instructional registers as intersubjectivity grew. The teacher's regulative register worked hard at the beginning of the topic to encourage students to persist when there was little shared meaning; with her positive feedback, her non-specific invitations to answer questions, and her obvious excitement when students did participate. As shared meaning grew, this work of the regulative register waned, with the framing becoming apparently weaker. Once students had a shared understanding of what was required, the work to maintain positive affect was not so necessary.

In contrast, the work of the instructional register grew in strength. To begin with, the scientific language in the instructional register was the domain of the teacher, evident in 'telling' and in her reconceptualisations of students' mostly commonsense comments and responses. The teacher's role was to introduce the new scientific language, from the beginning lesson, along with commonsense bridging terms to help initially with building meaning. As shared meaning grew, the new scientific and bridging terms in the instructional register began to come from students. By the end of the topic, the teacher expected a close approximation of the target language, and used the regulative register to reword commonsense language through questions such as 'How could we say that scientifically?'.

Much of the interactive trouble in the study came from difficulties with the instructional register. It was evident that a thorough understanding of scaffolding strategies was not sufficient without the lay science teacher also having a thorough understanding of the topic to be taught and how to talk about it. This included the use of 'bridging' language, which was an important strategy for making the boundary between science and the commonsense permeable. Finding the right commonsense terms to explain scientific concepts to 7-8 year olds in a way that assists rather than impedes understanding is a challenge. It required considerable thought, and trial and

error, and would be difficult for teachers to do on the spot. Establishing the bridging language is a necessary part of preliminary planning.

5.2.3.4 Identifying 'interactive trouble'

The study used the notion of 'interactive trouble' , proposed by Freebody et al (1995) to identify problems in classroom interactions. Interactive trouble was identified when a student response, either physical or verbal, was at variance with that anticipated by the teacher or observer. In the words of Martin and Rose, the response was neither compliant nor complementary (2007:223). In a framework developed by Freebody et al (1995), interactive trouble was classified according to a range of criteria previously described in Table 8, Section 3.2.5, p92.

However, when attempting to match the instances of interactive trouble in the study against Freebody's criteria, issues appeared. For example, an epistemological issue, where the student does not know the answer, requires further interrogation in the mind of a scaffolding teacher: it might be an issue of the teacher not having shared the information properly in the first place, or of not having chosen the appropriate speech function according to the level of intersubjectivity. Perhaps she should have given information rather than asked a question, or perhaps she should have preformulated the question, or perhaps she should have made a request rather than a demand. It became apparent that the issues identified in the study could fruitfully be identified as the responsibility of one or other of the pedagogic registers, either the regulative or instructional. Sometimes the trouble was compounded with issues from both. Accordingly, the classificatory categories of interactive trouble were reframed to align with the two pedagogic registers, and the specific instances of interactive trouble in the study were matched to these.

The criteria extrapolated from the study are as follows:

Table 35. Summary of interactive trouble in this study according to instructional and regulative registers

Interactive trouble in this study classified according to instructional and regulative registers
Regulative register • Issues with speech function choice: when the teacher made a command instead of a request; or when she prematurely removed preformulation when it was still necessary, and asked a bald 'wh-' question Issues with talking about 'what scientists do' in a way that had meaning for students
Instructional register • Language and conceptual issues: difficulties in distinguishing between abstractions and concrete objects; difficulties in expressing relationships between scientific phenomena • Issues with clarity: use of exophoric referents exacerbated by hands-on activity • Difficulties in distinguishing between procedure and principle • Unhelpful use of non-specific generalised reference items and 'empty' verbs: e.g. 'what's going on?', 'something to do with'…

There is no doubt that there were instances when the teacher made errors of judgement about what was contingent in the regulative register. No teacher is able to pick the right level of scaffold for every student at every point in a teaching and learning context. However, in this study, the teacher's control of scaffolding strategies meant that she could sometimes repair on the spot, and sometimes repaired interactive trouble after reflection, by adjusting the next lesson.

It was the instructional register where most of incidents of interactive trouble occurred, and the issues were recurrent. These were language issues with two different causes. The first was due to the teacher's struggle and effort to understand and talk about the new phenomenon of energy transformation in a coherent manner. The second was to do with the use of non-specific or 'empty' verbs such as 'going on', and reference items, particularly exacerbated in hands-on activity. Often these language choices did not provide students with sufficient scaffold around the topic when intersubjectivity was low.

In summary, some of the interactive trouble was to do with the teacher's knowledge of the content and appropriate language choices to express that content. Some of the interactive trouble was to do with the teacher's errors from time to time in regulating the unfolding and handing over of that content. The teacher needs control over both registers. The conclusion drawn from this analysis is that it is helpful to isolate interactive trouble according to the pedagogic register most likely to be responsible. Narrowing down the issue may make understanding and repairing the issue less overwhelming and more manageable for the classroom teacher.

5.2.4 Class grouping structures

Several class arrangements were used across the seven lessons in this study. They were:

- whole class activity
- groups of three working independently with the teacher rotating amongst groups
- groups of three working closely with the teacher
- a group of three making a presentation with the rest of the class as audience as a master class
- pairs when students rehearsed their farm-to-table chains

The whole class grouping was central in the introduction of new learning, and was also used as one structure for consolidating learning and for formal presentations. Whole class activity structures attended to developing common knowledge amongst all students with the teacher able to model a scientific orientation to activity when all students could attend together.

Independent small group activity. The pedagogy of both *Primary Connections* and the Teaching and Learning Cycle recommend small group work at the beginning of a topic to foster student engagement and curiosity. Small groups allow students to use their own language for making sense of the activity. They allow the teacher to find out what the students already know before the teaching begins. However, dedicating time to small groups when intersubjectivity is low is inefficient. The teacher cannot ensure that students have sufficient understanding to participate in the activity in a manner that is in any way scientific. The first small group activity with the four demonstrations of energy transformation provided a case in point. The structure had to be endured so that students became familiar with the materials, but evidence of scientific thinking and talking was scant. The teacher's time was spent rotating, calming students down, and only from time to time, talking to them about energy transformation.

As intersubjectivity grew, group work became more effective for some tasks. In this study, the teacher used threes and pairs to practice the farm-to-table chain. The task was very specific, and the roles for each student were clear. Because they had shared understanding and language, students were able to mediate to an extent with each other, helping each other out when they were stuck.

Groups of three with the teacher. The whole class structure was important for building common knowledge, as well as checking for handover to some extent. However, with so many students vying for air space, it was not effective in enabling students to practise new language. One structure tested here was that of setting the class to do a quiet and unchallenging task in the form of a work sheet while the teacher withdrew each student in groups of three to go through each of the four explanations once again, checking for handover and extending student talk. The students in this class had been trained not to interrupt in such a setting, and this small group withdrawal process was highly effective in monitoring all students for their control of new language, as well as continuing to scaffold as required.

The 'master class' was a novel class structure that is worthy of further investigation. It was only used when the level of intersubjectivity was high, and students were confident of their roles. The teacher still scaffolded as required, but she was sure that the students were able to perform in a high stress situation. She was able to use this organizational structure to check for handover of the whole class and model for the whole class.

5.3 Conclusions

Scaffolding science has demonstrated the benefit of shaping the insights and knowledge from Vygotskian activity theory, Bernsteinian sociology and Hallidayan systemic functional linguistics into a distinctive pedagogic framework. The pedagogic principles from this triad show an alternative to the fruitless dichotomies of progressivist versus transmission pedagogy.

Bernstein's work provides an important political motivation for this radical pedagogic position. Vygotsky ventures into the psychological where the other two theories do not venture. He takes our attention beyond the context of situation to the context of culture, elucidating the need to begin apprenticeship into new discourse with an orientation to the values and motivations of science. Halliday and subsequent academics make visible what we need to know about the language of science.

The study has demonstrated just how demanding a third way, labelled here as scaffolded pedagogy, is for science teachers in the early years. The classroom discourse analysis has shown how each word and word choice matters, and that effective teachers have to make contingent and conscious choices about their language at every point in classroom dialogue to provide contingent scaffolding for all. This process is far more sophisticated than attempting to cater for each student's zone of proximal development through group work .Both the regulative and instructional registers require this purposeful moment-by-moment attention if positive affect as well as academic rigour are to be maintained and strengthened as the teaching and learning progress.

Many of the scaffolding practices applied or recommended in this study are likely to be strongly challenged by educators in the early years of schooling. For example, the Early Years Learning Framework Perspectives on Pedagogy from the SA Department of Education states:

> *Quality pedagogy is less effective when aspects of early years education are independently planned by the educator, are inflexible…based on educators' agendas, expect all children to complete the same activity, are focused on talking rather than doing…*(DECD 2012a).

The contentious practices espoused in this study include the intentional and systematic shift from situated to decontextualised language such that students are not stranded in concrete activity; conscious modelling and knowledge construction as a whole class so that knowledge is shared; and intentional, goal oriented teaching and learning negotiation with the teacher contributing with crucial language resources. The principles underpinning the pedagogy call into question the provenance of the Early Years perspective exemplified in the quotation above.

When it comes to science education for marginalised students, the gap between what is and what could be is immense. Nevertheless, Australia has a significant number of intelligent, reflexive and committed scaffolding teachers. Assisted by the mandate provided by the language-focused Australian Curriculum, the work to develop marginalised students into participating citizens continues with these educators.

APPENDICES

Appendix 1: Nature of Science (AAS 2008)

Chapter 1: THE NATURE OF SCIENCE
THE SCIENTIFIC WORLD VIEW
The World is Understandable
Scientific Ideas are Subject to Change
Scientific Knowledge is Durable
Science Cannot Provide Complete Answers to All Questions
SCIENTIFIC INQUIRY
Scientists Demand Evidence
Science is a Blend of Logic and Imagination
Science Explains and Predicts
Scientists Try to Identify and Avoid Bias
Science is not Authoritarian
THE SCIENTIFIC ENTERPRISE
Science is a Complex Social Activity
Science is Organised Into Content Disciplines and is conducted in Various Institutions
Ther are Generally Accepted Ethical Principles in the Conduct of Science
Scientists Participate in Public Affairs both as Specialists and Citizens

AAS 2008, *Chapter 1: Nature of Science,* American Association for the Advancement of Science, viewed 22nd January, 2012. <www.project2061.org.publications/rsl/online/SFAA/CHAP1.HTM>

Appendix 2: Information for teacher and teacher consent

Ms XXXXXXXXX,
Cowandilla Primary School,
Jenkin St,
Cowandilla.

Dear XXXX,
Thank you for considering my request to carry out a study titled *Scaffolding Science (Teaching and Learning In Science)* at Cowandilla Primary School in your Year 2/3 class. Please find below additional information about the study to take into consideration before giving your consent to proceed.
The purpose of the study is twofold:
To identify presumptions and issues underlying current teaching practice as the teacher incorporates scaffolding principles into her Science education repertoire.
To identify teaching processes which enable the scaffolding of effective learning negotiation within subject Science.
I plan to collect data in your class across one topic in one term, expected to span about six Science lessons, one lesson per week. It is anticipated that you and I can meet for half a day each week during those six weeks to review video from the previous lesson and plan our way forward.
In order to evaluate the impact of our pedagogy on a range of students, I plan to study more closely the participation in Science lessons of 7 case-study students: 2 Aboriginal, 3 LBOTE, and 2 mainstream. Within each group, I would like you to identify a student who is working at least at age appropriate level, and one who is struggling with school learning. This will provide a cross section of students from the class.
I plan to collect the following data:

- Videoed and transcribed interviews of seven case study students, pre- and post- topic. The interview will consist of a 'warm-up', where I will ask students to chat about themselves, then a story retell, and a Science explanation retell. These retells will be analysed for their language content.
- Videos and transcriptions of the six Science lessons.
- Field notes and artefacts from our weekly planning meetings during that time.
- Photographs of students at work, and of the smartboard presentations at various stages through the lessons.

The data will be stored for five years at the Adelaide University Linguistics Department, in digital form, and at the home of the researcher in digital and hard copy form, in a locked box.
Because you and students will be identifiable from video footage, anonymity is not possible. You may choose to take a pseudonym, but bear in mind that students may refer to you by name in the video.
Presentation of the study: the findings from the study may be published as a thesis, in journal articles and conference presentations. You will be provided with a copy of the thesis, and an executive summary once the thesis has been accepted. I am also happy to present the findings with you to your staff during and after the study. I would like to also present our research to parents in an afternoon tea 'show and tell' as we did in 2008.
There is no intention to represent the school, the teacher or the students in any adverse manner during, or as a result of the study. The following processes are suggested to support this intention:

The principal may withdraw your school from participating in this research at any time without explanation. She may also renegotiate the study parameters with me at any time if she considers any aspects of the study are detrimental to the school, the teacher or the students.
The principal may veto the use of any video footage if she considers its use detrimental to the school, the teacher and the students.
The principal will be provided with a draft of the thesis. At this time, she may veto or renegotiate any representation of the school, the teacher or any student in the thesis.
Parents of case study students will be provided with a digital copy of their child's interviews. They have the right to veto their use.
The proposed study is collaborative in nature, and any Science lesson videoed during this study is a realisation of the planning and review that you and I have done together. Nevertheless, I understand the risk taken by you, as classroom teacher, in allowing your classroom practice to be scrutinised in a formal study like this. The following processes are suggested to ensure that you are not adversely affected by the study in any way:
You will be provided with field notes and video after each lesson. If I have misunderstood, or misrepresented your intentions or actions, you have the right to discuss and negotiate with me your interpretation of each lesson.
You have the right to veto the use of any part of the video.
You will be provided with a draft of the thesis. At this time, you may veto or renegotiate any representation of your classroom practice or comments represented in the thesis.
You have the right to withdraw from the study at any time without explanation.
The principal has the responsibility of monitor your ongoing wellbeing during this study, along with you yourself. You and she have the right to renegotiate the study parameters at any time if you consider any aspects of the study are detrimental to the school, yourself or the students.
Please note that I am a DECS employee, and have a duty of care for the safety and wellbeing of children and young people.
Please refer to the attached information on the University's Complaints procedures. It contains contact information should you have any query or complaint to make.
Once again, thank you for your willingness to consider involvement in this study. Please find the consent form attached for your signature if this information is to your satisfaction.
Yours sincerely,

XXXXX
PhD Student
University of Adelaide

CONSENT FORM FOR USE WHEN TAPED MATERIALS, PHOTOGRAPHS OR ORIGINAL WORKS ARE TO BE RETAINED: Class teacher

Project Title **SCAFFOLDING SCIENCE (TEACHING AND LEARNING IN SCIENCE)**

Researcher's name **XXXXX**

Supervisor's name **XXXXXX**

- I have read the Participant Information Sheet, and the nature and the purpose of the research project has been explained to me. I understand and agree to take part.
- I understand that I may not directly benefit from taking part in the project.
- I understand that I can negotiate with the researcher to modify aspects of the study if at any time I consider it to be detrimental to myself or the students.
- I understand that I can withdraw from the study at any stage and that this will not affect my status now or in the future.
- I confirm that I am over 18 years of age.
- I understand that I will be videotaped and photographed during the study.
- I understand that the tape will be stored at Adelaide University Linguistics Department for five years, with a copy kept by the researcher.
- I understand that I have the right to veto the use of any part of my video footage. On this condition, I grant the researcher the exclusive and royalty free right to reproduce and use in her ongoing activities photographs, video, or any other recording by any means of my voice or physical likeness which is produced in the course of the project.
- I understand that the researcher shall not be required to make any payment to me arising out of her exercise of this right.
- I understand that wherever practical, the researcher will acknowledge my participation in the project in exercising this right.

Name of participant .....

Signed .....

Dated .....

I have explained the study to subject and consider that he/she understands what is involved.

Researcher's signature and date .....

Appendix 3: Information for parents and parent consent

Dear guardian of students in XXXX's Year 2/3 classroom,

For the past 2 years, XXXX and I have been working together on teaching Science at Cowandilla Primary School. I am now studying for a PhD at the University of Adelaide, and wish to use some of the information we have collected in the past, and also gather some new information from lessons on Science in the Year 2/3 classroom. I would like your permission to involve your child in this study. Please find information below that you need to consider before you agree to this:

The title of the study is *Teaching and Learning in Science.*

Our aim is to find and solve some of the problems facing a teacher in teaching Science in the Primary School as we try to make sure that all students in the class learn to think and talk scientifically. For this reason, I will be videoing Science lessons in XXXX's class.

I will be videoing for one term, one lesson each week.

I will be collecting the following information in the study:

- Video footage
- Written record of some of the talk in the lesson
- Photographs
- Work samples

This information will be stored at the Adelaide University Linguistics Department for five years. The researcher will also keep a copy.

Your child will be able to be identified from this information.

There is no payment available for your child to take part in this study.

I need your permission to use the information in my thesis, in any written report, and in conference presentations. No payment is available for this.

There is no compulsory participation for your child in the project. If you do not wish for your child to participate there will be no negative consequences for the child. Participation is entirely voluntary.

You can withdraw your child from the study at any time, without explanation. If this happens, your child's face will be masked in some way in the video so it can't be identified.

You will be invited to have a look at what we've learned at an afternoon tea with the students later in the year.

Please note that I am a DECS employee, and have a duty of care for the safety and wellbeing of children and young people.

Please refer to the attached information on the University's Complaints procedures. It contains contact information should you have any query or complaint to make.

Thank you for considering this information. If you are willing for your child to participate, please sign the attached consent form and return to XXXX at Cowandilla Primary School.

Yours sincerely,

XXXXX

PhD student University of Adelaide

CONSENT FORM FOR USE WHEN TAPED MATERIALS, PHOTOGRAPHS OR ORIGINAL WORKS ARE TO BE RETAINED: Guardians of students in the class

Project Title **TEACHING AND LEARNING IN SCIENCE**

Researcher's name **XXXX**

Supervisor's name **XXXX**

- I confirm that I am the guardian of _____.
- I have read the Participant Information Sheet, and the nature and the purpose of the research project have been explained to me. I understand and agree for my child to take part.
- I understand that I may not directly benefit from my child taking part in the project.
- I understand that my child can withdraw from the study at any stage and that this will not affect my status now or in the future. If I withdraw my child during the study, I understand that images of my child's face will be masked in some way to remove identification.
- I understand that my child will be videotaped and photographed during the study.
- I understand that the video and photographs will be stored at Adelaide University Linguistics Department and a copy will stay with the researcher for a minimum of five years.
- I understand that I will be invited to Cowandilla Primary School to view examples of the classroom lessons videoed during the course of this study.
- I grant the researcher the exclusive and royalty free right to reproduce and use in her ongoing activities photographs, video, or any other recording by any means of my child's voice or physical likeness which is produced in the course of the project.
- I understand that the researcher shall not be required to make any payment to me arising out of its exercise of this right.

Name of guardian .....

Signed .....

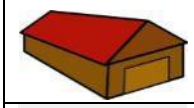
Dated .....

I have explained the study to subject and consider that he/she understands what is involved.

Signature and date .....

Researcher /Teacher /Principal/Other (Please specify)

Appendix 4: Analysis of farm-to-table explanation

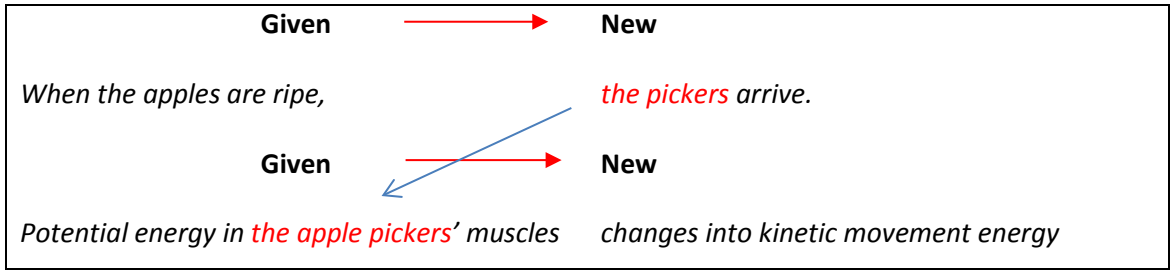
Stage	Text	"Written-like or scientific features
Step 1 Sun to earth 	Almost all the earth's energy comes from the sun. Kinetic energy, heat and light, is sent down to the earth in rays.	Modality: 'almost all' in expanded noun group. Use of technical terms. Nominalisations. Passive voice. Expansions of clause through circumstances of place and manner.
Explanation of energy change 	When the heat and light reach the apple tree, kinetic energy changes into potential chemical energy to make the trees and apples grow. Potential chemical energy is also stored in the apples.	Dependent clause as marked Theme. Non-human participants. Technical terms. Non-finite clause of purpose. Passive voice
Step 2 Tree to bin Explanation of energy change. 	When the apples are ripe, the pickers arrive. Potential energy in the apple pickers' muscles changes into kinetic movement energy to do the work of picking the apples and putting them in the bin.	Dependent clause as marked Theme. Technical terms. Expansion of noun group through circumstance of place. Expansion of noun group with defining relative clause. Non-finite clause of purpose.
Step 3 Washing Explanation of energy change. 	In the shed, first the apples are washed in big machines. Kinetic electrical energy changes to kinetic movement energy to do the work of washing and packing the apples.	Circumstance of place and time as marked Theme. Passive voice. Non-human participants. Technical terms. Expansion of noun group with defining relative clause. Non-finite clause of purpose,
Step 4 Shed to shop Explanation of energy change. 	Once the boxes of apples are packed, the semitrailer arrives to take the apples to the supermarket. Potential chemical energy stored in the petrol tank changes to kinetic movement energy to do the work of carrying.	Dependent clause as marked Theme. Passive voice. Non-finite clause of purpose. Expansion of clause through circumstance of place. Technical terms Expansion of noun group with defining relative clause.
Step 5 Explanation of energy change. 	Potential energy in their muscles changes to kinetic energy to do lots of work: pushing the trolley, packing the apples, paying for them.... …and taking them home.	Expansion of clause or noun group through circumstance of place. Technical terms Expansion of noun group with defining relative clause.
Step 6 Shop to home 	When the apples arrive at the supermarket, the customer comes to buy the apples and take them home.	Dependent clause as marked Theme. Non-finite clause of purpose.
Step 7 Explanation of energy change. 	When the children are hungry, they do the work of eating the apple. Potential chemical energy in the apple changes to potential chemical energy in their muscles, stored ready to do work.	Dependent clause as marked Theme. Expansion of noun group with defining relative clause. Non-finite clause of purpose. Expansion of noun groups through circumstance of place.

		Technical terms Expansion of noun group with defining relative clause.
Step 8 Bowl to play Explanation of energy change 	Finally the children go outside to play. Potential chemical energy in their muscles changes to kinetic movement energy to do the work of throwing, kicking, climbing, etc.	Marked Theme. Non-finite clause of purpose. Expansion of noun group through circumstance of place. Technical terms Expansion of noun group with defining relative clause.

Specific features of the text identified as 'scientific-like' follow:

- At genre level, the text was an explanation. Its initial purpose was to describe the steps taken to get an apple to the fruit bowl so a child could eat it (a typical farm to table sequence often used in Social Studies lessons), but it had a secondary, more important scientific purpose, to explain the process of energy transformation enabling work completed at each step.
- At stage level, the text consisted of a number of temporal steps. Each stage in the chain consisted of two phases: first the step in the process was described ('work' in scientific terms), second came an explanation of how the energy change enabled that work to occur.
- At clause level, several features distinguished this text as different from children's typical spoken language and moving towards both the written mode and scientific discourse:
- There were several instances of marked Theme, particularly the use of dependent clauses in Theme position. These clauses support the cohesion or logic of the text, linking each clause to the previous one. Several instances of the zig-zag pattern of thematic relations are evident, where the Rheme, or new information provided in one clause becomes the Theme, or given information in the first clause of the next sentence, acting as a launch for yet more new information. The figure below provides an example:

Given-new structure within text (New in the first sentence becomes given in the next)



The text includes a number of expansions to provide sufficient information for the reader or listener. Several clauses were enhanced with non-finite clauses of purpose, as would be expected in an explanation, and within these clauses came further expansions within noun groups. For example: *to do the work of getting the apples to the shed.*

At word level, the text used technical and scientific terms, such as heat, light, kinetic motion energy etc. Some of these were abstract, like *energy*, some were nominalisations of processes, such as *heat* and *light*

-Dependent clauses included conjunctions that supported the logical cohesion of the text through extension, eg When the apples had been picked,…

-The text made use of passive voice, rendering invisible the less important human actors. Along with the use of non-finite clauses, this has the effect of creating a more Lexically dense text, sounding more 'written-like', and enables the more important non-human participants to be placed in Theme position in the clause eg Once the boxes of apples are packed, the semitrailer arrives to take the apples to the supermarket

.

***Farm to table explanation*: instructions for test administration**

1. Have 2 laminated charts ready: one with labels included, and one without.
2. Say to student: *This is called a flow chart. It shows how one thing flows or moves to another. I'm going to explain how energy gets used so a child can ride their bike or do some exercise. It begins with energy from the sun, and flows all the way to a child riding a bike. Then I want* ***YOU*** *to explain what's happening. I'm trying to hear how well you can explain what's happening in this flow chart. I'll explain it twice, then I want you to explain to me how energy is used so a child can ride their bike or do some exercise. Now I'm going to begin.*

3. Read through the laminated chart which includes the labels. Include the following details.

Step 1. Point to the sun. Say *Here's the sun. Heat and light energy from the sun, that means kinetic energy, doesn't it, is absorbed by this apple tree,* (point to the apple tree) *and changes into chemical energy to make the apples grow. Potential energy is stored in the apples.*

Step 2. Point to the tractor. Say *When the apples are picked, potential chemical energy stored in the tractor's petrol tank changes into kinetic energy to move the apples to the shed.*

Step 3. Point to the shed. Say *We can't really see the machines inside that shed, but they're in there, making sure the apples are ready to get sold. In the shed, potential energy in machines changes to kinetic energy to wash and pack the apples.*

Step 4. Point to the truck. Say *When the apples are ready to do, the potential chemical energy stored in the petrol tank of the truck changes to kinetic movement energy to take the apples to the supermarket* (point to the supermarket) *and then home* (point to the house).

Step 5. Point to the child eating an apple. Say *When children are hungrythey eat the apple. Potential chemical energy in the apple changes to potential chemical energy in muscles.*

Step 6. Point to the child on a bicycle. Say *When the children run out to play, or ride a bike, the potential chemical energy is changed into kinetic movement energy.*

4. After reading through once, say *Now I'm going to explain the energy flow once more. When I've finished, I will give you this copy of the flow chart, without the words. Then I want you to do the explaining, okay?* (Make sure at this stage that the student understands they won't have the text to support them.)
5. Read the labels again.
6. Then say to the student: *Now I want you to imagine that you're explaining this flow chart to some kids who have never seen one before. I want you to explain how energy is used from the sun, all the way through to the child on the bike, giving as much information as you can so that they will understand what's happening. Here is the flow chart again. You start when you're ready*
7. (If they get stuck at any step, say: *What happens to the energy next?)*

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