Chigeza, Philemon Tatenda (2010) ***Cultural resources in science learning: research with Torres Strait Islander middle school students.*** **PhD thesis, James Cook University.**

Cultural Resources in Science Learning: Research with Torres Strait Islander Middle School Students

Thesis submitted by

Philemon Tatenda Chigeza

June 2010

For the Degree of Doctor of Philosophy

in the School of Education

James Cook University

STATEMENT OF ACCESS

I, Philemon Tatenda Chigeza, author of this work, understand that James Cook University will make this thesis available for use within the University Library and, via the Australian Digital Theses network, for use elsewhere.

I understand that, as an unpublished work, a thesis has significant protection under the Copyright Act, and I do not wish to place any further restriction on access to this work.

__________________ _______________

Signature Date

STATEMENT OF SOURCES

I, Philemon Tatenda Chigeza, declare that this thesis is my own work, and has not been submitted in any form for another degree or diploma at any university or other institution of tertiary education. Information derived from the published or unpublished work of others has been acknowledged in the text, and a list of references is given.

Signature   Date

ELECTRONIC COPY

I, Philemon Tatenda Chigeza, the author of this work, declare that the electronic copy of this thesis provided to the James Cook University Library is an accurate copy of the print thesis submitted, within the limits of the technology available.

_____________________ _____________________

Signature Date

STATEMENT ON THE CONTRIBUTION OF OTHERS INCLUDING FINANCIAL AND EDITORIAL HELP

The writing of this thesis was a sole endeavour, but the finished thesis can reflect insights and influences from colleagues, especially at the School of Education, James Cook University and the Indigenous College, who might be unaware of their contributions. I would like to thank all these colleagues whose influence had a beneficial effect on the thesis. I also wish to thank my supervisor, Dr. Hilary Whitehouse, Dr. Clifford Jackson and Jill Barber, for their significant input editing this thesis.

Lastly, I want to thank the School of Education, James Cook University for the financial help towards this research study.

SECOND DECLARATION

The research was conducted within the guidelines of "The National Statement of Ethics in Human Research and Keeping Research on Track: A Guide for Aboriginal and Torres Straits Islander people about health research ethics." The research received ethical clearance from the James Cook University Human Research Ethics Committee (Approval number H2417).

____________________ ____________________

Signature Date

ACKNOWLEDGEMENTS

I have been greatly supported by my family during the course of my research study. I wish to thank my wife Grace, my daughter, Philippa, and my sons, Flynn and Floyd, for their unwavering support. The journey was long, and my presence in the family was sometimes nominal, yet they continued to support me.

I wish to thank my principal supervisor, Dr. Hilary Whitehouse, for her guidance and the many hours she helped me with my research project. I also want to thank my co-supervisor, A/Prof. Mary Klein, for her support, A/Prof. Melissa Vick, Dr. Leah Simons, Dr. Clifford Jackson and Dr. Pauline Taylor, as well as many staff members in the School of Education and fellow postgraduate students in the school.

Finally I want to thank the group of Torres Strait Islander middle school students who participated in the study, their parents and guardian for allowing them to participate, six Torres Strait Islander adults in the school, for participating in the study and the principal of the Indigenous College, for giving permission for the study to take place. A big ‘ESSO’ to all.

ABSTRACT

Torres Strait Islander Year 9 students learning science negotiate many complex knowledge and language challenges. In the State of Queensland, the mandated Queensland Studies Authority, *Science: Years 1 to 10 Syllabus* (2004) is formulated, taught and assessed using Standard Australian English at the expense of every other language dimensions of Indigenous students. Masters (2009) reports Indigenous students from the Torres Strait and Cape District perform among the lowest five per cent of students nationally. Masters suggests that by Year 9, the ‘gap’ in achievement level between non-Indigenous Queensland students and Indigenous students from the Torres Strait and Cape District is, on average, equivalent to six to seven years of school.

A classroom action research study (Kemmis and McTaggart, 2000) that employed a socio-cultural analytical lens was conducted between 2007 and 2008 in a wholly Indigenous school. The purpose of the doctoral study was to look beyond the rhetoric of the ‘gap’ in achievement, to explore dimensions of pedagogical content knowledge of how 44 Torres Strait Islander Year 9 students can best use their cultural resources to engage with science curriculum as a cultural field. Cochran and colleagues (1993, p. 266) define pedagogical content knowledge as “a teacher’s integrated understanding of components of pedagogy, subject matter content, student characteristics, and the environmental context of learning”. Bourdieu’s (1984) cultural sociology transforms the dialectical relationship between agency and structure in terms of habitus, cultural capital and cultural field. This standpoint was employed to investigate, understand and improve classroom practice: how students employed everyday Creole and formal science language, participated in science activities, and applied and related to science concepts of energy and force. For second and third cycles of research, the following were explored: cultural resources that students drew on for developing their understandings, pedagogical content knowledge that enabled students to learn, know and (re)produce knowledge, and how the structure of the mandated Queensland Studies Authority science curriculum, Level 5 learning outcomes, enhanced or limited the agency of students.

Three categories of how students employed formal science terminology (in Standard Australian English) to demonstrate their understandings were identified. Three categories on how students actively participated in science learning were identified. Only 7 of a total 44 students were proficient in Standard Australian English. The majority of students struggled to understand concepts of energy and force as taught in English. But when Creole terminology was used in the classroom, the students were better able to talk about science in ways they could not do in the official language of instruction. No direct comparison could be made between meta-concepts of energy and force as constructed in the Queensland Studies Authority science curriculum in Standard Australian English and the concepts as constructed in Torres Strait Creole.

Dimensions of pedagogical content knowledge are discussed around six themes that emerged from the study. The first theme takes into account students' competence in speaking, reading and writing Standard Australian English with facility. The second theme explores how Torres Strait Creole can be used as a resource for learning school science concepts more productively in the classroom. The third theme takes into account the interacting language and knowledge systems when students engage in learning physical science concepts of energy and force. The fourth theme recognises that most students from communities in North Queensland are multi-lingual/cultural. The fifth theme calls for a rethinking on science literacy and classroom discourse with Torres Strait Islander students. The sixth theme explores ontological concerns that arise at conceptual content level (Nakata, 2007), and acknowledges that the Queensland Studies Authority science curriculum as it is currently constituted, makes little concessions to Indigenous ways of knowing.

Employing Bourdieu's cultural sociology suggests that using Standard Australian English for learning experiences does not fully facilitate students' negotiations from their vernacular languages into science. My conclusion is that developing pedagogical strategies that accommodate the multiple language and cultural dimensions of old and emerging Torres Strait Islander cultures is possible, but the practice of standardised assessment conducted in Standard Australian English remains a substantial obstacle to these students' achievement.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

THIS ARTICLE HAS BEEN REMOVED DUE
TO COPYRIGHT RESTRICTIONS

Figure 1: Article published in The Weekend Post on Saturday 17th October, 2009. The students were not part of the research study.

Chapter 1
An introduction to the study

1.1 My social trajectory

As habitus and cultural disposition are central to my socio-cultural theoretical frame, it would only be proper at this point to give a brief introduction to me. Habitus has been defined as a set of dispositions created through a conjuncture of structure and personal history and includes a person's (multiple) understanding(s) of the world (Mahar, Harker & Wilkes, 1990). I am a science educator, an immigrant to Australia, researching with a group of Australian Indigenous adolescents whose culture(s) I can respect but not expect to fully understand. I am a black, non-Indigenous Australian who grew up in rural Zimbabwe in southern Africa and taught mathematics and physics in rural and urban schools in Zimbabwe. I immigrated to Australia in 2002, settled in North Queensland and working at an Indigenous College, the school where this study takes place. I still think in my first language, Shona. My secondary education was conducted in southern African version of English. I have always taught in dialects of English and I wrote this PhD thesis in a version of Standard Australian English. The English(es) I have acquired have not replaced the different logic employed in thinking in my first language, Shona. To give one example: I am circumspect. To be direct is considered rude in the mind of a Shona-thinking person. As a researcher, I continually switch between different language and knowledge systems.

There follows a conversation I had with my supervisor in January 2006.

Hilary: Growing up and learning in rural Zimbabwe, can you recall a day at school you will never forget?

Me: That was when I moved to a new village school when I was in grade 3. That is about thirty years ago. I remember it as if it was yesterday. I can still feel my brother shaking in my arm.

Hilary: What happened that day?

Me: I was with my young brother who was starting school. When we approached the big imposing gate at the school, there was a huge man standing next to the gate and waving a big stick. I can still recall his voice shouting “You leave your village outside the gate! When you get through this gate you will speak in English. If I hear anyone speaking their village language they will be punished. We will teach you the ‘Queen’s language’ here”. I was very afraid that day, not for myself but for my brother who was starting school that day and who was shaking on my arm. You see, at that stage of my schooling, I had acquired a few English words, perhaps about twenty or more and my brother had not. I had already learnt that standing up right and saying “Sorry sir” or, “Thank you sir” would get you out of trouble, even if you did not mean it from your heart. I had been taught in the village to say sorry to someone only if it comes from your heart. Reflecting back, of course I never left my village outside the gate. I used my village language in the classroom to think and negotiate into the ‘Queen’s language’.

I have taught Indigenous students in southern Africa and Australia for twenty years (thirteen years in Zimbabwe and seven years in North Queensland). This experience has enriched me personally, and also shown me some of the diverse ways in which Indigenous students learn school science. I started teaching mathematics and science in rural Zimbabwe, at a secondary school catering for Indigenous students from under privileged backgrounds. All subjects were taught in English except the vernaculars Ndebele and Venda. The literacy levels of the students were low and more than half the student population did not speak my first language Shona. I did not speak Ndebele or Venda. After three years, I transferred to a reputable government boarding school in the Midlands province that recruited high achieving Indigenous Shona students across the province of about three million people. The school aimed to prepare students to become much needed teachers in science and mathematics, and enrol in courses at tertiary institutes in the country. My main responsibilities included teaching Advanced Level Physics and Mathematics and helping students through the University of Cambridge Advanced Level Examinations. I worked in the school for five years before joining an elite school in the capital city of Harare. In this elite school, about seventy percent of the students were of western origin from rich local farming communities and captains of industry, twenty percent were from the Indian business community and ten percent from affluent Indigenous African families in political and economic leadership positions in the country. One purpose of this school included preparing students for universities outside the country. I worked in this school for five years before migrating to Australia in 2002. In Australia, I was employed at an Indigenous College, a part-boarding independent Christian school, still in its infancy catering for Australian Indigenous students from communities in Far North Queensland. I boarded in with the boys for two years, helping to establish boarding protocol, and was introduced to the cultures of Australian Indigenous peoples. I then moved to co-coordinating and teaching middle school mathematics and establishing a science department.

Between 1994 and 2001, my experience as an examiner of University of Cambridge Examinations Council, in association with Zimbabwe Schools Examination Council: Physics Practical Papers afforded me insight into students' conceptual understanding of physical science concepts. The practical papers had: two 'perform practical questions' (students were given instructions for the investigation), and two 'design practical questions' (two physical phenomena were described, and students designed the instructions for investigation). The 'design practical questions' interested me more as we discussed the marking schemes, and searched for scientific and mathematical representations and descriptions in students' scripts, which were the only criteria for awarding marks. The discussions among physics teachers from diverse backgrounds gave me a wider picture of the diverse ways of representing and describing conceptual understanding of physical science concepts. I encountered rich and diverse scientific ways of understandings and descriptions of physical science concepts that enriched my own understanding. My regret is that the concerned Indigenous African students were never afforded the opportunity to demonstrate or describe their understanding of the concepts in their own languages to the examiners. Luykx, Lee and Edwards (2008) argue that students' understandings of science knowledge are influenced by their cultural values, everyday languages, experiences and epistemologies of their home communities.

My experience teaching and assessing Indigenous students from southern Africa and Far North Queensland in physical science has persuaded me to accept the notion that western forms of science as a human construction is only one way of knowing the truth about naturally occurring events among several others. I will attempt to persuade the reader of this thesis that the Western physical science that inhabits science curriculum has been privileged in status because its capital can easily be exchanged for technological and economic advantages. Of course capital from Indigenous knowledge systems can be exchanged for Indigenous technologies, but these technologies have not been credited with the same economic advantages. Anzaldua (1990) suggests that we generate theories based on those whose knowledge systems are traditionally excluded from and silenced by academia, and find practical applications for those theories and knowledge systems. My experience as an Indigenous person from Africa is that I am not allowed to enter Western scientific discourse on my own terms. For example, writing this thesis, I can be disqualified and excluded from the academia if I do not enter the linear academic English thinking. I argue that bringing Indigenous approaches and methodologies can transform those theories and knowledge systems.

I want the reader of this thesis to understand that I switch between my circumspect Shona thinking and tight, linear, point by point, heavily-imposed-on-reader logic that characterises Standard Australian English academic writing as I write this thesis. This thesis is a dialectical relation between my Shona thinking and academic English, and I make no apologies for it. My writing in academic English as my second language means that the reader should not take for granted assumptions about what a well constructed argument looks like. I ask the reader of this thesis to appreciate ways the thesis is constructed and organised, which reflects a dialectical relationship between my circumspect Shona thinking and the linear academic English thinking.

A further extract of conversation I had with my supervisor in January 2006 follows.

Hilary: What did you find strikingly different when you first arrived in Australia?

Me: When I first arrived in Sydney, I noticed that almost everyone in the street was wearing black. It was close of business, and I suspect that most people were going home. Having just left the streets of Harare and then Johannesburg, where people wear very colourful dresses and shirts, I could not help but notice the difference. My first thought was that someone important in that community had passed away and the people of Sydney were in mourning. Women in Zimbabwe wear black when they are in mourning.

1.2 What prompted me to undertake this study

In 2004, my second year at the Indigenous College, l was asked to coordinate and establish a science department in the middle school with two colleagues from mainstream Australian culture who were recent graduate teachers from James Cook University. The three of us taught science in the middle school, and collaborated and prepared a science program for the school. My two colleagues pushed for "fun science" to attract Indigenous students into science, which I reluctantly accepted as a starting point in the spirit of a good team player. This "fun science" program was a collection of simple experiments and demonstrations that covered the four strands in the Queensland Studies Authority, *Science Syllabus Years 1 to 10* (1999/2004): Life and Living, Earth and Beyond, Natural and Processed Materials and Energy and Change. The program ran for one year, but I became increasingly concerned that it was not providing Indigenous students with sufficient scientific methodology and understanding. I realised that the students were looking forward to this "fun science" because they simply wanted to "mix things up", and if these went "pop", everyone had a good laugh and was happy, and if things did not "pop", then everything was "boring". Klein (2007) warns against the overly naïve notion of 'having fun' as the sole criteria of engagement. I suspected that the students were not learning much science in this "fun science" program. Students displayed little knowledge of underlying scientific principles, and importantly could not reproduce scientific knowledge. Yunkaporta and McGinty (2009), researching how Indigenous knowledge can be used to provide innovative ways of thinking and problem solving in the field of design and technology, questioned repeated requests from teachers involved to abandon the unit, and do some fun cooking activities to improve behaviour and engagement. On the contrary, Yunkaporta and McGinty observed that successful learning and behaviour outcomes occurred when Indigenous students worked cooperatively in Indigenous learning circles, and when students were supported to work autonomously and creatively.

I was concerned that the "fun science" did not equip students with sufficient scientific reasoning to compete with non-Indigenous students in the wider school system, a scenario which further perpetuates the disadvantage Indigenous students are under in relation to classroom science participation. I questioned whether allegedly "fun science" was the best way to teach science to Indigenous students in the middle school. McTaggart and Curro (2009) argue that educational needs of Australian Indigenous students are not adequately met, and Keys (2008), researching year 8 Indigenous science classes in Darwin, describes how teachers were putting more emphasis on learning scientific terminology than on understanding scientific concepts (justified on grounds of improving students' literacy levels), and engaging students with mere copying, cutting and colouring activities in the science classroom. When l discussed my concern with my two colleagues, they did not share similar concerns. They indicated that they were content with the system as it was, and were not prepared to try a new system which might fail.

Towards the end of 2004, I approached the Principal about my concern and she advised me to write an alternative program for consideration by the school staff. Thus l began to research the very limited literature on how Australian Indigenous students can and do learn science. Most of this literature on Australian Indigenous students did not refer to the practicalities of teaching and learning science in a classroom, but discussed policy issues and social justice matters. I searched for examples of developed science teaching units specifically designed for Australian Indigenous students or a proven working strategy to show my colleagues and convince them to change course, but at the time I was unable to find any such programs. Of course, Primary Connections (Australian Academy of Science, 2006) has developed Indigenous perspectives within this national program.

At this point I approached James Cook University, School of Education. One senior science education lecturer, who later became my supervisor for this study, suggested that I research the Canadian Indigenous science education programs. The Canadian literature confirmed my suspicion that the "fun science" program implemented in my school was perhaps not the best way of teaching science to Australian Indigenous students. Aikenhead (2006) writes:

> A very limited amount of research has targeted cross-cultural teaching and learning because most science education projects have tended to be missions for improving marginalised groups' participation and achievement in science education rather than sites for publishable research (p. 119).

I eventually decided to undertake a higher research degree to explore more effective science teaching and learning strategies for my Aboriginal and Torres Strait Islander middle school students. Though for reasons explained in Chapter Four, my Aboriginal students were not included in this study, the original intention was to research improving practice for both mainland and islander students attending the Indigenous College. This was a very personal project. It was a matter of desire to teach my students well. It became a journey into the epistemology and ontology dilemmas between school science and Indigenous ways of knowing, as the students taught me a very great deal about the socio-cultural praxis of science education in Australia.

1.3 Background to the study

At the opening of the 42nd Australian national Parliament in early 2008, the Prime Minister of Australia, Mr Kevin Rudd, pledged to build new educational opportunities for Indigenous children of Torres Strait Islander and Aboriginal descent. The discourse used was that of “closing the gap” on both opportunity and academic achievement. The persistent difference in educational achievement and attainment between Indigenous Australians (Aboriginal and Torres Strait Islander people) and non-Indigenous Australians (immigrants to the continent since 1788 and their descendents) is a problem with many complexities including failure on the part of state and federal governments over many decades to vigorously address a persistent educational disadvantage. Australia has been described as a “high quality – low equity” country in that Australian schools, while operating under high quality policy frameworks, have found it difficult to address equity issues in teaching, learning and assessment effectively in practice (Klenowski, 2009).

> My grandfather taught me that the river is the river and the sea is the sea. Each has its own complex patterns, origins and stories, and even though they come together, they will always exist in their own right. Non-Indigenous Australians cannot be expected to learn or understand the lessons of my grandfather, but simply to respect that they are central to my identity. (Patrick Dodson writing in *The Australian* 13.09.96)

I consider “the gap” in relation to Indigenous school science education in Australia. I discuss the findings and implications of the research conducted in two middle school science classrooms in a wholly Indigenous school in far north Queensland, Australia. I document the complex reality of negotiations of language and culture in a science classroom by students from the Torres Strait Islands, who are not native English speakers, coming to the Australian mainland to go to school, and show how they were able to engage, or not, with learning non-Indigenous science wholly taught and assessed in Standard Australian English. I explore what Klenowski (2009, p. 5) calls the "mismatch between home and school language" that impacts on Indigenous student achievement. I have learned that when achievement is measured through a monochromatic lens, students' lack of fluency in the dominant language adversely affects their achievement in science.

1.4 The rationale of the study

Shulman (1986) argues that research on teaching and teacher education has ignored the research questions dealing with the context of the lessons taught, and introduced the concept of pedagogical content knowledge as a specific category of knowledge which goes beyond knowledge of subject matter and teaching methods. The elements of pedagogical content knowledge include knowledge of comprehensive representations of subject matter, understanding of content related learning difficulties and students' conceptions. Van Driel, Verloop and de Vos (1998) write that there is no universal definition of the concept of pedagogical content knowledge, but claim that it generally refers to teachers' interpretations and transformations of subject matter knowledge in the context of facilitating students' learning. It thus links research on teaching with research on learning. Pedagogical content knowledge implies a transformation of subject matter knowledge so that it can be used effectively and flexibly in the communication process between teachers and learners during classroom practice. Cochran and colleagues (1993, p. 266) define pedagogical content knowledge as "a teacher's integrated understanding of components of pedagogy, subject matter content, student characteristics, and the environmental context of learning". I propose here that pedagogical content knowledge can guide teachers to create culturally compatible pedagogies in their classrooms with Indigenous students. Van Driel, Verloop and de Vos (1998) suggest that most scholars agree that pedagogical content knowledge is developed through an integrative process rooted in classroom practice and may indeed surpass the individual level narratives, to generate knowledge of a more general nature and develop in their words, conceptual "frameworks" (p. 674).

Hanrahan (2005) argues in secondary science education that it is particularly hard to find evidence of curriculum reform that includes explicit changes in pedagogic discourses to accommodate the needs of students from a wide range of backgrounds. In this study, pedagogical content knowledge implies how I transform physical science subject matter knowledge, how I relate that transformation to my Indigenous students and how I use Indigenous students' cultural resources to transform the physical science subject matter. As science educators, do we create culturally compatible pedagogies in our science classrooms, and do we implement pedagogical content knowledge that draws upon Indigenous students' cultures? Contexts in which one's culture is recognised and valued are empowering, and contexts in which one's culture is unrecognised and not valued are disempowering (Sewell, 1999). Ideally there is need to develop pedagogical content knowledge that also draws upon the cultures of Indigenous students in order to improve their participation and negotiations in learning school science, and to facilitate classrooms that help Indigenous students explore connections between their cultures and school science practices.

> The effort to master the future cannot be undertaken in reality until the conditions indispensable for ensuring it a minimum chance of success are provided. (Bourdieu 1979, p. 73)

My research study sought to understand and improve an aspect of my practice: exploring dimensions of pedagogical content knowledge of how a group of Torres Strait Islander students engaged with the mandated Queensland Studies Authority science curriculum. This was a key factor in my decision to consider employing a classroom action research methodology. Primacy in classroom action research is given to teachers' self-understanding and judgement. The emphasis is on 'practical' interpretations teachers and students make when acting in the situation (Kemmis & McTaggart, 2000). I conceptualise my classroom practice as socially and historically constituted by human agency and social action, in this case, the agency and actions of Torres Strait Islander students and teacher. My research purpose is to make explicit connections across the objective and subjective, to focus on both the individual and the social group, and to investigate classroom aspects of structure and agency (Kemmis & McTaggart, 2005). As Klein (2004) has remarked:

> A particular strength of action research is that it challenges us to reflect more critically on our educational practice. It is empowering for the teacher – researcher when it enables him/her to look with new eyes at a particular aspect of teaching and effect change. However it is also important that any changes be educationally sound and empowering for students: this is why action research needs to be informed by critical social theory.

I chose to research middle school Torres Strait Islander students learning physical science concepts of energy and force as my own teaching expertise lies in the physical science subjects. My initial research questions for the study were:

- How did a group of Torres Strait Islander middle school students employ their everyday languages and formal science language when learning the concepts of energy and force?
- How did a group of Torres Strait Islander middle school students participate and communicate in science activities when learning science concepts of energy and force?
- How did a group of Torres Strait Islander middle school students apply and relate to science concepts of energy and force as described in Standard Australian English?

After completing one cycle of the research, I came up with three additional research questions for the second and third cycles of the research:

- What cultural resources did a group of Torres Strait Islander middle school students draw on for developing their understandings of the concepts of energy and force?
- How did the structure of Queensland Studies Authority science syllabus enable or limit the agency of a group of Torres Strait Islander middle school students?
- What pedagogical content knowledge enabled a group of Torres Strait Islander middle school students to learn, know and (re)produce knowledge of the concepts of energy and force?

Culture is regarded in this study as a dialectical relationship between a system of referents used to make sense of social life within a field and associated practices of the participants of that field (Sewell, 1999). In this study, the science classroom is considered a cultural field of social practice (Tobin, 2005). I will define cultural field, cultural capital and cultural resources as research concepts that constitute the backbone of this thesis in Chapter Two. For this study, I will also define the Level 4 and 5 learning outcomes of the mandated Queensland Studies Authority, *Science: Years 1 to 10 Syllabus* (2004), Energy and Change strand, as cultural capital in a middle school science classroom.

In this study, I aimed to:

(1). Gain insight into ways a group of Torres Strait Islander middle school students can learn, know and (re)produce knowledge of the science concepts of energy and force, using their everyday language and school science terminology.

(2). Contribute to initial and further understanding of how a group of Torres Strait Islander middle school students can use their cultural resources to learn, know and (re)produce knowledge of the science concepts of energy and force.

(3). Develop more effective micro pedagogy and educational outcomes for a group of Torres Strait Islander middle school students in the science concepts of energy and force, and explore how the mandated Queensland Studies Authority science syllabus as currently framed enables or limits the agency of these students.

(4). Provide practical teaching strategies and methods for improving science learning by Torres Strait Islander middle school students where they can mobilise and marshal their cultural resources, particularly with regards to learning the concepts of energy and force.

(5). Describe the qualitatively different ways in which a group of Torres Strait Islander middle school students were able to learn, know and (re)produce knowledge of the concepts of energy and force through speaking, writing, drawing and direct action (gestures).

I realised and acknowledged the importance of the point of departure: everyday ways of knowing and describing the concepts of energy and force by the group of Torres Strait Islander middle school students, and the point of destination: formalised school science ways of knowing and (re)producing knowledge of the science concepts of energy and force. While mobilising the cultural resources of these students was central, my main focus was on how to marshal these to enable their learning of science, with the aim of producing the all important shining-eyes, happy-faces outcome for science learning (Whitehouse, 2007). I used the abstract concepts of energy and force, common in all fields of science, as a vehicle these students employed in negotiating the learning.

1.5 The focus of the study

This study is my story illustrating my learning journey as a science teacher when researching pedagogical content knowledge of how the group of Torres Strait Islander students in my class could negotiate their use of their cultural resources to engage with an authoritative body of knowledge, the mandated Queensland Studies Authority science curriculum. I am not a psychologist, not a linguist, not an expert in child development, but a science teacher whose expertise lies in teaching physical sciences to middle and high school students. In this study, I attempted to extend my expertise to investigate a unique aspect of my practice, pedagogical content knowledge of how such a group of students can better mobilise their cultural resources to better their formal learning in science, and how I, as a teacher of formal science, undertook a complex research journey.

Indigenous education is a field where there are many interesting facets to explore, for example, the epistemological and ontological dilemmas that arise between Western science and Indigenous knowledge systems that exist at several levels (see Yore, 2008). The dilemmas and differences concern the structures of the knowledge systems. For this inquiry, I am most concerned with the agency of Indigenous students when learning classroom science. I explore the pedagogical content knowledge and knowledge at conceptual content level that Indigenous students engage with when learning, and levels of epistemology (ways of knowing) and ontology (ways of being) that inform these conceptual content levels (Nakata, 2007). The levels of epistemology and ontology that inform conceptual content are germane to an academic discussion of this study, and I do discuss this further. However, my research was always focused on improving classroom practice, and I deliberately stay within these limits.

1.6 The structure of the thesis

Chapter One introduces the study. I introduce my socio-cultural framework, my social trajectory and the background of my research study in terms of “closing the gap” in relation to Indigenous school science education in Australia and the complex reality of negotiations of language and culture by Indigenous students in science classrooms. I explain the rationale of the study, which was to understand and improve an aspect of my practice: pedagogical content knowledge of how a group of Torres Strait Islander students engaged with the mandated Queensland Studies Authority science curriculum, and was a key factor in my decision to consult classroom action research methodology. I discuss the limits of the study**,** which illustrates and embodies my learning journey as a science teacher.

Chapter Two argues a rationale for conducting socio-cultural research in my science classroom. I take up the idea of culture as praxis to research with Torres Strait Islander students, as agents of their own culture(s). I draw on Bourdieu’s cultural sociology which views structure and agency as dialectical – structure influences human action, and humans are capable of changing the social structures they inhabit (Jenkins, 2002). I discuss how Yosso (2005) challenges Bourdieu’s interpretation of cultural capital for Indigenous groups to conceptualise from community cultural wealth and how I reconcile the two ideas. I then explore the idea that English as Second Language educational needs of Australian Indigenous students are not adequately recognised or met (see McTaggart & Curro, 2009), and argue a case for socio cultural research in a science classroom with Indigenous students.

Chapter Three explores Indigenous knowledge and languages as cultural resources Indigenous students bring to classroom. I start by exploring why Indigenous students whose first language is not English, and who live in regional, rural and remote areas of the country, perform most poorly (Master, 2009), and ascertain what constitutes the ‘gap’ in Indigenous science classrooms. I explore the notion that Indigenous students can close their minds on explanations that sideline their own knowledge systems in favour of the supremacy of western model, and argue how integration of Indigenous students’ everyday ways of knowing and doing into science education becomes mandatory (Snively & Corsiglia, 2001). I then describe the accessible cultural resources Torres Strait Islander students bring to the science classroom and argue why my classroom is a cultural field able to be researched using a socio-cultural analytical lens.

Chapter Four discusses my socio-cultural standpoint, methodology, study participants, methods, data collection cycles, reflections and explanation of research decisions, and how I viewed my classroom practice with a group of Torres Strait Islander students as reflexive to be studied dialectically. I describe the study participants: forty four Torres Strait Islander middle school student boarders (twenty three girls and twenty one boys), five Torres Strait Islander assistant teachers and a Torres Strait Islander elder. I describe research design and why I chose to research Year 9 students learning physical science concepts of energy and force. I explain my rationale for adopting an ethical protocol that paralleled the research stages of: thematizing, designing, data collection, analysing, and reporting and explain why my classroom action research is value-laden. I describe the data collection cycles. The first cycle took place during the first semester of 2007, with forty nine students. Three students transferred during the semester. The second cycle took place during second semester 2007, with forty six students. Two students transferred during the semester. The third cycle took place during the first semester of 2008, with forty four students. The five assistant teachers participated in the second and third cycles of data collection.

Chapter Five presents my findings and interpretations from data analysis. Analysing data collected included scrutiny of students' documents and my research journal. I identify three categories of how Torres Strait Islander students were able to use science terminology, and participated in learning science. I undertake a second analysis to categorise the forty-four students in terms of my recorded observations of their level of engagement and participation in the science classroom. Of the forty-four students who attempted or completed the pedagogical activities in this study, I discover that the large majority, (n =37, or 84%), had limited to severe difficulty communicating in English, and about half the class struggled to understand the formal terminology of the science classroom. Furthermore, students with facility in English used Creole language substitute words and direct action (gestures) to 'translate' the science instruction words for the benefit of students with limited to severe difficulty communicating in English. I failed to find common, comparable, abstract concepts on the meta-concepts of energy and force in Torres Strait Islander students' diverse and complex languages. Using Torres Strait Islander knowledge systems was enabling for the students.

In Chapter Six, I discuss my thinking about pedagogical content knowledge with Torres Strait Islander students learning physical science concepts in the classroom, around six themes that emerged from the study. The first theme takes into account Torres Strait Islander middle school students' competence in speaking, reading and writing Standard Australian English with facility. Seven of these students (20%) spoke and wrote Standard Australian English with facility. The ways level five outcomes of *Science: Years 1 to 10 Syllabus* (QSA, 2004) are formulated are suited for these students. The second theme explores how Torres Strait Creole can be used as a resource for learning western science concepts more productively in the classroom. I express concerns for the 45% of Torres Strait Islander students in the study with limited facility in English over their inability to engage meaningfully with science learning. The third theme takes into account the interactivity of language and knowledge systems when these students engage in learning physical science concepts. The fourth theme recognises that most Torres Strait Islander middle school students from remote communities in North Queensland are multi-lingual, and deal with multiple language systems even before they engage with the English language challenges in science learning. The fifth theme calls for a rethinking on science literacy and classroom discourse, how these Indigenous students traverse these intersecting knowledge and language systems on a daily basis, responding, interacting, taking positions and making decisions (Nakata, 2002). The sixth theme concerns ontological issues that arise at conceptual content level (Nakata, 2007), how the Queensland Studies Authority science curriculum, as it is currently constituted, makes little real concessions to Indigenous ways of knowing.

Chapter Seven reflects on my learning from my study. I discuss the limitations of my study, which come from the fact that the research project was limited to Torres Strait Islander middle school students and Torres Strait Islander assistant teachers at the Indigenous College, and a concern that Torres Strait Islander students and Torres Strait Islander assistant teachers from other schools where not included. A further concern is that the study was highly personal, and my learning personal history cannot relate a ‘whole picture’. I discuss strengths of the study, which involve exploring individual and social experiences that real Torres Strait Islander middle school students bring to real science classrooms, and the various literacies (Gee, 2005) that the students can use to engage with science learning. A further strength is that I am an expert field negotiator, and bring a more informed insight on how Torres Strait Islander middle school students negotiate learning science in English as a second or third language. Finally, I discuss three recommendations and three areas which need further research.

Chapter Eight summarises my study. I review the study and discuss how I was involved with planning, implementing, observing, reflecting and replanning my research (Kemmis & McTaggart, 2000). I discuss my conclusion that learning experiences using Standard Australian English as the only science concept descriptor did not adequately facilitate Torres Strait Islander students’ negotiations from their vernacular languages into science, and that a teaching and learning framework that accommodates the multiple language dimensions of old and emerging Indigenous cultures is possible. I discuss my learning and development as a science teacher, my learning to do action research, and how this research encourages me to develop an educational practice that improves pedagogical strategies to improved learning for disadvantaged and marginalised indigenous students. I finally discuss presenting results of this study at conferences, and publishing papers in academic journals, and how this experience has resulted in my increased self knowledge, self awareness and confidence.

Chapter 2

Rationale for socio-cultural perspective in science classroom

2.1 Introduction

In this chapter, I provide a rationale for conducting socio-cultural research in my science classroom, taking up the idea of culture as praxis to research with Torres Strait Islander students, as agents of their own culture(s). Firstly, I draw on Bourdieu's cultural sociology which attempts to reconcile the notions of objectivism and subjectivism to transform them into a dialectical relationship between agency and structure in terms of habitus, cultural capital and cultural field, and discuss why I explore the concept of cultural disposition at a practical level. I discuss how Yosso (2005) challenges Bourdieu's interpretation of cultural capital for Indigenous groups to conceptualise from community cultural wealth and how I reconcile the two ideas as 'cultural resources' of the students. I then discuss the rationale for affirming the students' cultural resources in the classroom. Secondly, I explore language and literacy in socio-cultural practice. Thirdly, I discuss the definitions of science literacy and the rationale to improve Indigenous students' second language skills. Fourthly, I explore constructivism, conceptual change and context-based leaning models. I conclude by exploring a case for socio-cultural research in science classrooms with Indigenous students who have Standard Australian English as second or third language.

2.2 A socio-cultural perspective

I approach my study from a socio-cultural perspective (Giddens, 1979) and take up the idea of culture as praxis to research with Torres Strait Islander students, as agents of their own culture(s). Klenowski (2009) suggests that a socio-cultural perspective views learning as socially negotiated and embedded within a cultural community. I argue that a socio-cultural lens provides insights into ways of rethinking the learning of classroom science by these students, and resuscitates and embodies the inherent logic of lived experiences, where Torres Strait Islander students' socio-cultural interactions cannot be analysed in isolation from the meaning systems that are inherent in them (Bauman, 1973). Indigenous students may learn and represent their thinking in ways that are distinct from those valued in ‘standard’ school practice (Zevenbergen et al., 2008). A socio-cultural perspective can and is applied in this thesis to inform the conditions for the possibility of learning of Torres Strait Islander students’ class activity and participation in culturally organised science classroom practice.

A central theorem of cultural sociology is the dialectical relationship between agency and structure, and explores how one can access the resources in a field. Bourdieu (1984) likens a field to a social arena within which struggles or manoeuvres take place over specific resources at stake and access to them. Agency (social actions by individuals and groups) and structure (social arrangements, relationships and practices) presupposes each other – they cannot be considered to be independent theoretical categories that at times interact (Tobin, 2005). Resources are tools one can acquire and use in a field (Giddens, 1979). The structure of a field such as a science classroom can consist of humans (e.g., people and social network), materials (e.g., space, time and equipment) and symbolic resources (e.g., status, relationships and qualifications) (Tobin, 2005). Individuals use resources to meet their goals and in so doing, change schema and practices which then become part of the structure of the field and resources for the production of culture (Archer, 1996). Tobin (2005) argues that resources can be accessed and appropriated by students as they exercise agency with or without conscious awareness, to produce schema and practices that can both reproduce and transform the culture of science. Drawing from the central theorem of cultural sociology, students in a science classroom participate in culturally organised face-to-face interactions. Aikenhead (2006, p. 107) writes: “some researchers in science education have discovered that cultural anthropology can be fruitful to their work, it views teaching and learning as cultural transmission and acquisition”. Furthermore, the culturally organised face-to-face interactions can be primary explanatory constructs of the students’ learning in a science classroom.

Employing this view of cultural sociology, science classes can be seen as cultural fields, where all science class activity is mediated by a complex history of social and cultural phenomena (Tobin, 2005). Regarding science as cultural practice implies doing science as cultural enactment, and learning science as cultural (re)production (Tobin, Elmesky & Carombo, 2002). The focus moves from the individual as the only determinant of learning to include the many activities in which the individual is engaged, and the participants and the actions they undertake, using the resources and tools available. Negotiating meaning is central to learning from a socio-cultural perspective (Murphy et al., 2008). Negotiation of meaning by Indigenous students takes place at the cultural interface. The cultural interface is the intersection of Western and Indigenous domains; it is a place of tension, which requires constant negotiation, where there are so many woven, competing and conflicting discourses (Nakata, 2002). At the cultural interface, Torres Strait Islander students learning classroom science traverse and reconcile many different ways of understandings.

2.3 Adapting Bourdieu's cultural sociology

I draw on Bourdieu's cultural sociology for what it offers my research with regards to language/culture/science education, and also for its stance that theory and research are mutually implicated. Bourdieu's cultural sociology views structure and agency as dialectical – structure influences human action, and humans are capable of changing the social structures they inhabit (Jenkins, 2002). I found Bourdieu's cultural sociology to be suitable and effective to describe the contested aspects of concern to Indigenous students in general, and Torres Strait Islander students in particular, when learning classroom science. Bourdieu's (1986) cultural sociology attempts to reconcile the notions of objectivism and subjectivism to transform them into a dialectical relationship between agency and structure in terms of habitus, cultural capital and cultural field.

Habitus refers to a set of dispositions created and formulated through the conjuncture of objective structures and personal history; it also includes a person's understanding of the world, which makes a separate contribution to the reality of that milieu. Cultural capital is associated with culturally authorised attributes, skills and awards, which include forms of language. A cultural field is a site of struggle over a particular form of capital, which can be defined as rules that produce and authorise certain discourses and activities (Mahar, Harker & Wilkes, 1990). Jenkins (2002) acknowledges that Bourdieu was not defining but characterising the concepts of habitus, cultural capital and cultural field to communicate a theoretical stance, a certain way of looking at the world. A generative formula that provides a useful heuristic device for summarising, and not a solution to analysing the relation between the major concepts at work is: (Habitus × Capital) + Field = Practice (Bourdieu, 1984, p. 101) where (Habitus × Capital) informs agency, the idea that individuals are equipped with the ability to understand and control their own action, regardless of the circumstances of their lives.

In my work, I explore the notion of 'cultural disposition' instead of habitus. Bourdieu's cultural sociology suggests that habitus is the site of interplay between structure and practice, and that while structure and practice can be observed directly, habitus cannot. In this sense, habitus can be understood as a person's mental and inner processes formulated as a result of cultural disposition (Jenkins (2002). This means, at a practical level, classroom teachers might not have the tools to access the students' habitus. It thus makes sense to me, as a classroom teacher, to explore the accessible cultural dispositions of students.

Yosso (2005) challenges Bourdieu's interpretation of cultural capital for Indigenous groups arguing that many Indigenous cultures are not individualistic. This can be a limitation to Bourdieu's thinking in researching Indigenous classrooms. Rogoff (2003) suggests that human development occurs on at least three levels: personal, interpersonal and cultural/institutional, and that these three levels are inherently interwoven in all human activities. Morris (2004) writes that Indigenous people share their cultural capital with one another and develop their social capital (Indigenous social capital) for survival and success in a segregated world bounded by the omnipresent forces of racism and discrimination. Beginning with the perspective that communities of Indigenous people are places with multiple strengths, Yosso (2005) conceptualises the notion of capital of Indigenous groups as forms of community cultural wealth, including aspirational, navigational, social, linguistic, familial and resistant capital nurtured within communities. Aspirational capital is the ability to maintain hopes and dreams for the future, even in the face of real barriers. Indigenous people experience the lowest educational outcomes in Australia, but maintain consistently high aspiration for their children's future. Navigational capital is skills to manoeuvre through social institutions, sometimes through racially hostile institutions, sustaining high levels of achievement, despite stressful conditions. Social capital is peer and social contacts, networks that provide support to navigate through institutions, and emotional reassurance. Linguistic capital is intellectual and social skills attained through communication experiences in more than one language or style. Familial capital includes a broad understanding of kinship, nurtured by extended family (living or long passed on). Resistant capital is oppositional behaviour that challenges inequality, and is grounded in the legacy of resistance to oppression (Yosso, 2005).

Osborne and Tait (2002) argue that ignoring the socio-historico-political contexts of schooling is foolish if we, as teachers, take seriously our fundamental commitment to help all students. Students' culture, lived experiences and home language are foundations for academic learning and they must be recognised, respected and utilised to anchor abstract concepts. I argue that science educators can recognise and utilise capital those Indigenous students bring to the science classroom to include their community cultural wealth (Yosso, 2005). My thinking reconciles Bourdieu and Yosso's notions of capital which I conceptualise as cultural resources of Torres Strait Islander students. In this study, I argue that the cultural resources (cultural disposition, cultural capital and community cultural wealth) inform the agency of Torres Strait Islander students learning science.

2.4 Affirming students' cultural resources

Sewell (1992) analyses relationship between resources, agency and power. Power occurs through acts of accessing and using resources learned through engagement in practices, in an attempt to further accumulate resources. Humans engage in acts of agency when they transpose resources learned in one context to another. Thus contexts in which one's resources are valued, recognized and legitimized are empowering, and contexts in which one's resources are marginalized or forbidden are dis-empowering.

It becomes imperative to acknowledge and value cultural resources that students bring to the classroom. Norma Gonzalez and colleagues (2005) urge teachers to understand students' funds of knowledge, and utilize that knowledge to connect with their students in the classroom. Funds of knowledge are the historically accumulated and culturally developed bodies of knowledge and skills that are essential for household or individual functioning and well-being. With this new knowledge, teachers can provide culturally responsive and meaningful lessons that tap students' prior knowledge. While understanding students' funds of knowledge and fostering a disposition towards valuing Indigenous and local knowledge systems are noble and steps in the right direction, there is need to further explore the elements of the cultural resources and how these elements can be employed to combat deficit views (Boykin, 1994) and address capacity building perspectives.

In this study, I distinguish the interwoven elements of cultural resources (cultural disposition, community cultural wealth and cultural capital), which I propose inform the agency of students. I find using the computer analogy helpful as a starting point, to explain the elements of cultural resources, though reality is much more complex than the computer analogy. Cultural disposition is like computer hardware and refers to a student's patterns of behaviour created as a result of cultural experience. Community cultural wealth is like all the software in the computer and refers to an array of cultural knowledge, skills, abilities and contacts possessed by a student's community. It is important to highlight that the student is not expected to know or have acquired most of this community knowledge, just like the software is in the computer, but an individual might not have acquired the skills to use the software. Cultural capital is like a handful of computer programs that an individual has learnt to use and refers to a student's acquired skills, awards, knowledge and forms of language.

The deficit model blames the student, without looking at the learning environment or instructional practices (Biggs, 2003), and thus explains failure in terms of poor motivation, low interest and low ability levels of students. The focus is to criticise and pass judgment on the student. Biggs (2003) suggests in the deficit model that knowledge is 'delivered' with little time for interaction and digestion of new ideas. The learning environments are teacher-centred and curriculum-driven, rather than student-centred and to promote student interaction and deeper understandings of the subject.

Boykin (1994) suggests that pedagogies based on the deficit model fail to acknowledge, legitimise and build upon the students' cultural resources. As an educator, I struggle with educational approaches that work from the assumption that Indigenous students "lack" necessary knowledge, social skills, abilities and cultural capital. Taylor (2005) writes that in Australia, Indigenous students' place is built on historically derived social constructions of deficit and disadvantage that are replicated through policy implementation processes. These traditional approaches can be replaced by those that acknowledge and value the students' cultural resources.

Acknowledging and valuing elements of the cultural resources (cultural disposition, community cultural wealth and cultural capital) of the students becomes important, since contexts in which one's cultural resources are not valued are dis-empowering (see Sewell, 1992). Like Sewell, Bourdieu and Boykin, I suggest that these elements of the cultural resources are tools that the students use to engage with learning science. In this study, I conceptualise the deficit model as disregarding the three elements of cultural resources, and the token approach as valuing only one or two elements of the cultural resources. Smyth (2007) urges educators to reject pedagogies that use token approaches by listening to and valuing the students' lived experiences.

Sutherland (2003) writes that when the idea of capacity building was introduced as a goal in development education, a multitude of policies that reflect people-centred approaches were created. The idea of capacity building, originally argued for by Freire (1970), is closely associated with programs in developing nations; hence the goal of capacity building recognises historically oppressive policies and seeks change.

Capacity building in science education links the concepts of science with the everyday lives of the students and their community (Sutherland, 2003), and cues teachers to identify the congruencies and incongruencies between school and home, and to create negotiated spaces through praxis. From a capacity building perspective, Eade (1997), emphasises that: 1) students' experiences and knowledge play a central role, 2) awareness learning, self esteem, and the capacity for political action are mutually reinforced, and 3) marginalised students have the right and the capacity to organise and challenge authority in order to create learning environments that are not oppressive. Hence, a capacity building perspective, as a goal in science education, affirms the students' cultural resources.

A capacity building perspective shifts approaches to education from a deficit model or token approach to one of building existing capacity, where arrays of cultural knowledge, skills, abilities and contacts possessed by socially marginalised students are recognised and acknowledged. In this study, I suggest that a capacity building perspective should satisfy two conditions: 1) acknowledge and value all the three elements of cultural resources, and 2) use these elements of cultural resources as springboards to build the students' capacity. Acknowledging and valuing the elements of cultural resources implies using the students' cultural disposition to inform pedagogy (in this case capacity building), community cultural wealth as context to situate learning experiences, and cultural capital as currency they use to make meaning. Using the students' elements of cultural resources suggests an attempt to help the student negotiate from their: 1) cultural disposition to move towards a more scientific disposition, 2) community cultural wealth as contexts of experience to scientific contexts, and 3) acquired cultural capital to acquire scientific capital. Bourdieu's cultural sociology views agency and structure as dialectical – structure influences human action, and humans are capable of changing the social structures they inhabit (Jenkins, 2002). Accordingly, contexts in which one's cultural resources are valued, recognized, and legitimized become empowering (see Sewell, 1992).

It is important to emphasize at this point that these elements of cultural resources are interwoven (see Rogoff, 2003) and expressed through language. In taking science classrooms as cultural fields, with Torres Strait Islander students as agents of their own culture(s), it becomes imperative to look at the languages the students employ, as language is at the centre of cultural practice, to refract Bourdieu's position that language and culture are unthinkable without the other. According to Jenkins (2002, p. 152), Bourdieu insisted that, "language cannot be analysed or understood in isolation from its cultural context and the social conditions of its production and reception". Winford (2003, p. 35) reminds us that languages are not "merely systems of rules … they are also vehicles of social interaction and badges of social identity … shaped by socio-cultural forces". As such, my perception, even faith, in any language, including that of Standard Australian English, the language of formal education in Australia, is “conditioned by social practice, social relationships and attendant ideologies”, meaning any linguistic prejudices I hold can be seen as a matter “of race or class or ethnic prejudice in a subtle guise” (Winford 2003, p. 35).

2.5 Language in socio-cultural practice

One way to think about language is as a systematic way of combining smaller units into larger units for the purpose of communication. Wareing (2004) writes that language is a system or rather a set of systems (a system of sounds, a system of grammar, a system of meaning); and variations in usage are often systems as well. Within these systems, there is scope for creativity and intervention. How individuals use the system available to them varies according to who the speakers are, how they perceive themselves and what identity they want to project. Language use varies also according to the situation, whether it is private or public, formal or informal, who is being addressed and who might be able to overhear. Integral to these choices we make about language use is the dimension of power.

Language is a fundamental human activity through which we communicate our particular representation of the world. It is primarily through language that cultural values and beliefs are transmitted from one member of a society to another and from one generation to the next (Peccei, 2004). Thus we can often see within the structure of language reflections of the way that a particular culture views the world, and the kinds of distinctions that are held to be important. Singh (2004) acknowledges that every language can be said to be a particular system of representation that mirrors, and indeed so reinforces, the ‘world’ of its speakers. Individual languages are made up not just of linguistic signs, but knowledge at the level of the structural principles which allow us to create utterances that are meaningful in our native language. The representations of reality offered by the sources of each language are not just reflections of a particular ways of looking at the world; they also reinforce those perceptions for their users. Hence languages of different cultures comprise distinct systems of representation which are not necessarily equivalent.

Language education involves the learning of language skills – listening, speaking, reading, and writing. The role of Standard English in education is to give access to literacy and to wider communication. Thomas (2004) writes that of the many different dialects of English both within Britain and beyond, the dialect known as Standard English has special status. Standard English (whether British, American, Australian, etc.) is the dialect of institutions such as government and the law; it is the dialect of literacy and education; it is the dialect taught as ‘English’ to foreign learners; and it is a dialect of the higher social classes. It thus is the prestige form of English. Thomas argues promotion of the standard should not invalidate non-standard varieties, and access to, and acquisition of, the standard does not have to be at the expense of a home dialect.

Verhoeven (2000) writes that the human capacity to think symbolically and to interpret and produce sound makes it possible to create a language system, and human culture, social behaviour and thinking would not exist without language. On the other hand communication would be meaningless in the absence of thinking. Language and thinking are so closely connected that it is hard to discuss one without the other, for speech can serve thought and thought can be revealed in speech. Given the close connection between language and thinking, language can be viewed as an instrument to develop higher-order cognitive skills; and because the roots of both language and thought are social, language learning will enhance children’s social skills as well.

Human language is used for communication with others and also for communication with oneself if that language is employed for reflection, categorisation and other cognitive functions (Mirolli & Parisi, 2006). According to Vygotsky (1978), the most important moment in child development is when the child begins to use language not only for social communication but for controlling his or her own actions and cognitive processes. Through culture, children acquire much of the content of their thinking, that is, their language, knowledge and understanding. Eventually children can use the acquired language to direct their own behaviour. So, for example, it is that Torres Strait Islander students’ own language(s) comes to serve as their primary tool of intellectual adaptation and manoeuvre in classroom science learning, just as Shona remains the primary tool for my academic learning.

Gumperz and Levinson (1996) argue that each native language encourages its speakers to pay different kinds of attention to events and how to express such events. This training is carried out in childhood and is exceptionally resistant to restructuring in adult second-language acquisition. Understanding what someone says depends on construing the context in the same way and applying the same complex interpretive principles that link context and interpretation. Contexts within meaning systems can meander, drift and evolve over time, and for non-English speakers, disentangling the meaning system of words and then using each in the right context is fraught with difficulties and pitfalls (Cleote, 2010). Accordingly, when some Indigenous students come to the science classroom they are thinking in their own language, and when talking with classmates, they use the home language they share with their peers. If everything in the science classroom is expressed in Standard Australian English, not all Indigenous students can be expected to have the code to comprehend it (McTaggart & Curro, 2009).

Giddens (1979) argues that language provides useful clues in conceptualising the processes of cultural production and reproduction, not because any society is like a language, but because language as a practical activity is so central to social life that in many respects language can be treated as exemplifying cultural processes in general. To speak a language, one draws on language rules and concepts, and simultaneously contributes to the reproduction of that language. Yore and Treagust (2006) point out that almost every science classroom learner is a second language learner regardless of their home language's alignment with the language of instruction. Every Year 9 student faces similar problems as a second language learner, navigating and negotiating the 'border crossings' between home, school and science discourse communities. 'Border crossing' is a metaphor that captures the act of negotiating the transition from a student's home language and culture to the language and culture of school science (Aikenhead, 2006).

Language is more than terminology; it is a cultural repository of worldviews that teaches people what to assume, how to think, and how to socially interact (McKinley, 2005). Thus symbolic forms such as language and body posture become important in understanding their cognitive and social functions. Snook (1990) argues that in seeing language as an institutional practice as well as a social practice, Bourdieu provides a solution to the problem of the connection between language and the world in which people exercise control over others. Language is a particular kind of practice, complementing and competing with other important practices. As human beings, language becomes a practice we utilise to construct ways of constituting our world, which we express through our language. Language essentially becomes an instrument of action, and it therefore becomes imperative in this study to research the languages Torres Strait Islander students utilise in science classrooms, and to research conceptual learning and application.

Language serves parallel functions for science learning. Language facilitates negotiations and reflections about knowledge claims constructed from a collection of sensory experiences, conversations, print information sources and prior knowledge in an interactive socio-cultural context (Yore & Treagust, 2006). We continually and actively build our worlds through language along with actions, interactions, symbols, objects, tools, technologies and distinctive ways of thinking, valuing, feeling, and believing (Gee, 2005). In educational research, it therefore becomes imperative for everyday languages, communication skills, and cultural and personal beliefs of different cultures to be explicitly considered in teaching and learning environments where a different language of instruction and an English-dominated science discourse interact (Yore, 2008). Language and personal context play a significant role in any student’s understanding of science.

Gee (2005) argues that two primary functions of human language are: to support the performance of social activities and social identities, and to support human affiliation within cultures, social groups and institutions. This means that language is a means of doing science and constructing science understanding. Malcolm (2002) writes that exclusion of Aboriginal and Torres Strait Islander languages and Aboriginal English from classroom communication is a symbolic exclusion of the identity and perspectives of those who speak them. Yet the Queensland state sanctioned lower secondary science curriculum, as produced by the Queensland Studies Authority *Science: Years 1 – 10 Syllabus* (1999, 2004) document does not (yet) equally acknowledge and value the linguistic cultural capital, knowledge, skills and experiences that Aboriginal and Torres Strait Islander middle school students bring to the classroom. Science in the state of Queensland is taught only in Standard Australian English in secondary schools, no matter what the culture(s) of students and teachers.

As language is the primary means of cultural transmission and cultural production of knowledge systems (Klenowski, 2009), middle school Indigenous students are left faced with the triple task of negotiating learning in English, learning a new language of science, and being able to negotiate a new culture, that of Westernised science, when they are taught and assessed in science classrooms. This has significant and far-reaching equity considerations, which are explored in this study.

2.6 Literacy in socio-cultural practice

Central to this study is how literacy is conceptualised. Freebody (2007) writes that there is no neutral space in which literacy can be generically defined for all practical purposes. Freebody argues that the term literacy has various histories of use, and each of these histories of uses has produced a manageable object of study and practice for researchers and educators.

For this study, and aligning with socio-cultural practice, literacy can be understood as a repertoire of socially and culturally constructed practices developed to meet students' communicative needs in a variety of settings. This understanding of literacy is informed by Luke, Freebody and Land's (2000. p. 9) definition of literacy as "the flexible and sustainable mastery of a repertoire of practices with the texts of traditional and new communications technology via spoken language, print, and multimedia". This definition of literacy is further informed by the work of Alloway, Freebody, Gilbert and Muspratt (2002, pp. 7-8) who advocate that "literacy is thus seen as referring to particular forms of communication that themselves entail particular valued repertoires of physical, psychological, social and cultural practice, demeanour and disposition".

Literacy is identified as a 'general capability' in the document *The Shape of the National Curriculum* (National Curriculum Board, 2009), however, no definition is offered. In this document, literacy is referred to as "the foundation on which much further learning depends" (p. 10) and that the "foundation for literacy will be built primarily in English" (p. 6). As indicated by the quotations, literacy is positioned as an integral component of the English curriculum. Another national curriculum document offers the following definition of literacy as it relates to English as a school subject:

> Conventionally it (literacy) refers to reading, writing, speaking, viewing and listening effectively in a range of contexts. In the 21st century, the definition of literacy has expanded to refer to a flexible, sustainable command of a set of capabilities in the use and production of traditional texts and new communications technologies, using spoken language, print and multimedia. In English, students learn to read, write, listen, speak accurately, flexibly and critically, and to view and create increasingly complex text for a variety of contexts (Australian Curriculum and Reporting Authority, 2010, p. 6).

This understanding of literacy is synchronous with the definition that underpins the current Queensland literacy policy documents and informs current professional development.

Gee (2008) writes that there are those who dispute the claims that literacy "leads to logical, analytical, critical, and rational thinking, general and abstract uses of language, sceptical and questioning attitudes, a distinction between myths and history, a recognition of the importance of time and space" (p. 50). Gee argues that the traditional meaning of the word 'literacy' – the 'ability to write and read' situates literacy in the individual person, rather than society, and that literacy in its full range includes the cognitive, social, cultural, political, institutional, economic, moral and historical contexts.

There is a growing acceptance by the literacy education community that literacy is best conceptualised as a range of social and communication practices rather than one universal attribute to learning capacity (Martin, 2008). From this perspective, there are many different literacies, such as community or everyday literacy, street literacy, visual literacy, computer literacy, and school subject literacies, such as science (Gee, 2005). Each of these literacies may entail reading and writing, but also involve talking, thinking, viewing and acting for a wide range of purposes.

Everyday literacies are processes and practices that represent what learners can know, do or demonstrate when they communicate (examples are: small group discussion, drawing, reading aloud, written, verbal and visual explanations, gestural demonstrations). These literacies are not just oral or written languages but involve multiple modes, including verbal language (oral and written), visual language (signs, drawings, photographs), mathematical language, embodied language (gestural, role play), or combination of some or all of these modes (Gee, 2005; Snively & Williams, 2008). Examples of 'everyday literacies' students can use in science learning include: using vernacular languages and slang, reading street signs, playing computer games, sending and receiving emails, talking with friends, watching television programs, presenting a verbal thank you, play – acting with friends, participating in a group to solve a problem through discussion or calculating the correct change when buying something (*Primary Connections*, 2006).

2.7 Science literacy as a key component of school science

There is no universal agreement on what science literacy means, except that it means more than understanding and using scientific concepts learnt in a classroom. It is easier to describe how a scientifically literate person may act. One suggestion is that a scientifically literate person is able to read articles on science and technology published in newspapers or magazines with reasonable understanding and make informed judgements (Shamos, 1995; Bybee, 1997; Millar & Osborne, 1998). Another is that a scientifically literate person possesses knowledge, skills and attitudes similar to those of professional scientists (Blenkin & Kelly, 1983; Zen, 1991; Bisanz, Zimmerman & Bisanz, 1998). The role of science education in school is to lay the foundation for science literacy (Hodson, 2000).

In this study, I am going to use three definitions of science literacy. The definition of science literacy used by the Australian Academy of Science (Goodrum, Hackling & Rennie, 2001) is that science literacy is more than just knowing and using science content, but being able to understand and be interested in the world around, engage in discourses of and about science, be sceptical and questioning of claims made by others about science, be able to identify questions, investigate and draw evidence-based conclusions, and make informed decisions about environment, health and well-being. The 2006 Program for International Student Assessment (PISA) project describes a science literate person as having science knowledge and being able to use that knowledge to identify questions, to acquire new knowledge, to explain science phenomena, and to draw evidence-based conclusions about science-related issues. The Queensland Studies Authority: *Years 1 – 10 Science Syllabus* (1999, 2004), in summary, aims that students acquire an understanding of the characteristic features of science as a form of human knowledge and enquiry, an awareness of how science and technology shape our material, intellectual and cultural environments, a willingness to engage in science related issues and ideas of science as reflective citizens as desired characteristics of science learning.

Science educators work from the assumption that their students will express different levels of science literacy. ByBee (1997) identifies progressive levels for the development of science literacy, starting from the simple recognition of science terms: the nominal stage, progressing through the functional stage, the conceptual and procedural stage and the multi-dimensional stage of deeper understanding. This model implies that science literacy can develop and deepen as a student moves from one level to another. What is not included in this model is the effects that different cultural understanding may have on the students being able to demonstrate these levels of scientific literacy. For example, if a Torres Strait Islander is to be deemed literate they must engage in the discourse of science and have the ability to evaluate science evidence and argument. Torres Strait Islander students come from different islands with distinctive cultures, and so they are different, and have different strengths and interests. It is safe to assume that their progressive levels of science literacy will not be identical to ByBee's model.

Bisanz and colleagues (1998) have argued that all school students must be taught scientific culture: the communal nature of science, the tentative nature of new findings, the continually self-correcting mechanism of science, and the consensual processes that are critical for evaluating science knowledge. However, the dominant definitions of science literacy and science culture do not adequately address what it means to be science literate from an Indigenous perspective, particularly for Indigenous students who do not speak English language with facility. Snively and Williams (2008) suggest that science literacy from an Indigenous perspective involves being knowledgeable about the extensive examples and applications of Indigenous science knowledge, as well as western science knowledge, and science discourse about the nature of science. I struggle to conceptualise how examples and applications of Indigenous knowledge can be applied at the level of the classroom when engaging Torres Strait Islander students with mandated Queensland Studies Authority science curriculum that does not accommodate their forms of literacy as suggested by Martin (2008). Chinn, Hand and Yore (2008) struggle with what it means to be literate from various cultural and linguistic perspectives in the discourse of and dealing with knowledge systems about nature and naturally occurring events and with the knowledge and understanding that such systems establish, value and use. Keys (2008) struggles with how a science teacher can effectively provide understanding of scientific concepts to Indigenous Australian students with low literacy levels without the lesson resorting to rote learning and copying down science terminology. There are not many signposts to assist as the intersection between Indigenous Australian cultures and standardised forms of scientific literacy is poorly researched. Michie, Anlezark and Uido (1998, p 4) argue that “only fragmented approaches, such as teaching about bush tucker, bush medicines and knowledge of seasons has been done,” without looking at deeper understandings.

2.8 Paying attention to students’ second language skills

McTaggart and Curro (2009) assert that there is extensive literature arguing and demonstrating that English as Second Language educational needs of Australian Indigenous students are not adequately recognised or met. McTaggart and Curro argue that relevance of English as a Second Language for Indigenous learners is being swamped by other discourses – cultural difference, behaviour management, morale, literacy, attendance, hearing disability, traditional language maintenance, socio-economic status and National Assessment Program – Literacy and Numeracy (NAPLAN) scores. The only way this can be addressed is by improving Indigenous students’ English as Second Language skills theoretically, practically and organisationally. Students use their own representational, cultural and cognitive resources to engage with subject specific representational practices of science (Hubber et al., 2008). The cognitive load created through working in a second language can limit the potential to develop new representation and meaning. I propose here that making Indigenous students negotiate representation and meaning in familiar languages can be empowering for them. Indigenous students are shown to engage more actively in developing conceptual understanding when they are able to 'code switch' between their home language and instructional language (Zevenbergen et al., 2008). Harris (1990) defines 'code switching' as conscious and deliberate switching of chunks of language.

Four recent studies investigating English as second and third language learners in science education conclude that students are marginalised from science learning if Standard English is the only medium of communication when first teaching and then assessing conceptual understanding. In South Africa, Dempster and Reddy (2007) investigated readability of 73 text only multiple choice questions from Trends in International Mathematics and Science Study (TIMSS) 2003 with grade eight students. Three readability factors were investigated: sentence complexity, unfamiliar words and long words in the multiple choice questions. Dempster and Reddy investigated the performance of two groups: students with limited English language proficiency attending African schools and students with better English language proficiency attending non-African schools. Both groups were exposed to the same intended curriculum, but differed with respect to the quality of teaching they received, the availability of resources and the level of functionality of their schools. Dempster and Reddy (2007) concluded that students with better English language proficiency attending non African schools performed significantly better than students with limited English language proficiency attending African schools. High sentence complexity resulted in random guessing with students who had better English language proficiency, and incorrect answers with students who had limited English language proficiency attending African schools. The recommended maximum readability was not met, and the TIMSS items were therefore invalid to learners with limited English language proficiency. I argue here that readability, comprehensibility and (re)production of knowledge might not be met when Australian Indigenous students with limited English language proficiency are taught and assessed using Standard Australian English.

Luykx, Lee and Edwards (2008) investigated science lessons with fourth grade English language learners in Miami. They examined regular lessons in which the monolingual teacher speaks English while a bilingual co-teacher interprets, and a typical lesson without a co-teacher in which the teacher relies on a few more English proficient students to interpret for others. Luykx, Lee and Edwards suggest that the first scenario in which a bilingual co-teacher interprets expands students' engagement and the second without a co-teacher limits students' engagement. An analysis of classroom discourse suggests an underlying ideology that views languages as neutral, semantically equivalent vehicles for science concepts that are themselves viewed as independent of language and context. Luykx, Lee and Edwards (2008) propose that linguistic and cultural factors shape science knowledge for students and teachers, and must be critically examined if educational policy and practice are to productively engage the interpretive work demanded of English language learners in science classrooms. I argue here that for Australian Indigenous students, who are English language learners, their understandings of school science are influenced by cultural values, experiences and epistemologies of their home communities. Further, linguistic and cultural factors can shape educational practices in ways that can either limit or enhance Indigenous students' engagement with science learning.

Berber-Jimenez and colleagues (2008) explore how knowledge of expository text (text written to inform) and the language of science required for reading and writing in science hinder students, especially English language learners from gaining the knowledge and skills required to handle the 'increased factual load' in middle and high school science. They argue that vocabulary, along with expository text structure, often is not taught in middle and high school science classrooms, especially classrooms with English language learners. Unlike vocabulary used in language arts and social studies, knowledge of expository text and the language of science are required for reading and writing science. Berber-Jimenez and colleagues (2008) developed a modified sentence completion to teach students about the language of science more effectively.

Brown and Spang (2008) explored the language practices that emerged as a teacher taught a lesson designed to promote science literacy development for traditionally underrepresented students in a Detroit middle school science classroom. The ethnographic study examined the teacher's use of science language and its influence on students' use of science language. Using socio-linguistic discourse analysis, a mode of classroom language was identified. The teacher used a hybrid method of language, involving her explaining science ideas by using vernacular as well as scientific language. This parenthetical type of speech, which was described as "double talk" was also found in students. Students appropriated this same strategy for using science language in which they produced vernacular as well as scientific descriptions during explanations. The findings of this research are significant in their contribution to my research about teaching and learning for Australian Indigenous students.

Results from these four international studies reinforce the need for socio-cultural approaches in science classrooms. These results imply the need to teach science explicitly as a second language for Australian Indigenous students, and the need to explore, mobilise and marshal Australian Indigenous students' cultural resources in terms of their cultural disposition, cultural capital and community cultural wealth in their learning of school science.

The case I make is that there have been few international studies that have investigated Indigenous students learning classroom science from a socio-cultural perspective (Aikenhead, 2006), and even fewer ethnographic studies that have investigated Australian Indigenous students learning classroom science (Christie, 1991; Chigeza, 2007; Key, 2008). Michie, Anlezark and Uido (1998) argue that there have been very few Australian studies that have investigated science learning by Australian Indigenous students from the students' perspective, suggesting that only fragmented approaches have been done, which have not looked at deeper understandings. I propose here that a socio-cultural approach can make heard the 'little voices' of Australian Indigenous students in the context of learning school science as well as to illuminate their experience of learning school science. Bennett (2003) suggests that teaching, as an evidenced-based practice, requires that research inform both the planning and actual delivery in the classroom. Research literature can do more than just focus on policy issues and what the experts say about Indigenous education; they can explore what the Indigenous students say about their classroom science learning.

Brown and Ryoo (2008) used web-based software to teach biology to grade five students in Michigan using a “context-first” approach that allowed students to transition from everyday understanding of phenomena to the use of science language. The research was guided by the assumption that students who learn to understand phenomena in everyday terms prior to being taught science language develop improved understanding of new concepts. Forty nine minority students were randomly assigned into two groups for analysis. A treatment group were taught with everyday language prior to using scientific language, and a control group were taught with scientific language. Brown and Ryoo (2008) used a pre-post-test control group design to assess students’ conceptual and linguistic understanding of photosynthesis. The results of this study indicated that students taught with the “context-first” approach developed significantly improved understanding when compared to students taught scientific language first. I propose here that when Australian Indigenous students are taught with a context first approach, they can develop improved understanding of school science.

Indigenous students need to develop an internal belief that they can control science outcomes and become a part of science from their socio-cultural subjectivities and experiences. Sensevy and colleagues (2008) suggest that students need to engage in construction of representations and relationships between the abstract and the concrete through modelling activities during group work, before elaborating specific science language and appropriate thought processes. This means that Indigenous students learning to understand phenomena in everyday terms can use their vernacular languages prior to being taught scientific language to develop improved understanding of new science concepts. In this way, Australian Indigenous students with limited facility in English can draw from their socio-cultural language dimensions for the purpose of learning school science.

2.9 Constructivism, conceptual change and context-based learning models

Contemporary research and development studies in Australian schools on effective learning tend to prefer constructivism, conceptual change and context-based learning in science (Cuttance, 2001). Such approaches are argued to be sympathetic to students in the transition from their everyday-life world to the world of school science, but my twenty years experience teaching Indigenous students in southern Africa and Far North Queensland has turned me towards a socio-cultural learning approach when dealing with Indigenous students learning school science. These are the views with which I am entering this research.

Constructivism is the pedagogical idea that students construct meaning from experience (Bennet, 2003; Fleer & Hardy, 2001). Constructivism in its broadest sense centres on the recognition of the knowledge, experiences and skills students bring with them into a science classroom. Constructivism tends to focus on individual students as each individual student inquires and explores phenomena, and, in the process, constructs personal meanings and understandings. Driver and Bell (1986) identify the features of a social constructivist view of learning as: construction of meaning is influenced by existing knowledge of the learners as well as the learning environment, construction of meaning is an ongoing and active process by the learners, constructed meanings are evaluated by the learners and can be rejected or accepted, meanings students construct are influenced by experiences with the physical world and language, and learners have final responsibility for their learning. The aim is for students as individuals or in groups to achieve deep understanding, generate ideas, demonstrate concepts and not just repeat what they have learned.

Therefore constructivism (in all its many promulgations) holds that, given the appropriate mix of teaching strategies and pedagogical approaches, students learning science will construct their own understandings from what they already know of the world and from what they are invited to know in the classroom. Skamp (1998, p. 6) describes how many science educators view constructivism not only as a theory of learning but as a "way of knowing … a theory about what knowledge is and how it is generated". However, what if students as constructors of knowledge do so in non-Western languages that reproduce ontologically different ways of being in the world? I struggle to understand how constructivist approaches can work in Indigenous classrooms in the ways set out in the multiplying literature that assumes "a learner" is "white" and nominally English speaking.

The conceptual change approach to teaching science involve an exploration of and challenging of students' prior ideas, establishment of science ideas, extension of these ideas to a range of phenomena, and explicit evaluation of the new perspective (Hubber, 2005). Central to this model is the notion that different ideas and conceptions hold different degrees of "status". Status here is the degree to which the person holding the idea accepts the idea and finds it intelligible, fruitful and plausible (Posner et al., 1982). According to this model, learning something new happens when the person raises the status of an idea to a position above the knowledge that they currently have. As defined, I find this model misaligning with what I wish to achieve in my study. I argue that what one holds valuable consciously or unconscionably is informed by ones' societal ways of talking, thinking, feeling and acting. Lovat (1987) argues that a child learns what his or her society considers to be necessary well before they come to school, giving attention to particular sets of stimuli and ignoring others. Through socialisation, reinforced by personal experience, a child or group of children learn to give attention to particular sets of stimuli and to ignore others. Gee (2005) emphasises that the mind is a pattern reader, and socio-cultural experiences 'tell' the mind what to respond to and what to ignore. I suggest here that cultural training some Australian Indigenous students experience in their communities might limit their ability to raise the status of new or different knowledge to above the knowledge and experiences they currently have, a necessary condition of learning prescribed by the conceptual change model.

Hubber and colleagues (2008) argue that recent work in cognitive science challenges the conceptual change learning model, and emphasise the role of languages and personal contexts when learning and understanding science. Hubber and colleagues (2010) write that a large body of research in the conceptual change tradition has shown the difficulty of learning fundamental science concepts, yet conceptual change schemes have failed to convincingly demonstrate improvements in supporting significant student learning. The focus shifts attention from emphasis on science knowledge structures imagined to exist in a resolved form in students' heads, to science knowledge as a set of subject specific literacies. Focusing on science knowledge as subject specific literacies means learning science involves the recognition and development of these literacies and students' representational resources (Yore, 2008). I propose that Australian Indigenous students can use their own representational and cultural resources to engage with subject specific literacies and representational practices of science.

Hampton, Licona and Izquierdo (2005) suggest that a context-based approach to science learning prescribes that the science curriculum is embedded in the community and interest of the learner. Daily activities are integrated with other content and are rich in interactive dialogue with fellow students and the teacher in both the home language and English. The teacher listens to students' points of view, and then taps that prior knowledge to launch the learning experiences. I find a context-based learning approach to be useful when teaching science to indigenous students. I agree that a context-based learning approach links science to the everyday life experiences of students at every stage, and the learning is structured in situations which the students encounter in the world. What I find challenging, though, is how a teacher socialised in a different culture can come to understand different groups of Indigenous students' perspectives. Since Gumperz and Levinson (1996) suggest that understanding depends on applying the same complex interpretive principles that link context and interpretation.

The merits of a context-based learning approach have been reported. Results from context-based empirical studies on years 11 and 12 students in the USA, the UK, the Netherlands, Canada and South Africa reveal positive results for both boys and girls in motivation and understanding science concepts (Bennett, Hogarth & Lubben, 2003), though the concerned students were not necessarily indigenous. A small-scale case study research project involving secondary students on the effects of context-based learning reveals a significant difference in attitude between students who follow a context-based approach from those who follow conceptual change methods. The context-based learning approach encouraged students to plan and organise their own work more than the other group, with increased interest and enjoyment in science (Barber, 2000). The Evidence for Policy and Practice Information and Co-ordinating Centre (EPPI, 2005) analysed studies from different countries and revealed that: students in classes using context-based learning show significant conceptual understanding and a more positive attitude towards science; a context-based learning approach narrows the gap between boys and girls in conceptual understanding and positive attitude towards science, and low ability students in classes using context-based learning show a significantly better conceptual understanding and a more positive attitude than low ability students using constructivist approaches. I propose here that indicators in a context-based learning approach show promise in facilitating smoother negotiation into school science and the conceptual meaning-making of Indigenous students.

Tytler (2007) argues for re-imagining the science curriculum with pedagogy that conceptualises the diverse, socio-cultural learning needs of our diverse student population. It is easier to conceptualise a re-imagined science curriculum as it applies to students who have English as their thinking language, and then conceptualise the learning needs. However, what if the students are using a home language or Creole as their thinking language, and negotiating learning science in that home language or Creole, which produces different ontological and epistemological perspectives? How can a re-imagined science curriculum and pedagogy work in such contexts? How can a re-imagined science curriculum incorporate and recognise Australian Indigenous students' cultural resources in its framing, teaching and assessment? How can a re-imagined science curriculum look at school science ways of knowing in a dialectical relation with Indigenous students' everyday ways of knowing? These questions are addressed in the next sections.

2.10 A case for socio cultural research in the classroom

Aikenhead (2006) writes that recent teaching and learning models have moved towards students learning through social interaction. This means that the Indigenous student can be positioned as a purposeful communicator and creator of meaning within their social contexts. The shift thus centres on the Indigenous student's language system and the social contexts in which the language system occurs, and for Australian Indigenous students in a science classroom, it encompasses a broader range of issues, which include pidgin and Creole languages. The languages students use is a crucial consideration in Indigenous science classrooms, which are heavily dependent upon negotiation and acquisition of a new language (scientific language) for success. Christie (1985) suggests that in science classrooms that do not employ socio-cultural perspectives, the visual, tactile and other sense modalities of Indigenous cultures and languages can virtually disappear, and the skills for processing them can become irrelevant to the learning situations and possibly becoming impediments.

Socio-cultural perspectives on learning can focus attention on the social and cultural processes underpinning learning. Hubber and Tytler (2004) suggest that elements in a socio-cultural perspective on learning can include: the active role of the teacher in providing opportunities for students to engage with and explore phenomena, support for students to engage with meaningful contexts, the negotiation of meaning implied in the teacher's guidance of students towards scientific views, and the meta-cognitive implications of making ideas explicit, and extending and evaluating them. A socio-cultural approach can detail mechanism classroom teachers might offer in support of Australian Indigenous students when negotiating from their everyday ways to scientific ways of talking, thinking, doing and knowing. I propose here that when research focuses on Indigenous students' languages, it can bring greater understanding and increased knowledge of what is happening in the science classroom, and the Indigenous language and knowledge awareness can permeate throughout the curriculum.

My work on exploring the notion of agency and Indigenous students' negotiation of language and culture in science classrooms aligns with recently introduced global work on cultural studies of science education. Roth and Tobin (2006) suggest that cultural studies of science education focus on employing social and cultural perspectives as foundations for research and other scholarly activities in science education and studies of science. Global work on cultural studies of science education is published in a journal: Cultural Studies of Science Education through Springer, which seeks to establish a broader context for rethinking the role of traditional local knowledge systems in science education, and examines science education as a culture, cross-age, cross-class, and cross disciplinary phenomena. It provides an interactive platform for researchers working in multidisciplinary fields of cultural studies and science education. Moreover, the journal establishes bridges between science education and social studies of science, public understanding of science, science and human values and science literacy.

By taking a cultural approach in science education, this global work on cultural studies of science education focuses on postcolonial theories and pays close attention to socio-cultural theories and methodologies from cultural studies (Aikenhead, 2006). This new global work on cultural studies of science education reflects the current diversity in science education. It reflects the variety of settings in which science education takes place, including schools, museums, zoos, laboratories, parks, aquariums and community development, maintenance and restoration programs (Tobin, 2009). Cultural studies of science education connect social groups within fields, and promote respect for difference, creating a context that takes into account more recent developments in thinking about science knowledge, such as social studies of science, socio-cultural studies, actor network theory and cultural historic activity theory (Roth & Tobin, 2006).

I participated in the Third Forum of Cultural Studies of Science Education (CSSE) in San Diego in April 2009. I was privileged to interact with a group of science educators who realise that Indigenous students with limited facility in Standard English do not start from the same point as students with facility in Standard English, the language of instruction, and the Indigenous students need to negotiate language and culture in their science classrooms. These science educators recognise positive effects of legitimizing Creole, pidgin and minority dialects in science classrooms. My experience at this forum reinforced my understanding of how socio-cultural approaches benefit Indigenous students learning science.

2.11 Summary

In this chapter, I have argued why my science classroom with Indigenous students who have English as a second or third language can be a dynamic and interactive socio-cultural environment. The idea was taken a step further to explore why it is imperative to value and acknowledge the cultural resources that the students bring to the classroom. I argued that acknowledging and valuing the elements of cultural resources of Indigenous students can mean using their cultural disposition to inform pedagogy (in this case capacity building), community cultural wealth as contexts to situate learning experiences, and cultural capital as currency they use to make meaning. The ways of thinking about language and literacy in socio-cultural practice were reflected on; the definitions of science literacy explored and a proposal to improve Indigenous students' second language skills was discussed. Three learning models: constructivism, conceptual change and context-based learning models were examined to find how useful they can be effectively employed in classrooms with

Indigenous students who have Standard Australian English as a second or third language. The themes discussed in this chapter will help explore cultural resources Indigenous students bring to the classroom in the next chapter.

Chapter 3
Cultural resources in science classrooms

3.1 Introduction

In this chapter, I explore the idea of cultural resources in science classrooms. Firstly, I discuss how science awareness is held to be important in Australia and the reported underachievement on benchmarked science assessment by Indigenous students. Secondly, I explore why the science classroom can be considered as a cultural field that defines the science capital: rules that produce and authorises science discourses and science activities, and how Indigenous students are expected to acquire the science capital. Thirdly, I explore Indigenous knowledge and Western science knowledge, and then examine science education research and development that has been done in this area, and how it aligns with my research. Fourthly, I explore the accessible cultural resources Torres Strait Islander students bring to the science classroom and argue why my science classroom is a cultural field able to be researched using a socio-cultural analytical lens.

3.2 Science awareness in Australian

Science awareness is held to be important in Australia. The Australian Federal government places emphasis on developing science awareness in its population and a report of the Prime Minister's Science, Engineering and Innovation Council (November 26, 1999), highlighted three main reasons why science literacy is important to the general public: (1) to develop a science literate society that deals flexibly with change and is capable of informed decision making, (2) to encourage students to choose science as an attractive career option, and (3) to drive economic growth and advance social and environmental wellbeing.

The Australian Council of Deans of Science "firmly believe that Australia's future prosperity and independence require a community which has a significantly higher level of scientific literacy than at present" (Committee for the Review of Teaching and Teacher Education (CRTTE), October 2003, p.32). However, Australian results from the Third International Mathematics and Science Studies (TIMSS) reveal that Australian students' attitudes towards science deteriorate markedly between primary and secondary education. Almost forty per cent of secondary students surveyed in the study reported that they never got exited about what they do in science (CRTTE, 2003).

Australian fifteen-year-olds were asked in the OECD Program for International Student Assessment (PISA) 2006 about their interest in various science subjects (physics, chemistry, plant biology, human biology, astronomy and geology). They expressed very low average levels of interest. Australian average for each of the six science subjects (physics, chemistry, plant biology, human biology, astronomy and geology), was below the average for each of the 41 participating countries. Indigenous students were found to have significantly lower levels of interest than non-Indigenous students, and the level of interest was much wider in the lower secondary than middle primary school. In Queensland, fifteen-year-olds are not taught separate science subjects, though the subject may be partitioned into different strands.

The Australian Academy of Technology, Science and Engineering reports that progress in the state of Queensland and regions is uneven, and that there is still a long way to go before all state schools can deliver on the 1999 ministerial commitment to science. The regularity and quality of science teaching in the independent school sector is also highly variable (CRTTE, 2003). The importance for schools to deliver science education that will result in a population who are science literate cannot be over emphasised. The question that remains to be answered is: What is science literacy in a diverse cultural context, and how should we teach all our citizens?

Masters (2009) observes that knowledge-based economies are demanding more highly skilled and knowledgeable workers, and global developments are demanding more informed citizens who can engage with, and make positive contributions to, the complex environmental, financial, political and social challenges of the 21st century. The learning of rational, empirical, scientific concepts by Indigenous students is fundamental to contemporary, techno-industrial society. In preparing Indigenous students for these future challenges, a fundamental understanding of science is essential. Indigenous students need to cross into the science world in order to participate fully in modern economic and technology systems.

In Queensland, all mandated Queensland Studies Authority science curricula are formulated in Standard Australian English. Martin (2008, p. 79) argues that the "historical, social and racialised context of schooling for Aboriginal [and Torres Strait Islander] students have meant that taking risks with learning and applying knowledge have not been a simple endeavour". I argue that it becomes imperative to capture the everyday oral and written languages of Aboriginal and Torres Strait Islander students, the ways of communication that they bring to the science classroom and the means by which they engage with the school science curriculum. Mellor and Corrigan (2004) suggest that a distinction exists between two groups within Indigenous communities. The first group is those from traditional and remote communities, where Standard Australian English is used only in schools. The second group is those communities where Standard Australian English or a dialect of Indigenous English, or a common Creole (derived from English) is the community and school language.

In April 2008 the Queensland Studies Authority launched a statement acknowledging the importance of understanding, maintaining and promoting the diverse Australian Indigenous languages spoken in Queensland and across Australia. The Queensland Studies Authority statement does not give pedagogical content knowledge or practical socio-cultural guidelines that classroom teachers can follow to implement this important aspect of Australian Indigenous education. I argue that by not giving classroom science teachers the pedagogical strategies or practical socio-cultural guidelines to follow, the April 2008 Queensland Studies Authority effort to acknowledge the importance of Australian Indigenous languages can be reduced to mere rhetoric. The historical exclusion of Aboriginal and Torres Strait Islander languages from classroom communication is a symbolic exclusion of those who speak the languages (Malcolm, 2002). I strongly believe that building educational opportunity for Aboriginal and Torres Strait Islander students can be possible if considerable effort to embed their cultural resources in the curriculum is achieved. There is need to mobilise and marshal these students' cultural dispositions, cultural capital and community cultural wealth they have accumulated in their individual social trajectories to help them engage with science learning.

‘Underachievement’ on benchmarked science assessment by Australian Indigenous students has been extensively reported. The OECD Program for International Students Assessment (PISA) 2006 results showed that 40% of Australian Indigenous students performed below the OECD “baseline”, and the Third International Mathematics and Science Studies (TIMSS) reported that Australian indigenous students have significantly lower average scores than non-Indigenous students, and that the gap is much wider in the lower secondary school. The 2006 National Year 6 Science Assessment Report acknowledges that only 49% of Queensland students were at or above proficiency standard, compared with the national average of 54%. Australian Indigenous students whose first language is not English and who live in regional, rural and remote areas of the country, performed most poorly. The Indigenous students referred to in these international reports are Aborigines (found all across Australia) and Torres Strait Islanders (originating from the Torres Straits Islands in North Queensland).

Following what was labeled as ‘poor results’ in the 2008 National Assessment Program – Literacy and Numeracy, the Premier of Queensland, Anna Bligh, commissioned Professor Geoff Masters, Chief Executive Officer of the Australian Council for Education Research, to review Queensland curriculum and educational standards. Masters (2009) reports that Indigenous students from the Torres Strait and Cape District (where my students come from) perform among the lowest five per cent of students nationally. The report suggests that by Year 9, the ‘gap’ in achievement level of students in literacy, numeracy and science between non-Indigenous Queensland students and Indigenous students living in very remote parts of the state is, on average, equivalent to six to seven years of school. The report emphasises that there are factors beyond remoteness underlying these ‘achievement gaps’, which include higher proportions of students from lower socio-economic backgrounds and higher proportions of Indigenous students speaking English as a second language. Klenowski (2008) argues that equity in relation to standards-based assessment is a socio-cultural issue. I argue in this thesis that a strongest factor in generating inequity in terms of secondary school science achievement by Torres Strait Islander students is that the Queensland Studies Authority science curriculum is taught and assessed using Standard Australian English, “at the expense of every other [language] variety possessed by Aboriginal and Torres Strait Islander people" (Malcolm, 1998 p. X). The rest of this thesis tests the rationale for such an argument.

A discussion paper released by the Premier of Queensland, Anna Bligh titled: *Towards a 10-year plan for science, technology, engineering and mathematics (STEM) education skills in Queensland* on 11 October, 2007, can be employed, as I now do, to articulate rationale for conducting socio-cultural research with Australian Indigenous students in science classrooms. A number of questions arise from this report which can be applied to Indigenous students learning science. What approaches can be employed to enrich the middle school science learning experiences of Aboriginal and Torres Strait Islander students? What strategies could be implemented in junior secondary schooling to promote the uptake of science subjects in post-compulsory years by these students? What are the essential skills, understanding and knowledge to be associated with general science literacy and preparedness for science related occupations by them? What strategies currently work well to improve their participation and achievement in science? What evidence is there to demonstrate their effectiveness? What types of targeted interventions might assist to increase their participation and achievement in science subjects, particularly noting the following backgrounds: Indigenous, low socioeconomic, non-English speaking and from remote locations? I propose here that these questions flag the need to develop pedagogical strategies and employ a socio-cultural analytical lens in the classroom situation to investigate how these Indigenous students engage with science learning.

3.3 The year 9 science classroom as a cultural field

A cultural field has been used by Bourdieu to represent a site of cultural practice, and a site of struggle over particular forms of capital. Webb, Schrato and Danaher (2002) write that a cultural field can be defined as a series of institutions, rules, rituals, conventions, categories, designations and appointments which constitutes an objective hierarchy, and which produce and authorise certain discourses and activities. In this study, the site of struggle is the science class. The science class as a cultural field defines the science capital: knowledge of science discourses and science activities. The Level 4 and 5 learning outcomes of the mandated Queensland Studies Authority, *Science Syllabus Years 1 to 10* (2004) are the forms of science capital that students struggle to acquire. For this study, they are the Level 4 and 5 learning outcomes of the Energy and Change strand. The students are expected to explore the effects of forces in their lives, and consider methods of harnessing energy, the ways energy is used, and the social and environmental consequences of energy use. The key discourses and activities on concepts of Energy and Change strand are (QSA, 2004):

- Forces acting on objects influence their motion, shape, behaviour and energy.
- In interactions and changes, energy is transferred and transformed but is not created or destroyed.
- There are different ways of obtaining and utilising energy and these have different consequences (including nuclear energy).

The science capital, that is, rules that produce and authorise science discourses and science activities from the QSA (2004) outcomes-based science syllabus calls for active and explicit teaching of students about scientific texts, language and vocabulary. It also requires teachers to allow time for students to develop competency in scientific texts, language and vocabulary commonly used in scientific context.

Indigenous students are expected to acquire the science capital, meaning to communicate science ideas, explanations, conclusions, decisions and data, using scientific argument and terminology in appropriate formats, on the concepts of energy and force. The mandated Queensland Studies Authority science curriculum and associated science capital are formulated, taught and assessed using Standard Australian English concept descriptors, the Indigenous students' second, third or even fourth language. McTaggart and Curro (2009) suggest that English as a Second Language consciousness and Indigenous language awareness needs to permeate right through the Key Learning Areas (KLAs), the curriculum, in teacher education and in educational research practice. The concepts of energy and force are not new to Aboriginal and Torres Strait Islander students. Their people have traditionally used the wind directions and force for sailing, wind directions to define their seasons, and sea currents to manage aspects of their lives (Sharp, 1993). Students would have used different discourses and activities, and different forms of capital associated with these concepts of energy and force in their communities. Hubber and colleagues (2010) write that learning science emphasises the more fundamental roles of context, perception, feelings, embodiment, metaphor and narrative in learning.

Aboriginal and Torres Strait Islander students with limited facility in English would struggle to acquire the science language used in science learning. Yet language learning is a core constitution of science (Norris & Phillips, 2003), which includes manipulation of images and symbols such as, graphs, diagrams, charts, mathematical symbols, chemical symbols, formulae and equations. Valentine (1996), who researched students' understanding of logical connectives in science writing concluded that students with English as a first language had fewer difficulties than students with English as a second or third language. I argue that Indigenous students with English as a second or third language are marginalised from science learning in North Queensland, when Standard Australian English is the only medium of communication for learning, teaching and assessing. At present, the learning and assessment of Aboriginal and Torres Strait Islander students in science classrooms is highly dependent upon their acquisition of Standard Australian English.

The introduced terminology employed to constitute science content can be unfamiliar to Indigenous students as concepts are not easily transferable from Indigenous languages to Standard Australian English (Michie, 2002). Research literature suggests that specific language challenges in science are of two main types: vocabulary and grammatical challenges (Wellington & Osborne, 2001). The specific types of vocabulary difficulties are: technical terms that give new names to familiar objects (e.g., "trachea" for windpipe), technical terms that give new names to unfamiliar objects including those that are only encountered in laboratory settings, technical terms for the purpose that can be demonstrated and observed (e.g., evaporation, distillation, combustion), technical terms for the purpose that can not be observed in direct action (e.g., photosynthesis, evolution), theoretical entities (e.g., electron, gene, atom), abstract idealizations (e.g., point mass, frictionless surface) and mathematical words and symbols. There is also the problem that Indigenous languages may have a range of words for relational characteristics of place but much fewer words than English for scientifically described phenomena (Wolmer, 2007).

The grammatical features of a science text that can cause reading and reasoning difficulties include: logical connectives (e.g., frequency, simultaneous, consequently, thus, conversely) which are vital components of the language of hypothesising, comparing, sequencing, attributing cause and other key features of scientific reasoning; qualifying words (e.g., the majority of; in a few cases) can be a barrier between the reader and the information; objectification or use of passive voice that removes human agency in science; lexical density content or factual words that are presented in much higher density at the expense of the narrative prose (e.g., the atom emits energy in quanta or discrete units), nominalisation, where nouns can be substituted for verbs (e.g., crystallization, evaporation, acceleration) or nouns that can be used as adjectives (glass crack growth rate). Berber-Jimenez and colleagues (2008) argue when Indigenous students are explicitly coached in these language challenges and strategies to cope with the difficulties they pose, they stand a better chance of achieving the desired science literacy outcomes.

3.4 Framing classroom research: Indigenous knowledge and Western science knowledge

In Chapter One, I highlighted that my research does not focus on the ‘big’ dilemmas and differences between Indigenous knowledge and Western science knowledge because they concern the structures of the knowledge systems (Yore, 2008) and not the agency of Indigenous students when learning classroom science. My research concerns pedagogical content knowledge, and thus focuses on conceptual content knowledge levels that Indigenous students engage with when learning school science and levels of epistemology and ontology that inform these conceptual content levels (Nakata, 2007). I explore Indigenous conceptual content knowledge relating to the Western science meta concepts of energy and force available in published literature. Synott and Whatman (1998) write that Indigenous knowledge is embedded in culture, and is unique to a given location or community. Additionally, it is the basis for decision making by communities in matters of food, security, human and animal health, education and natural resource management.

Australian Indigenous peoples’ cultures are diversified. There are around 350 different Indigenous groups in Australia, each with its own language, knowledge, beliefs and kinship with the land, although some of the languages have similar words and structure (Sharwood, 2005). Australian Indigenous people consider themselves as belonging to the country, and their knowledge is holistic and purposeful to the owners, the process of obtaining knowledge is more important than knowledge itself (Ross & Read, 2003), and it is passed from generation to generation by word of mouth. Some knowledge is available only to particular people; for instance, there is men's knowledge, women's knowledge and sacred knowledge. Others can be aware, but will not claim the knowledge in public (Michie & Linkson, 1999). Knowledge is accessed by participating in ceremonies, *storytelling*, art, song and dance, focuses on co-existence rather than on control, and centres on relationships between individuals, groups, a spirit world of ancestors and on land and sea. This can imply that some Indigenous people's knowledge can be difficult to access in classroom situations. What must concern the science educator is what Indigenous knowledge they can access in the classroom environment.

Chinn, Hand and Yore (2008) emphasise that both Indigenous knowledge and Western sciences employ rational ways of knowing (school science is a sub-culture of Western science). Michie (2002) writes that Indigenous people develop their knowledge within the context of their environments, and are able to demonstrate the ability to change as the environment changes around them or as they move from one environment into another. In addition, in recent times Indigenous people have demonstrated the ability to adapt Western technologies to suit their own purposes. What conceptual content knowledge Indigenous students arrive with in the classroom is also based on a series of rational assumptions, so they are quite capable of thinking rationally and scientifically in their home language. Indigenous knowledge systems are guided by the fact that the physical universe is mysterious, but can be survived if one uses rational empirical means. In contrast, Western science is guided by the fact that the physical universe is knowable through rational empirical means, but their culture-laden rationalities differ to varying degrees in several ways regarding social goals, intellectual goals, association with human action, notion of time and general perspectives (Aikenhead, 2006).

Table 1: A contrast between Indigenous ways of knowing and Western scientific ways of knowing is summed up by Aikenhead (1998):

Indigenous ways of knowing	**Scientific ways of knowing**
1. Indigenous knowledge concerns survival of a people.	Scientific knowledge concerns gaining knowledge and power over nature.
2. Indigenous knowledge emphasises co-existence with nature by celebrating it.	Science knowledge eradicates mystery by explaining it.
3. Indigenous knowledge is intimately and subjectively interrelated.	Scientific knowledge is formally and objectively de-contextualised.
4. Indigenous knowledge is holistic, gentle, accommodating, intuitive and spiritual.	Scientific knowledge is reductionist, aggressive, manipulative, mechanistic and analytical.
5. Indigenous time is circular.	Scientific time is rectilinear.

The notion of causality does not sit neatly between Indigenous ways of knowing and Western science ways of knowing (Yore, 2009). Western science utilizes physical causality rather than mysticism or spirituality to move toward explanations. While explanations based on authority, magic, mysticism, and spirituality may be personally useful and socially relevant to a group of people, it cannot be regarded as science (Cobern & Loving, 2001). The notion of causality rather than rationality fundamentally differentiates Western science from Indigenous knowledge systems. Yore (2009) writes that modern Western science is driven by inquiry, limited by human abilities and technology, and guided by hypotheses, observation, measurement, plausible reasoning, creativity and accepted procedures. Although temporary and tentative, the explanations attempt to produce persuasive arguments with coordinated claims, evidence, backings and rebuttals, and seek to establish physical causality, and make generalised claims, based on the current evidence and canonical understanding.

When Indigenous students learn school science using a socio-cultural perspective, they negotiate from their everyday ways of knowing to school science ways of knowing. Yore (2008) writes that Maori people of New Zealand represent a situation where dominant science discourse communities and science language differ from Indigenous students' home language and language of instruction used to teach and learn about science. This implies that Indigenous students negotiate from their home culture and languages into school culture and language and then into the culture and language of school science. To enter the world of school science, Indigenous students learn to use particular ways of talking, thinking and doing (Chigeza, 2008). I argue that, in an attempt to develop pedagogical content knowledge, there is need to establish how Indigenous students can marshal their cultural resources to help them acquire school science capital. There is need to theorise from socio-cultural perspectives about how Indigenous students learn to talk, read and write about science, in ways that promote scientific argument as a means of building understanding of the science concepts (Aikenhead, 2006). There is also need to investigate how a science curriculum can limit or enable Indigenous students' negotiations and agency as they move from one knowledge system to another.

3.5 What has been done and how it aligns with my research

Traditional school science teachings have sought to enculture or assimilate students into the subculture of science, making students think and act like scientists (Aikenhead, 1996). One could argue that school science teachers attempt to make students act and think like the teachers think scientists act and think. These traditional ways of teaching science have produced three avenues for learning school science: enculturation, assimilation and Fatima's rules, (rules for passing a science course by memorising key concepts without understanding science). Aikenhead (2006) explains that playing Fatima's rules does not achieve meaningful learning because it promotes rote memorization and going through the motions of learning without being intellectually engaged.

Cobern and Aikenhead (1996) suggest that most Indigenous students often reject enculturation and assimilation, and opt to play Fatima's rules. Students of different cultural backgrounds interpret science concepts differently; hence the need to reform cross-cultural science teaching (Snively & Corsiglia, 2001). I argue that, when developing pedagogical content knowledge, employing a socio-cultural approach that integrates Indigenous students' everyday ways of knowing and doing into science education becomes mandatory. A socio-cultural approach can focus on the personal orientation of the student, the subcultures of a student's family, community, peers, school, media, and the subcultures of science and school science as conveyed by a science teacher (Aikenhead, 1998).

Cobern (1996) advises that Indigenous students can shut out explanations that reject their own beliefs in favour of the supremacy of western models; hence the need to develop pedagogical content knowledge that can inform cross-cultural science. Situating the students in environments where learning is negotiated in groups and which take into account students' cultures can promote a continual process of constructing, interpreting, and modifying their representations of school science ways of knowing and doing through experience and negotiation with their peers (Grabinger, Aplin & Ponnappa-Brenner, 2007). I suggest here that Indigenous students learn school science in authentic contexts and in collaboration with others, and situating them in socio-cultural environments can enable them to negotiate into school science ways of knowing and doing. On a topic about the biological or physical world, there is need to identify and use their personal knowledge through discussion and brainstorming. There is need for them to explore their everyday cultural ways of knowing and school science ways of knowing on the topic to identify similarities and differences (Hooley, 2003). There is need to give them space to negotiate the language and knowledge systems. They can then reflect and evaluate the learning process, and modify their representation of the new knowledge.

There have been some reported successes of Indigenous students learning school science. These successes depend on the degree of cultural difference that pupils perceive between their world and the science classroom, how effectively students move between their world and the culture of school science and the assistance students receive in making the transition easier (Jegede & Aikenhead, 1999). According to Aikenhead (1996), the movement of students between their everyday ways of understanding to school science ways of understanding produce four groups of students:

1 Potential scientists, who have a smooth transition due to similarities between the two ways of understanding,

2 Smart students, who have a manageable transition though the two cultures may be different,
3 "I do not know students", who have a hazardous transition due to the diverse cultures,
4 Outsiders, who find the transition impossible because the two cultures are discordant.

The first two groups are in the minority (Phelan et al, 1991). Costa (1995) explains that the categories are not stable, but depend on context. Aikenhead (2000a) expands Costa's focus on student achievement by considering the relevance of school science to students, their self-esteem, and their image of themselves as science students. Considering the needs of the students encouraged me to explore paradigms that have the potential to positively influenced Indigenous students to learn science.

Two paradigms have informed my thinking. The first is an eco-cultural paradigm designed by Jegede (1995) for teaching science to African students in ways that are related to their socio-cultural backgrounds which suggests:

1. Generating information about the student's everyday environment to explain natural phenomena.
2. Identifying and using Indigenous science and technology principles, theories and concepts within the student's community.
3. Teaching the typical values of the Indigenous community in relation to, and in the practice of science, technology and human enterprise.

The second is an eco-cultural paradigm designed for Indigenous Canadians that is sympathetic to cultural differences, promotes emotional support for students and facilitates smooth cross-cultural teaching which suggests five tools (Aikenhead, 1996; Cobern & Aikenhead, 1998):

1. Making the 'border crossing' explicit for students.
2. Facilitating the 'border crossing'.
3. Promoting discourse in both the student's cultural interpretive framework as well as the framework of school science.
4. Building on the validity of students' personal and cultural constructed ways of knowing.
5. Teaching the canonical content of western science in the context of science's societal roles.

I argue that these paradigms flag pedagogical content knowledge that take into consideration Indigenous students' dispositions created and formulated through their personal history, culturally authorised attributes and skills, and forms of language that they have accumulated in their individual social trajectories (see Bourdieu, 1986).

Three models that have been suggested to facilitate smoother negotiation of Indigenous students from their cultural everyday ways of knowing into school science ways of knowing are: a cross-cultural model, a multi-cultural model and a pluralist model (Snivel & Corsiglia, 2001). The cross-cultural model calls for the inclusion of traditional ways of knowing, which might include attitudes and ideas rejected by western science. Students inquire into a problem from a scientific perspective, employing various ways of measuring its components. At the same time, they also look at the problem from indigenous people's ways of knowing. The cross-cultural model frames knowledge in a more holistic manner than the socio-scientific, but might not make 'border crossing' explicit to students. A multi-cultural model calls for the inclusion of different ways of knowing, an explanation about what science is and how it works, a highlighting of the different worldviews, and making 'border crossing' explicit. Students inquire into a problem from a scientific perspective, and frame and measure the components. They then frame the same problem from the indigenous people's ways of knowing, and identify underpinning statements in both perspectives as they work towards a solution to the problem. It is suggested that both the multi-cultural and cross-cultural models signal a socio-cultural approach and imply 'border crossing', while the pluralistic model defines western science as the 'gate keeper', and looks at other ways of knowing. Students inquire into a problem using exclusively scientific descriptors and theories, and represent their learning through an agreed science report format. In another part of the lesson, they look at how indigenous people value some components of the problem. The pluralistic model introduces knowledge systems on different terms (Hooley, 2003; Waiti & Hipkins, 2002). These theoretical models produce guidelines describing how Indigenous knowledge systems can be incorporated into a science class. Aikenhead (2006), however argues that they have not conducted research at classroom level into how science teachers follow the guidelines to develop materials for classroom use. This means that the models do not have pedagogical content knowledge that the science teacher can use in his or her classroom with Indigenous students. This has been my frustration with literature on Indigenous students learning science, as a classroom practitioner. It is easy to imagine and formulate these models in a quiet office, but how does one implement the models at the classroom level with twenty five Indigenous middle school students?

Jegede (1995) proposes another avenue of negotiating into classroom science by Indigenous students: collateral learning. Collateral learning is a coping mechanism and involves Indigenous students taking in western science ideas that conflict with their everyday ways of knowing, and rationalising the two conflicting perspectives simultaneously in their long term memory. For example, students learn that reflection of light by droplets of water causes rainbows. Rainbows signify a python crossing a river or the death of an important man in some African cultures. This can produce three models of collateral learning: parallel collateral learning, dependent collateral learning and secured collateral learning. Parallel collateral learning involves keeping the two kinds of knowledge separate; dependent collateral learning involves a mixed product of the two kinds of knowledge; and secured collateral learning involves a reflection on similarities and purpose of the two kinds of knowledge (Aikenhead & Jegede, 1999). Collateral learning has helped some African students, including me, to negotiate between their everyday worldview and school science worldview. This avenue of learning flags pedagogical content knowledge by generating information about the African environment to explain natural phenomena, identifying and using Indigenous scientific and technological principles, theories and concepts within African society, and teaching African humane feelings.

Aikenhead (2006) identifies examples of research at classroom levels that prescribe a generic, socio-cultural guideline to develop classroom protocols, and teaching and learning strategies that take into account Indigenous students' cultural resources that they have acquired from their different socio-cultural trajectories.
(1). A unit that formalises a branch of biology and ecological science in Canada that has become known as traditional ecological knowledge (TEK) using traditional knowledge and wisdom of long resident and oral peoples, and providing a general framework for producing a TEK unit in cross-cultural science learning (Snively & Corsiglia, 2001).

(2). A unit that integrates Indigenous knowledge, ways of knowing and worldviews into educational systems in rural Alaska. The Alaska Federation of Natives and the National Science Foundation worked together to integrate native ways of knowing and teaching, to adapt culturally aligned curricula, and to develop an Indigenous science knowledge base and village science applications (Kawagley, 2000).

(3). A more modest action research project in Canada: Rekindling Traditions, a community involvement to decide what is worth learning in school science, to encourage elders and other knowledgeable people to teach local content to students and their teachers, and to model six Rekindling Traditions units that other teachers can print from their CD or Web-site (Aikenhead, 2000a).

These research projects flag pedagogical content knowledge and have helped me to develop a socio-cultural framework to mobilise Indigenous middle school students' cultural resources for the project of learning classroom science.

In Australia, the *Primary Connections* Indigenous perspective (2006) project highlights six key concept areas: diversity, relationship and partnerships, students' worldview, the teacher's worldview, pedagogy and curriculum, but does not give pedagogical content knowledge and specific guidance on how a classroom practitioner can incorporate these six key concepts. The *Primary Connections* project promotes teachers' awareness of cultural diversity and cultural understanding, emphasising that Australia's population and Indigenous population is diverse, which means that a multiplicity of perspectives is the reality of classroom diversity in Australian schools. The *Primary Connections* project calls for genuine relationship and partnership based on cross-cultural and mutual respect between teachers, students, parents, schools and communities and draws on them as opportunities that improve the educational outcomes of Indigenous students. Students' and teachers' worldviews (frameworks of ideas and beliefs through which an individual interprets the world and interacts in it) are suggested as important because learning is culturally based. The *Primary Connections* project uses a constructivist approach, and gives a list of websites teachers should select for resources. The *Primary Connections* emphasises that curriculum documents should outline content and outcomes for students, and that it is the teachers who must develop learning experiences that cater to the diversity of their students.

I am of the opinion that the *Primary Connections* Indigenous perspective approach sidelines the real learning concerns of negotiation of the language and culture of Indigenous students in science classrooms. The *Primary Connections* project does not show how English as a Second Language awareness and indigenous languages can be made to permeate right through the Key Learning Areas (see McTaggart & Curro, 2009). Moreover, this project is silent on pedagogical content knowledge and Indigenous students' conceptual engagement and negotiation of meaning. The project leaves the classroom teacher to do the hard yards. Tytler (2007) suggests that it is silent concerning the pathways by which the learning occurs. I take knowledge of pathways by which learning occurs as suggested by Tytler as pedagogical content knowledge: transforming of subject matter knowledge so that it can be used effectively and flexibly in the communication process between teachers and learners during classroom practice (Van Driel, Verloop & de Vos, 1998). The *Primary Connections* project can develop detailed materials for classroom use that elaborate how Indigenous students can use their cultural resources when learning science. Bull (2008) in a small study in Western Australian schools has reported some success teaching the 'Plants in action, Incorporating Indigenous perspectives, Stage 2' unit. The Stage 2 unit is designed for students in grade 3 or 4. Bull's study enrolled grades 1 to 7 students (fifty Indigenous students and one hundred and eighty non-Indigenous students) in urban, rural and semi-remote schools. However, the study does not explore the central issue in my research project, how the group of Indigenous students who had limited facility with English negotiated learning science in Standard Australian English.

3.6 What year 9 indigenous Torres Strait Islander students bring to the classroom

This research study involved only Torres Strait Islander students for reasons explained in Chapter Four. The concept of their cultural resources is central to this study. I will describe the accessible cultural resources that they bring to the science classroom – the most significant being that Torres Strait Islander people identify themselves as a sea people, and Torres Strait Creole is their common language capital - and argue why my science classroom is a cultural field, able to be researched using a socio-cultural analytical lens.

Torres Strait Islander people identify themselves as a sea people and the movement of the seas and the winds order their lives. Traditional activities are determined by two different seasons - the dry time of southwest winds from April to August and the rainy time of the northwest winds from December to March, though these seasons are shifting now with climate change, the winds still determine the sailing, fishing and gardening seasons as they have for millennia (Sharp, 1993). The original languages spoken in the Torres Strait Islands are Kalaw Lagaw Ya, a related dialect Kalaw Kalaw Ya and Meriam (Shnukal 1988). The sophistication of island and mainland Australian Indigenous languages has long been underestimated. As Malcolm (1998, p. 119) remarks Australian Indigenous languages, “far from being limited or primitive [are] extremely complex and highly sensitive communication resources, alongside of which, in some respects, languages such as English appear to be quite blunt instruments”. During the 19th and 20th centuries, the arrival of other groups to the Torres Strait Islands including South Sea Islanders, Japanese, Malay and European settlers created a Pidgin English from which grew a Creole language, known as Broken, Pizin, Blaikman or Torres Strait Creole (Tripcony 2000, Sharp, 1993, Shnukal 1988).

Pidgin and Creole are considered contact languages; they arise in areas where people of different languages have to interact and verbally communicate. There are many social and historical reasons for the formulation and evolution of these languages. Holmes (2000) describes a pidgin as a “reduced language” that results from extended contact between people with no languages in common. A pidgin is no one’s native tongue. A Creole, by contrast, is an established complex language of relatively recent appearance, usually with pidgin origins and “used by an entire speech community” (Holmes, 2000, p.6). As Shnukal (1988, p. 4) explains Creoles, “are no different from any other normal languages in terms of the complexity of their sound and grammatical systems and the richness of their vocabulary. They are true languages in that they are capable of expressing their speaker’s need for self-expression and communication”. Torres Strait Creole emerged in the latter half of the 20th century and is a true language and not a pidgin (Crowley and Rigsby 1979, Tripcony 2000). Crowley and Rigsby (1979) documented the Cape York and Torres Strait Island area as “linguistically complex”. Torres Strait Islander students arrive at boarding school with Torres Strait Creole (in both its formal and informal varieties) as their common language capital and with English - or with versions Tripcony (2000) called “englishes” – as a second, third or fourth language.

Superficially it may appear that Torres Strait Creole and English/es are similar in that they share a similar vocabulary. However, the sounds of Creole are very different, and Torres Strait Creole bears very little cultural resemblance to English in that it does not carry meanings associated with western ways of thinking (Crowley and Rigsby 1979, Shnukal 1988).

> Broken [Torres Strait Creole] has borrowed about 85% of its vocabulary from English although the borrowed words have changed in the process. On a deeper level, however, both the systems of meanings and the way the language is used resemble the traditional languages of the Torres Strait much more than English. It is far easier to translate from a traditional language into Broken and vice versa than into English. Speakers of any island language (including Broken) always remark on how uncomfortable they feel when using English, how ‘frozen’ they find it, even when they speak it extremely well. They find it difficult to express themselves fully. This is because, as a product and shaper of European culture, English is alien to much of Islander thinking. (Shnukal 1988, p. 4)

Research conducted for the Queensland Indigenous Education Consultative Body (QIEC 2002) identified that very few Indigenous students from remote communities, including those from the Torres Strait, spoke English as a first language. These findings were confirmed in a socio-linguistic analysis of Indigenous students from sixteen North Queensland boarding schools, including the College where this study took place (Catholic Diocese of Townsville, 2003). The Aboriginal and Torres Strait Islander students who boarded at each of the sixteen schools were grouped into four categories that describe the language capital they brought to boarding school: Group 1: A student’s first language is a traditional language or dialect, the second language is Aboriginal English (AE) or Torres Strait Creole (TSC) and Standard Australian English (SAE) is, for all intents and purposes, a foreign language; Group 2: SAE (or a version) is a second or third language and the student’s first language is either AE or TSC; Group 3: SAE (or a version) is a second dialect and AE or TSC is the first dialect; Group 4: SAE (or a version) is a first language. Few Indigenous student boarders from remote Aboriginal communities on Cape York or from the Torres Strait Islands have English as their primary language capital. When they arrive at boarding school they are taught and assessed in Standard Australian English though they originally learned to construct concepts in Aboriginal and or Torres Strait Islander languages.

Most Torres Strait Islander students are multilingual. They speak their traditional languages, Torres Strait Creole and an English language. Torres Strait Islander people also have an elaborate sign language that may either replace or be used in addition to verbal communication (Sharp, 1993). Bourdieu (1984) suggests that language cannot be understood in isolation from its cultural context and the social conditions of its production and reception. Standard Australian English is a derivative of a dialect from the south-eastern part of the United Kingdom. The fact that this dialect derivative became the language of formal instruction and assessment in 21st century Australian schools, in a continent with about 600 original languages from 250 language groups at the time of British settlement in 1788, is a matter of power and politics (Tripcony 2000). Bourdieu argues that any ‘standard language’ is only one of many versions, socially highly specific and “generally bound up with a history of state formation” (Jenkins 2002, p. 153).

Winford (2003) writes that it is “problematic” to come to school with any kind of Creole as your thinking and learning language. There is a persistent “linguistic prejudice” against Creole languages in many parts of the world, based on the fact that they are new or recent languages and are the products of colonisation. The lower status of Creole languages is an ideological position, and, “like other ideologies based on race, class or similar differences, language ideology helps to promote the interests of a dominant group or class at the expense of less powerful groups” (Winford 2003, p. 32). To be Indigenous in this case is to both belong to a country that became the nation state of Australia, and to also belong to a severely disadvantaged group of peoples. Any state policy that advocated for officially teaching Indigenous children in their first or second languages has been contested, though many primary schools practise forms of bilingual education in remote areas at the classroom level. McTaggart and Curro (2009) highlight that in Queensland, for example, bilingual schooling was tried in the 1980s at Aurukun and Hopevale, but soon lapsed. The only way for Indigenous students to be seen is to assimilate dominant ways, English speaking images (Taylor, 2005).

English is the language of power in this nation and Indigenous children and migrant children are expected to gain mastery of English in order to gain access to powerfully hegemonic ways knowing. Cleote (2010) writes that being at ease with the English language in terms of structure, vocabulary and conceptualisation and, on certain occasions, accent, increases ones' social and economic capital and expands access to the very significant resources available in that language. In Australian curriculum documents, Standard Australian English is positioned as neutral even with indigenous students from rural and remote areas. Taylor (2005) argues that Indigenous students are recognised only in partial images, as in need of fixing up to fit the dominant ways of being successful literates, and this can only be possible in English. Torres Strait Islander middle school students learning science must accommodate and negotiate differentiated traditional knowledge systems, a number of languages, school science taught in English, and their own emerging youth cultures and dialects. Home language and Creole thinking students learning a western science curriculum must be outstanding field negotiators in order to be positioned as successful learners within formal education systems. In reality, only a small percentage of students are so adept, and Indigenous students who do succeed in these fiendishly difficult and complex negotiations are rarely fully appreciated for how skilled they are (Chigeza & Whitehouse, 2010).

Martin (2008) notes that while there has been extinction of the majority of original Indigenous languages since European settlement – the number has dropped from about 250 to between 50 and 60 – the remaining languages have survived as the first languages of communication within Indigenous communities. Torres Strait Islander students arrive at school speaking at least one home language and a Creole. If they do have command of Standard Australian English, it is usually as a second or third language. Linguistic standardisation in science teaching and assessment is common throughout the world, but in the Queensland Studies Authority mandated science curriculum, Standard Australian English is positioned as neutral. Standard Australian English is not a neutral language for Indigenous learners of science from rural and remote areas of the country. A socio-cultural approach can illuminate these differentiated fields of knowledge (and languages), explore porous boundaries and the differing social rules, procedures, values, beliefs and resources that inform these fields of knowledge and languages (Tobin, 2005). Torres Strait Islander middle school students' differentiated languages and fields of knowledge can then be positioned as enabling and not limiting their classroom learning.

Synott and Whatman (1998) write that Torres Strait Islander cultures have traditionally been oral cultures, where storytelling, song and dance were the main media of cultural information and transmission. As a consequence, the literature on Torres Strait Islander culture has been dominated by the writings of anthropologists, such as A. C. Haddon, who lead the "Cambridge Expedition" to the Torres Strait in 1898. Traditionally, Torres Strait Islander people have regarded the world as a sacred place, of which people are an integral part. They maintain a distinctive belief system and spiritual understanding of their connection to the water, reefs and land of their island homes. Their cultures and knowledge systems have developed around the spiritual links to the land, the central place of extended families and social organisation and the importance of economic activity from the sea. They have used various technologies to assist with gathering and processing food. Fishing is one example. Fish traps were used on coastal lagoons, along with construction of stone walls, which trapped fish when tides receded, and the use of fish poison from roots of a particular tree. I argue here that when Torres Strait Islander middle school students come to school, they would have used and acquired these forms of knowledge capital, the discourses and activities inherent in their communities.

There are features in Indigenous people's lifestyles in the communities that enhance scientific understanding. For example, children watching and learning from experience as they go hunting, fishing and collecting food and medicines with their elders. The children learn to improve their listening and observational skills. The Australian Bureau of Meteorology *Indigenous Weather Knowledge* website: (http://www.bom.gov.au/iwk/) is an example of Indigenous people's systematic observations over many years, and how these observations have contributed to current scientific understanding. This knowledge and understanding of the world is contextual and relevant to the needs, concerns and personal experiences of traditional indigenous communities. Science teachers should allow Indigenous students to add these experiences and languages from their communities to classroom discussion to facilitate a two-way exchange of language, knowledge and cultural understanding. In this study, I explore a learning protocol with pedagogical content knowledge that promotes a dialectical relationship between Indigenous knowledge systems and classroom science knowledge.

Indigenous people's knowledge systems have been identified as having scientific perspectives. Cultural anthropologists (Brindon, 1988) identified Indigenous knowledge that resembles scientific ways of understanding which includes: use of plant, animal and mineral material to treat or relieve ailments; removing poisons from bush foods; knowledge of vegetation management by fire to maximise food; knowledge of environment and animal migration patterns; knowledge of navigation and sea currents, knowledge of local fauna and flora and use of indigenous tools and weapons. I suggest here that these knowledge systems should and can be added to science classroom discussions.

The concepts of force, which is defined as a push or pull with magnitude and direction, and energy, which is defined as the capacity to do work (QSA, 2004), are not new to Aboriginal and Torres Strait Islander groups in North Queensland. These indigenous groups have used these physical phenomena to manage aspects of their lives (Sharp, 1993). The Queensland Studies Authority science curriculum document includes the study of historical and cultural factors that influence the nature and direction of science as one of its learning outcomes in its scientific process strand. Students are encouraged to realise how science is developed within the constraints of their cultures as well as how science is influenced by social, political and economic factors. What should concern science classroom teachers is how not to demean any form of cultural understanding of Indigenous students, but how to use it to enrich scientific literacy. As a science classroom teacher for Indigenous students for the past twenty years, I realise that both perspectives can be valid for the Indigenous students; hence the need to look at them in a dialectical relationship. Mueller and Tippins (2009) make the case for considering dialectical relationships between science and traditional ecological knowledge in order to ensure cultural diversity in science education.

The 1995 Review of Education for Aboriginal and Torres Strait Islander people calls for Torres Strait Islander people's involvement in all aspects of their children's education. These include socio-cultural and linguistic aspects that influence the students' approaches to learning. The socio-cultural and linguistic aspects can be recognised in school organisations, teaching approaches and assessment. The review calls for Torres Strait Islander people's culture, knowledge systems and values to be given recognition and respect throughout school and university curricula.

However, Indigenous students are expected to learn the disciplines of western science knowledge systems which inhabit Australian school science curriculum which is formulated, taught and assessed in Standard Australian English, the students' second, third or even fourth language. Synott and Whatman (1998) observe that Torres Strait Islander students experience cultural shock from misalignment of their home discourse and the new discourse they encounter in schools. Frigo and colleagues (2003) suggest that the education system fails Aboriginal and Torres Strait Islander students because of mixed acknowledgement of the knowledge(s) and dialects of Aboriginal English and Torres Strait Creole within and across schools. This raises concern over whether Torres Strait Islander students are getting good teaching.

3.7 How I conceptualise my classroom practice

As an educator, I struggle with educational approaches that work from the assumption that Torres Strait Islander students come to the classroom with cultural "deficiencies" and "lack" necessary knowledge, social skills, abilities and cultural capital. Taylor (2005) writes that the place of Indigenous students as English Second Language students is built on historically derived social constructions of deficit and disadvantage that are replicated through policy implementation processes. These traditional approaches can be replaced by those that are capacity building. Yunkaporta and McGinty (2009) advise educators to set aside deficit models, and to embrace sophisticated Indigenous ways of knowing that enhance capacity-building. A capacity building perspective shifts approaches to education from a deficit model to one of building existing capacity, where arrays of cultural knowledge, skills, abilities and contacts possessed by socially marginalised groups are recognised and acknowledged. Mr Ernie Grant advocates creating "the total picture" that encompasses Land, Language and Culture by contextualising Time, Place and Relationships. A capacity building approach to science education acknowledges the multiple strengths that Indigenous students bring to science classrooms and serves the larger purpose of greater social and racial justice (Chigeza & Whitehouse, 2010).

It must be remembered that English is a “colonial language” whose “potency as an authoritative and hegemonic discourse of the post colony cannot be underestimated” (Cleote, 2010, p. 1), and that from an educational perspective, students often “engage only with the naturalised meaning systems available in English”, which cannot include alternative “cultural histories and Indigenous knowledge systems’ (Cleote, 2010, p. 2). If English as a discourse is taken up in the Foucauldian sense as a “field of thought” then I can argue, in trying to understand how Indigenous students engage with formal science curriculum, that I can employ a socio-cultural research lens to illuminate participation and representations of these students in the culturally organised practice of science education. Hubber and colleagues (2008) write that scientific ideas cannot be separated from their representations. These representations and literacies are building blocks for thinking and working scientifically, as well as necessary components for representing science understandings.

Indigenous students’ cultural resources inform how they make primary sense of their world (see Gee, 2005), and ontological differences between Indigenous and western cultures are embodied in their respective languages (see Harris, 1990). I argue for socio-cultural learning models, where the pedagogical content knowledge is framed by Indigenous structures to address the dilemma of Indigenous students learning school science. Harris (1990) acknowledges that similarities between Indigenous and Western cultural traits cannot exist after substantial comparison. The cultures tend to be antithetical (Chigeza, 2007), consisting of more opposites than similarities (Michie, 2002). McKinley (2005), exploring the bilingual network of Maori schools in Aotearoa, writes that the difference in epistemology, ontology, and axiology between both knowledge systems is so discordant that a simple transformation from one system to another is often not feasible. A socio-cultural model can value Indigenous structures to an equal extent with western structures, and can look at Western structures and Indigenous structures in a dialectical relationship (see Mueller & Tippins, 2009), since Indigenous structures shape cultural resources of the Indigenous students, and Western structures shape classroom science curriculum. I investigate in this research whether an educational program that takes Indigenous students' agency in dialectical relation with the structure of mandated Queensland Studies Authority science curriculum can resolve any of the dilemmas with formal science education.

Chinn, Hand and Yore (2008) suggest that it is important to attribute human agency rooted in historical, social and philosophical positions to inform on ontology and epistemology positions in science classrooms. My classroom experiences with Indigenous students are dynamic and interactive socio-cultural environments. These learning environments are shaped by the agency of Indigenous students as they interact with each other, me, the science curriculum and material resources in ways that afford their agency while constraining what they can accomplish (see Tobin, 2005). I recognise that Indigenous students are active knowing beings. This has persuaded me to facilitate a more democratic and autonomous educational structure which reflects the students' agency acting in concerned, responsible and creative ways.

A student's agency constructs their science world and is in turn conditioned by it, conditioned by not only the constraints of that world, but also by the enabling power inherent in it (Webb, Schirato & Danaher, 2002). Indigenous students use their agency to interact with classroom science organisational structures in a dialectical relationship, as they produce and reproduce science. I take the agency - structure dialectical relationship as my practical and theoretical standpoint.

3.8 Summary

In this chapter, I have discussed how science awareness is important in Australia and underachievement on benchmarked science assessment by Indigenous students. I have argued why year 9 science classrooms can be considered as a cultural field able to be researched using a socio-cultural analytical lens. The ideas were taken further to explore Indigenous knowledge and Western science knowledge, and how it aligns with my socio-cultural analytic lens. In the section on cultural resources Torres

Strait Islander students bring to the science classroom, the accessible cultural resources were examined and how they align with science discourses and science activities explored. An argument emerged that Indigenous students use their cultural resources to interact with classroom science organisational structures in a dialectical relationship, as they produce and reproduce science. I then adopted this dialectical relationship as my practical and theoretical standpoint. The next chapter explores how I used this agency - structure dialectical relationship as my practical and theoretical standpoint.

Chapter 4

Methodology for theoretical and classroom research

4.1 Introduction

In this chapter, I discuss my socio-cultural standpoint, research approach, study participants, methods, data collection cycles, reflections and explanation of research decisions. My dialectical standpoint aligns with Kemmis and McTaggart's (2000) classroom action research and McNiff & Whitehead's (2006) "lived experience" model of action research. I elaborate on why my classroom practice with a group of Torres Strait Islander students is reflexive to be studied dialectically. I describe the study participants: forty four Torres Strait Islander middle school student boarders (twenty three girls and twenty one boys), five Torres Strait Islander assistant teachers and a Torres Strait Islander elder. I discuss my research methodology, design and why I chose to research year 9 students learning physical science concepts of energy and force. I then discuss my rationale for adopting an ethical protocol that paralleled the research stages and why my classroom action research is value-laden.

In the second part of the chapter, I describe the data collection cycles. The first cycle took place during the first semester of 2007, with forty nine students. Three students transferred during the semester. The second cycle took place during second semester 2007, with forty six students. Two students transferred during the semester. The third cycle took place during the first semester of 2008, with forty four students. The five assistant teachers participated in the second and third cycles of data collection. In this section, I also discuss my reflection of the data collection cycles.

4.2 My standpoint as an action researcher

I came into this study as a teacher researching my classroom as a cultural field. My cultural experiences, accumulated in the trajectory of my life, consciously and unconsciously have influenced the shape this study has taken, have influenced my choice of research topic, methodology, data collection methods, data analysis methods and reporting of the study outcomes (see Denzin & Lincoln, 2003b). Any form of research objectivity I have attempted to bring to this study is guided, again consciously or unconsciously by my cultural experiences. I realise that no practical or theoretical framework provides a perfect explanations of what is being studied (Anfara & Mertz, 2006). In defining my practical and theoretical standpoint, I am cognizant that my standpoint allows me to 'see' and understand certain aspects of my practice: exploring dimensions of pedagogical content knowledge and how a group of Torres Strait Islander students can use their cultural resources to engage with the science curriculum.

I adopted Bourdieu's notions of habitus, cultural capital and cultural field in order to make an epistemological break with the prominent objective-subjective binary of much science education research. It is important to realise that Bourdieu's concepts of habitus, cultural capital and cultural fields are proposed as flexible, and to be examined in empirical setting (Jenkins, 2002). In Chapter Two I expanded the notion of cultural capital to incorporate Indigenous students' community cultural wealth (from Yosso, 2005). As participants in a science classroom cultural field, my students and I and our collective capitals constitute the field under study. Habitus manifests the structures of the field, and the field mediates between habitus and practice (Jenkins, 2002). The epistemological approach I argue for in this thesis considers (westernised) school science knowledge in dialectical relationship with Torres Strait Islander students' cultural knowledge systems, in a science classroom where the students engage with formalised science learning. I adopted this agency – structure, dialectical, practical and theoretical standpoint to investigate how a group of Torres Strait Islander middle school students were socialised into understanding school science curriculum, as a means for exploring their learning of physical science concepts.

My agency - structure dialectical standpoint aligns with Kemmis and McTaggart's (2000) epistemological position on the nature of truth about practice in the human and social sciences as well as McNiff and Whitehead's (2006) model of "lived experience". Kemmis and McTaggart (2005) perceive practice as reflexive and to be studied dialectically. Being reflexive meant I had to conduct research with conscious attention to the effects of my position, my set of internalised structures, and how these were likely to distort or prejudice my objectivity (see Denzin & Lincoln, 2003b). Dialectical meant I had to explore opposed and often contradictory, but mutually necessary aspects of human, social, and historical reality, in which each aspect helps to constitute the other (Kemmis & McTaggart, 2000). I have also consciously explored my own journey as a science educator and field negotiator in this thesis.

McNiff and Whitehead's (2006) model of "lived experience" suggest that participatory action research seeks to improve workplace practices through improving learning, promoting the ongoing democratic evaluation of learning and practice, and creating good social order by influencing the education of social formations. McNiff and Whitehead's model of participatory action research is: (1) value laden: it is research done by people who are trying to live in the direction of their values and commitments that inspire their lives, (2) morally committed: action researchers choose values to subscribe to and show how they hold themselves accountable for their choices, and (3) the action researchers perceive themselves as in relation with one another and everything else in their social context.

How formally derived Queensland Studies Authority science curriculum enabled or limited the agency of Torres Strait Islander students in my science class is what I wanted to understand. I did not wish to reduce my study to mere statistics, the general, the abstract or the ideal. By adopting a reflexive dialectical perspective, I am able to also investigate my practice from the perspective of the insider with other group members (Torres Strait Islander middle school students, and in the second and third research cycles, five Torres Strait Islander assistant teachers in my school) as we interconnected and constituted our school social life. By adopting a reflexive dialectical approach, I was placed at the centre of my enquiry and I have accepted this responsibility of showing how I accounted for myself and others in the study.

> Action research is ideally informed by critical social theory but my contention is that such theory must become constitutive of the persons acting in setting … and revive those of democratic dialogue and reflective theorising which, under the impact of positivism have been increasingly rendered marginal. .. Action research can be coopted as an instrument of teacher evaluation and curriculum innovation (Klein, 1994, p. 3).

Traditional theory perceives as two separate activities, the work of a researcher and that of a classroom teacher (Carr & Kemmis, 1986). Distanced or external researchers produce theory and insights that classroom teachers may apply to their practice. For twenty years, I have been invited to quiet offices by school administrators and distanced researchers and given advice on how to improve my science classroom practice with different groups of Indigenous students from southern Africa and North Queensland. Every time I left these quiet offices, I could not help but reflect how far an office was from my science classroom and how far removed the advice I had been given was from the lived realities of what happens in my science classes with Indigenous students.

In this research work, I challenge such a divide in favour of self-reflective research, where I am placed at the centre of the inquiry, which means that this work differs from traditional approaches on epistemological assumptions, methodological assumptions, ontological assumptions and the social purpose of the research (McNiff & Whitehead, 2006). My study is an attempt to step out of the impasse of the structure/agency divide in science education research.

My study concerns my educational practice with a group of Torres Strait Islander students. I also invited five Torres Strait Islander assistant teachers to participate in the second and third cycles of data collections. Keys (2008) writes that teacher aides were found to influence classroom activities and Indigenous students do rely on the teacher aides to assist their learning. I consider Torres Strait Islander students and Torres Strait Islander assistant teachers as equal participants with me in the research process. I realised that each one of us brought different expertise and experiences to the study. I collaborated with a group of Torres Strait Islander students who I recognised as bringing different expertise, experience and agency to the study. For example, I realised that some students had more knowledge about the wind names, wind movements and sea currents from their respective islands and communities than other assistant teachers who came from different islands or communities. Because I adopted a socio-cultural approach, which implied the importance of learning from others, I realised that each one of us, including each Torres Strait Islander student, was an active agent in co-constructing classroom knowledge and practice. Kemmis and McTaggart (2000) suggest that action research is a collaborative process but achieved through the critically examined action of individual group members, as do McNiff and Whitehead (2006), who write:

> Action research is a form of research that enables practitioners to learn how they can improve practice, individually and collectively. The focus is on the 'I' in company with other 'I's (p. 256).

While the Aboriginal students were part of the classroom activities as part of their school study program, data for this study was not collected from them because most of them were not boarding in the school. I explain this further in section 4.4. My research focus was on students who were guaranteed sustained attendance and likely completion of participation in the research cycles. The study did not analyse cultures, but focused on pedagogical content knowledge as to how a specific group interacted with the negotiation or "border crossing" into school science. Nakata (2002) acknowledges that there is a difference between Aboriginal and Torres Strait Islander people, and diversity within each group. Torres Strait Islander middle school students who participated in the study responded positively to the invitation, their parents or guardians agreed to their participation, and they willingly attempted and/or completed the pedagogical research activities.

4.3 Study participants

As cultural disposition and habitus are central to my study, there is need to also highlight the study participants' cultural background. The study participants were forty four Torres Strait Islander middle school student boarders (twenty three girls and twenty one boys), five Torres Strait Islander assistant teachers, a Torres Strait Islander elder and me. For confidentiality purpose the twenty three girls who participated are referred as Girl 1, Girl 2, and the islands are referred as Island A, Island B, etc so that they can not be identified, as I promised them from the ethics protocol I followed. All students were boarders at the school. These descriptions are of the students who participated in the research cycles in 2007 and 2008.

Girl 1 (G1) is fourteen years old. She comes from Island A where she attended primary school. Her parents and three siblings live there.
Girl 2 (G2) is fourteen years old. She lives with her uncle, aunt and four cousins on Island A where she attended primary school.

Girl 3 (G3) is fifteen years old and uses English with facility. She originally comes from Island B but has lived in Cairns with her aunt for six years. She completed part of her primary school there.

Girl 4 (G4) is fourteen years old and uses English with facility. She is originally from Island C but has been living on mainland Australia for most of her life.

Girl 5 (G5) is fourteen years old. She comes from Island B where she attended primary school. Her parents and five siblings live there.

Girl 6 (G6) is fifteen years old. She comes from Island D where she attended primary school. Her parents and three siblings live there.

Girl 7 (G7) is fifteen years old. She is originally from Island D but has lived in a number of places on mainland Australia. She uses English with facility.

Girl 8 (G8) is fifteen years old. She is originally from Island C but has lived on mainland Australia for many years. She uses English with facility.

Girl 9 (G9) is fifteen years old. She is originally from Island E but has lived on mainland Australia with her family for nine years. She uses English with facility.

Girl 10 (G10) is fourteen years old. She is from Island F where she attended primary school. Her parents and four siblings live there.

Girl 11 (G11) is fifteen years old. She is from Island I where she attended primary school. She lives with her grandparents there.

Girl 12 (G12) is fifteen years old. She is from Island I where she attended primary school. Her parents and four siblings live there.

Girl 13 (G13) is fifteen years old. She is from Island D where she attended primary school. Her parents and five siblings live there.

Girl 14 (G14) is fifteen years old. She is from Island I where she attended primary school. Her parents and four siblings live there.

Girl 15 (G15) is fifteen years old. She is from Island A where she attended primary school. She lives with her grandmother there.

Girl 16 (G16) is fourteen years old and comes from Island B where she attended primary school. Her parents and siblings live there.

Girl 17 (G17) is fourteen years old and comes from Island C where she attended primary school. She lives with her grandparents there.

Girl 18 (G18) is fifteen years old and comes from Island B where she lives with her grand parents. She attended primary school there.

Girl 19 (G19) is fourteen years old. She lives with her uncle, her aunt and seven cousins on Island C where she attended primary school.
Girl 20 (G20) is fifteen years old. She comes from Island J where she lives with her grandparents and four siblings.
Girl 21 (G21) is fifteen years old. She comes from Island E where she attended primary school. She lives with her grandparents there.
Girl 22 (G22) is fifteen years old. She comes from Island F where she lives with her uncle and aunty. She attended primary school there.
Girl 23 (G23) is fifteen years old. She comes from Island J where she attended primary school. She lives with her grandparents there.

These are the twenty one Torres Strait Islander middle school boys who participated in the study in 2007 and 2008.
Boy 1 (B1) is fourteen years old. He comes from Island B where he attended primary school. His parents and three siblings live there.
Boy 2 (B2) is fourteen years old. He comes from Island B where he attended primary school. He is the eldest in a family of eight.
Boy 3 (B3) is fifteen years old. He lives with his grandparents on Island C. He attended primary school there.
Boy 4 (B3) is fifteen years old. He lives with his uncle and aunty on Island F. He attended primary school there.
Boy 5 (B5) is fourteen years old. He comes from Island D and has five siblings. He attended primary school there.
Boy 6 (B6) is fifteen years old. He comes from Island B where he attended primary school. He has two brothers in the school.
Boy 7 (B7) is fifteen years old. He lives with his grandparents on Island I where he attended primary school.
Boy 8 (B8) is fourteen years old. He comes from Island B where he attended primary school. He has two sisters in the school.
Boy 9 (B9) is fifteen years old. He lives on Island F with his uncle where he attended primary school.
Boy 10 (B10) is fourteen years old. He is a first cousin to B9 and attended primary school on Island F. He lives with B9’s family.

Boy 11 (B11) is fifteen years old. He comes from Island D and has a brother and sister in the school. He attended primary school on Island D.
Boy 12 (B12) is fifteen years old. He comes from Island B where he attended primary school. His parents and five siblings live there.
Boy 13 (B13) is fifteen years old. He comes from Island B where he attended primary school. His parents and four siblings live there.
Boy 14 (B14) is fifteen years old. He comes from Island B where he attended primary school. He lives with his grandmother there.
Boy 15 (B15) is fifteen years old. He comes from Island B where he attended primary school.
Boy 16 (B16) is fourteen years old. He lives with his grandparents in Island A where he attended primary school.
Boy 17 (B17) is fifteen years old. He comes from Island A.
Boy 18 (B18) is fifteen years old. He is from Island C where he attended primary school. He lives with his uncle, his aunt and seven cousins.
Boy 19 (B19) is fifteen years old. He comes from Island F where he attended primary school. His mother and two siblings live there.
Boy 20 (B20) is fifteen years old. He comes from Island B where he attended primary school. He lives with his aunt and four cousins there.
Boy 21 (B21) is fourteen years old. He comes from Island F where he attended primary school. His parents and five siblings live there.

These are five Torres Strait Islander assistant teachers and a Torres Strait Islander elder who participated in the study.
Torres Strait Islander assistant teacher 1 (T1) is a twenty-six-year old male who comes from Island C, and works in the sports department at the school.
Torres Strait Islander assistant teacher 2 (T2) is a thirty-two-year old male who comes from Island K, and works in the sports department at the school.
Torres Strait Islander assistant teacher 3 (T3) is a thirty-seven-year old female who comes from Island I, and works in the hospitality department of the school.
Torres Strait Islander assistant teacher 4 (T4) is a twenty-eight-year old female and comes from Island F, and works in the primary school.
Torres Strait Islander assistant teacher 5 (T5) is fifty-two-year old male who comes from Island C, and works in the primary school.

The Torres Strait Islander elder (T6) is a fifty-five-year old male who comes from Island C, is the cultural advisor and traditional dance instructor in the school and took the role of 'gatekeeper' in the project. As explained in section 4.5, the 'gatekeeper' explained the research project to parents, guardians and students, and also acted in *loco parentis* to enhance the care of student participants in the research.

4.4 Research approach

The research required a multiplicity of approaches to accommodate all aspects of the research. My research approach then was richly informed by socio-cultural theory and conducted within an action research paradigm, in particular within McNiff and Whitehead's (2006) lived educational theory approach and Kemmis and McTaggart's (2000) classroom action research. McNiff and Whitehead's lived educational theory approach suggest that participatory action research seeks to improve practices through improving learning and promoting the ongoing democratic evaluation of learning and practice.

For Kemmis and McTaggart (2005) a reflexive-dialectical approach views practice as socially and historically constituted by human agency and social action. My educational research practice can be considered as reflexive-dialectical because it:

- engages a group of Torres Strait Islander middle school students, five Torres Strait Islander assistant teachers and me in a collaborative social process of science education research.
- is emancipatory. The group of students, the assistant teachers and I attempt to remake and improve the learning of science in the classroom to attempt to overcome inherent distortions, incoherencies, contradictions and injustices.
- transforms the learning of science by the students and my understanding of the learning and the situations in which the learning of science occurs.
- aims to be a process where aspects of the learning of science by the students can be transformed through collaborative action, with the aim of improving science learning and understanding science pedagogical knowledge.

- aims to make explicit connections across the dimensions of objective and subjective. I focus on the individual and social, on structure (as the science field) and agency of the students.
- helps us understand ourselves as people; we act in ways framed by discourses formed beyond any one of us individually, and as people we make meaning for ourselves in communication with the others alongside whom we stand, and whose fates, one way or another, we share.

The notion of self-reflexive study that I adopted aligns with the educational theory proposed by Carr and Kemmis (1986) who argue for educational research to reject positivist notions of rationality, objectivity and a single truth, and instead employ the interpretive capacities of teachers. Educational theory must identify and expose those aspects of existing social order which frustrate the pursuit of rational goals, and offer theoretical accounts which can make teachers aware of how these may be coherently addressed or overcome. The question of educational status is determined by the ways in which theory relates to practice. My study concerns a group of Torres Strait Islander students' participation in culturally organised practice, that is, formal science education where I, as the teacher-researcher, research conditions and the possibility for students to learn school science. The thesis narrates my learning journey to conceptualise factors affecting Torres Strait Islander students' struggle for self-definition against the dominant disciplinary formations of the school science curriculum.

> Action research in its most effective form focus on people's actual lived experience/reality, on their interpretation of acts and activities and the meaning people make of events in their lives (Stringer, 2007).

My aim is to apply critical reasoning about and to both theory and practice and their coincident consequences (McNiff & Whitehead, 2006). My research study evolved through a spiral of self-reflective cycles: planning a change; acting and observing the process and consequences; reflecting and repeating the whole process (from Kemmis & McTaggart, 1988). I argue that my research study was a social process, practical, collaborative, and possibly emancipatory as it concerned my interaction with forty four Torres Strait Islander students and five Torres Strait Islander assistant teachers to examine cultural knowledge and interpretive categories

(Kemmis & McTaggart, 2000). I sought to understand, describe and interpret the qualitatively different ways the students were able to describe and represent science concepts of energy and force through speaking, writing, drawing and direct action, with the explicit intention of conducting research for improved learning outcomes.

4.5 Research design

While all students in the researched classes were involved in the study, the data was gathered only from the forty four students identified primarily as Torres Strait Islander students, all of whom boarded at the school. I made the decision to analyse this group for a number of reasons. Firstly, because this group lived at the school, they had a sustained attendance record, and were able to participate in the full research cycles. Many Aboriginal students were day students, and consequently their attendance was not as regular as the Torres Strait Islander group. I made the decision to try to eliminate school attendance as a confounding variable in this research for the reason that school attendance is shown to strongly influence Indigenous educational attainment in Australia (see McTaggart & Curro, 2009). I wished to investigate practices other than attendance when researching with students. All year 9 students participated in the classroom learning activities; however formal data was collected only with Torres Strait Islander boarders who had their parents and guardians permissions to be in the study during the research cycles in 2007 and 2008. Secondly, the key Indigenous support teachers, whose expertise I needed to draw upon, were from the Torres Strait islands. Thirdly, I had access to print resources on Torres Strait Island language and culture, including dictionaries on two original languages spoken in the Torres Strait Islands: Kalaw Lagaw Ya (KLY) and Meriam, and dictionaries and researched work on Torres Strait Creole language of the Torres Strait (Ray, 2001; Shnukal, 1988) that helped me come to an understanding of the language complexities negotiated by participating students in the study. There are different varieties or dialects of the Creole language but all Torres Strait Creole speakers can understand one another. I assumed that the majority of Indigenous students from the Torres Strait learned to think in the Torres Strait Creole language as a first or second language (just as I learnt to think in Shona as my first language), and that they arrived at school with the Torres Strait Creole language in its varied formal and informal forms as their socio-cultural language capital.

I chose to research year 9 students learning physical science concepts of energy and force as my own teaching expertise lies in the physical sciences. My initial research questions in the study were:

- How did a group of Torres Strait Islander middle school students employ their everyday languages and formal science language when learning the concepts of energy and force?
- How did the group of Torres Strait Islander middle school students participate and communicate in science activities when learning science concepts of energy and force?
- How did the group of Torres Strait Islander middle school students apply and relate to science concepts of energy and force as described in Standard Australian English?

After completing one cycle of the classroom action research, I came up with three additional questions for the second and third cycle:

- What language and cultural resources did the group of Torres Strait Islander middle school students draw on for developing their understandings of the concepts of energy and force?
- How did the structure of science curriculum constituted by the Queensland Studies Authority *Science Years 1-10* (1999/2004), enable or limit the learning agency of the group of Torres Strait Islander students?
- What pedagogical content knowledge enabled the group of Torres Strait Islander middle school students to learn, know and (re)produce knowledge of the concepts of energy and force?

As already indicated, the concepts of energy and force were defined in the Level 4 and 5 learning outcomes of the Queensland Studies Authority, *Science: Years 1 to 10 Syllabus* (1999/2004), Energy and Change Strand.

I used qualitative instruments to capture students' socio-cultural interactions and science learning in the science classroom. Kemmis and McTaggart (2000) suggest that classroom action research typically involves the use of qualitative, interpretive modes of inquiry and data collection by teachers with a view to making judgements about how to improve their own practice. The students attempted or completed a sequence of pre-inquiry concept mapping, group brainstorming of everyday ways of knowing, group guided hands-on/minds-on inquiry into scientific ways of knowing, group construction of Venn Diagrams to compare and contrast ways of knowing, group post- inquiry concept mapping and individual student reflection. Students were encouraged to draw bubble diagrams, pictures and cartoons to represent their feelings during data collection. Hubber and colleagues (2008) argue learning involves the recognition and development of students' representational resources, and that learners use their own representational, cultural and cognitive resources to engage with subject specific, representational practices of science. I made detailed observations on the languages students employed to discuss science concepts in my research. In many instances students who identify as Torres Strait Islander abandoned English to use Torres Strait Creole to explain their understandings to one another in the group situation and I recorded such instances in my research journal. Students were very uncomfortable with audio recording, so I did not use electronic recording technology.

I used concept maps because they are both a learning and assessment tool. I used concept maps as a research tool to track down and establish the descriptions and representations of the concepts of energy and force by the students. 'Pre- inquiry' concept maps revealed students' existing descriptions, data which was used to inform learning. 'Post-inquiry' concept maps elicited changes in concept description and knowledge representation of the students after a teaching cycle. Concept maps are two-dimensional (Bennett, 2003) in that they have a graphical representation and show relationships between a hierarchy of ideas from concrete to abstract. Students were able to modify their maps at a number of points during classroom inquiry to establish how their descriptions, representations and thinking were developing. Group concept mapping was an ideal research tool for socio-cultural research because it positions students as active learners because they negotiate their descriptions, representations and understandings during small social group interaction. Brown (2003) found that students involved in group concept mapping outperform students who developed concept maps as individuals as well as those who did not create concept maps at all. A number of studies have concluded that use of concept maps in classroom situations is an ideal strategy for promoting meaningful learning (Novak, 1976; Novak & Gowin, 1996). According to Enger (1998), examining pre- and post-inquiry concept maps can trace changes in vocabulary usage and the nature of new knowledge representation, a notion I used and found very useful in data collection.

I found out that when Torres Strait Islander students progressed through pre-inquiry concept mapping, group brainstorming of everyday ways of knowing, group guided hands-on/minds-on inquiry into scientific ways of knowing, group construction of Venn Diagrams to compare and contrast ways of knowing, group post- inquiry concept mapping and individual student reflection on a topic, they showed increased levels of ability in describing and representing the concepts of energy and force. Chittlebrough, Hawkins and Treagust (2001) suggest that when students progress through brainstorming, to Venn-diagram, to concept mapping, their understanding and problem solving ability is enhanced. Brainstorming gave the students time to think, to consider others, to repeat, to improve their skills and to listen to alternative views. Venn-diagrams helped them to categorise and show patterns. As a research tool, students were asked to use Venn-diagrams to distinguish between everyday cultural ways of knowing, school science ways of knowing and where the two knowledge systems interact. Nakata (2002) calls the intersection of Western and Indigenous knowledge domains a cultural interface. The Venn-diagrams also proved popular and were advantageous because they are visual devices. The concept maps set out and reinforced concept descriptions and meaningful learning by organising ideas on paper and by inference in students' minds. Nesmith (2001) advises that only when students are challenged to express their understanding do they consider alternative views, which can lead to an acceptance of new ideas, and a deeper understand of their learning. Working in groups helped students to share, co-operate and correct each other. Yunkaporta and McGinty (2009) suggest that Indigenous students work cooperatively in Indigenous learning circles, an idea I found very useful in this socio-cultural study.

I used formative assessment as a research tool during teaching and learning experiences. Black (1993) suggests that good formative assessment can be a powerful tool for raising the student's standard of learning if it is reflected in the preparation of future work, and re-evaluated against the work already done. The two types of formative assessment I used when collecting data were planned formative assessment and interactive formative assessments. Planned formative assessment involved prepared instruments to elicit information. Interactive formative assessment occurred spontaneously when I noticed a student's behaviour. I used these forms of assessment as part of my data collection in assessing a range of work and activities attempted or completed by the students.

4.6 Data source and analysis

My research methods were designed to support the research study, and I propose are the best practicable approach to answer the study's research questions, given the constraints inherent in the research context. My reflections on the research context are expressed in Appendix N. Data collection took place during weekly science lessons. The two year 9 science classes were timetabled for two forty five minutes lessons a week. As a teacher in the school, I was required to adopt the Queensland Studies Authority, *Science: Years 1 to 10 Syllabus* (1999/2004) curriculum statements and learning outcomes, and was free to choose the teaching methods and science activities students engaged with.

On a topic in the Energy and Change Strand, I encouraged students to attempt or complete a sequence of pedagogical strategies: pre-inquiry concept mapping, group brainstorming of everyday ways of knowing, group guided hands-on/minds-on inquiry into scientific ways of knowing, group construction of Venn Diagrams to compare and contrast ways of knowing, group post-inquiry concept mapping and individual student reflection. Students used their science writing books. I also encouraged the students to draw bubble diagrams, pictures and cartoons to represent their understanding and feelings during these learning cycles. I collected data on how the students were able to describe and represent science concepts of energy and force through speaking, writing, drawing and direct action, during the learning and research cycles.

The first learning and research cycle took place during the first semester of 2007, with forty nine students. Three students transferred during the semester. The second cycle took place during second semester 2007, with forty six students. Two students transferred during the semester. The third cycle took place during the first semester of 2008, with forty four students. The five assistant teachers participated in the second and third cycles of data collection.

In the first and second cycles of data collection, students referred to incidents and experiences that occurred elsewhere, for example, in their communities and islands. These experiences were taken to be relevant to the study because I was focused on mobilising students' cultural resources: languages, experiences and knowledge they have accumulated in their lives. In the third cycle of data collection, the sports field and hospitality, outdoor, cooking area formed part of the research locations as some of the science classes took place in those areas. Whitehouse (2007) suggests that taking students outside classrooms expands possibilities for exploring physical and chemical science concepts in interesting and engaging ways. The sports field and hospitality constituted as main sites where students exercised their agency in the third cycle of data collection and became sources of valuable data.

The sources of data for the study were: (1) observational notes on how students were able to use science terminology and participate in learning the concepts of energy and force, which were recorded in my research journal, (2) students' written work when they attempted or completed the pedagogical activities on the concepts of energy and force in their science writing books, (3) class discussions noted during and immediately after, and recorded in my research journal (students were very uncomfortable with audio recordings), and (4) reflections from my research journal. Kvale (1996) advises that if the research concerns meaning and understanding of a group or culture, then participant observation and field studies of actual behaviour supplemented by informal interviews may give more valid information. Using the Queensland Studies Authority curriculum statements, I developed a rubric (see Appendix J) to assess how students represented the science concepts of energy and force from their learning experiences. Bean (2005) writes that a well designed rubric is a powerful assessment tool that states the requirements and range of skills.

Burns (2000) writes that data collection using the observation technique is done through the observer as part of the context being observed, and the end result can be an analytic description and interpretation of a highly complex system. Making reference to the rubric (see Appendix J), I observed how students were able to use science terminology and participate in learning the concepts of energy and force, and my observational notes were recorded in the research journal. Burns suggests that participant observation is a process of waiting to be impressed by recurrent themes that reappear in various contexts and that the greatest asset of the process is that it can be possible to record behaviour as it occurs. I was able to observe and record how students produced and reproduced knowledge to explain and demonstrate concepts of energy and force through speaking, writing, drawing and direct actions.

Making reference to the rubric (see Appendix J), I analysed the students' written work when they attempted or completed the pedagogical activities on the concepts of energy and force in their science writing books. The students were encouraged to attempt or complete the science learning activities embedded in pedagogical strategies, and the science activities are listed in detail in the teaching units (see Appendices L and M) as part of their science learning experience. The students attempted or completed the pedagogical strategies throughout the learning and research cycles. The aim was to provide exemplars of students' engagement and representations of the science concepts of energy and force. Samples of the exemplars of students' reflection and written tasks and my explanatory notes are in the appendices (see Appendix K).

Free-flowing conversations are helpful when an individual's subjective experiences are being elicited, and can facilitate access to events and activities that cannot be directly observed by the researcher because they occurred in the past (Burns, 2000). In the second cycle of data collection, students and assistant teachers referred to activities and experiences in the sports field and hospitality, outdoor, cooking area in the school. The sports field and hospitality, outdoor, cooking area were locations of work of three of the assistant teachers who participated in some science class activities during the second and third cycles of data collection. Accounts of these experiences were taken as valid cultural experiences for the study. In the third cycle of data collection, the sports field and hospitality, outdoor, cooking area formed part of the research location as some of the science classes took place in those areas. But, some of the participating students were very reluctant when I attempted to audio record the class discussions and the audio recording process was necessarily abandoned. The students expressed suspicion that their voices might be used by "evil spirits".

What enabled me to do the research in the first place was my strong relationship with the students. My attempt to introduce audio recording equipment seemed to interfere with that relationship. The class discussions were then noted during and immediately after and recorded in my research journal. There is concern however that the noted class discussion in the journal may not be precise, but these field notes of conversation attempt to capture the interchanges from my teacher/researcher perspective only.

Field notes should not only include records of observations and conversations but also detail the researcher's thoughts, impressions and reflections (Burns, 2000). Burns also suggests that the thoughts, impressions and reflections of the researcher can start to identify and discuss the conceptual issues and emergent themes, and can be organised around topic areas as a basis for the analysis of the data. Making reference to the rubric (see Appendix J), my thoughts, impressions and reflections during the learning and research cycles were recorded in the research journal.

The purpose of analysing the data is to find meaning in the data, and this can be done by systematically arranging and organising the information so that comparisons, contrasts and insights can be made and demonstrated (Burns, 2000). The data set for analysis were observational notes recorded in my research journal, students' written work in their science writing books, class discussions noted in the research journal and my thoughts, impressions and reflections from the research journal. The Erickson's (1986) data analysis template was used to search for emerging themes. The analysis focused on similarities and differences presented by the students to establish the attributes that distinguished them by category (Coupland & Crawford, 2002). The product of analysis was a range of possible ways students can learn, know and (re)produce knowledge on science concepts of energy and force. The range of possible ways students can learn, know and (re)produce knowledge on science concepts of energy and force represents a partial understanding of the phenomenon, that cannot be empirically tested, but argued for (Akerlind, 2002).

4.7 Ethics consideration

Complications in teacher research can arise from the potential abuse of a privileged position. In recruiting for this study, I minimised this potential abuse by adopting a suggestion from the British Educational Research Association (BERA, 2004) to use a 'gatekeeper'. I enlisted a Torres Strait Islander elder who was the cultural advisor and traditional dance instructor in the school to act as the 'gatekeeper'. The 'gatekeeper' phoned parents in their communities to explain the project, before I sent out invitation letters, which included information about the project and informed consent forms. The parents and guardians' invitation letters, information sheets and informed consent forms were posted with return addressed, stamped envelopes. The 'gatekeeper' followed up by phoning the parents to encourage them to return the consent forms. The 'gatekeeper' emphasised to the students that though their parents had agreed to their taking part in the study, they could still refuse to be involved. The 'gatekeeper' acted in *loco parentis* to reduce the potential abuse of student participants in the research. He read, translated and explained the information sheets and consent forms to both students and their parents or guardians.

My study involved Torres Strait Islander students and Torres Strait Islander adults. The study recognised and was committed to respecting Aboriginal and Torres Strait Islander cultural values and principles. The study considered the principals and protection afforded children under the *National Statement of Ethics in Human Research and Keeping Research on Track: A Guide for Aboriginal and Torres Straits Islander people about health research ethics* (2006) in the conception, design and conduct of research. The six values that lie at the heart of the guidelines incorporated into this study were: spirit and integrity, reciprocity, respect, equality, survival, protection and responsibility.

I adopted an ethical protocol that paralleled the research stages of: thematizing, designing, data collecting, analysing, and reporting. This was necessary to address ethical and moral issues that arose during the research process (Kvale, 1998). The ethical and moral issues were addressed as a set of rights to self determination, privacy, anonymity, fair treatment and protection from discomfort or harm (Greene & Hogan, 2005) of the group of Torres Strait Islander students. Rights were addressed as follows: involvement of the children in the research; consent and choice of them and their parents or guardians; all possible minimization of harm or distress to the children; and privacy and confidentiality promised. This protocol ensured that not only parents and guardians, but also students were told of the aims of the research, of the time and commitment required, of who would know the results and how they would receive feedback. They were promised confidentiality and that data collected would be used only for the purpose of the research. Lewis and colleagues (2004) makes the point that gaining permission from parents and guardians, gaining consent from students, ensuring that students were never pressured to respond, and agreeing that any research activity could be terminated by the student at any point is mandatory.

I was always conscious that my dual role of teacher and researcher meant that I had to be scrupulous at distinguishing between my voice and experience, and that of the student participants. In addition, the teaching experiences had to be placed into an objective context. Hitchcock and Hughes (1989) suggest that there is no value free research since the researcher might have more power than other participants. I realised that students were vulnerable and was very careful when involving them in this research, which had to adhere to the same principles and rigour as the rest of the research community.

To gain ethics approval from James Cook University Human Ethics Committee, I advised the committee on the research methodology and the approximate number of participants in the research, of how I requested consent from students, their parents or guardians and Torres Strait Islander members working in the school. I also explained the levels of consultation with the elderly Torres Strait Islander member in the school who took the role of explaining the project to parents and guardians, and the procedure of how informed consent of the students and their parents or guardians was obtained. The project approval was granted on 29th August 2006: Ethics Number H2417 (see Appendix H). The collection of data commenced in January 2007 and was completed on 30th June 2008. The Human Ethics Committee, through the Ethics Monitor, was periodically informed on the progress of the research project. I requested informed consent from the school, through the Principal and coordinator of the middle school. The Principal gave written consent for the project in a letter to the James Cook University Human Ethics Committee. The project was then explained to the Torres Strait Islander adults working in the school who were invited to participate in the project. The Torres Strait Islander elder consented to be the 'gatekeeper' in the project, and five Torres Strait assistant teachers accepted the invitation to participate in the study, and three of them participated in science classroom discussions in the second and third cycles of data collection.

4.8 Validity of the research

Traditionally, a teacher's role in research was limited to data collection in studies designed and controlled by academic researchers. The idea that teachers could design and carry out research on their own practice, and that the results of the study had meaning, was only accepted in the late 20th century (Corman, 1957; Campbell & Stanley, 1963; Olson, 1990; Foshay, 1994; Hitchcock & Hughes, 1995). I am not only a teacher researcher, but researching for the highest level research degree and guided by two James Cook University, School of Education senior science education lecturers. According to Zeichner and Noffke (2002), five major traditions of practitioner research in education that were developed in the 20th century lead to increased recognition of the value of this type of research: 1. the action research movement developed in the United States at the Horace Mann-Lincoln Institute at Columbia University around 1950; 2. the British teacher as researcher movement that evolved between 1960 and 1970; 3. the contemporary teacher researcher movement in North America developed primarily by teachers with support from their university colleagues; 4. the recent growth of self study research by college and university educators as teacher educators studying their own practice and; 5. participatory research that evolved out of work in Asia, Africa and Latin America with oppressed groups and was adapted to community-wide research in North America that included, but went beyond, the formal educational domain.

As a teacher and higher degree research student, I was concerned with the practical impact of my findings for my science classroom. According to Parson and Brown (2002), the validity of a research project refers to two different, yet related issues: internal validity and external validity. Internal validity refers to the extent to which the changes in the outcome can be attributed to the introduction of the action strategy rather than other factors. External validity refers to the extent to which research findings can be generalised to a broader group or situation. At the heart of the research problem is the fundamental disregard for Torres Strait Islander students' cultural ways and languages within formal science learning and teaching (Martin, 2008). I attempt to illuminate Torres Strait Islander students' experiences in the science classroom in this study. Winter (2002) suggests that research has authenticity, epistemological validity and cultural authority when it gives 'genuine voices' to those whose life worlds are being described. I argue that the issue of internal and external validity of my study may translate to whether the strategies will work with future Torres Strait Islander students, rather than whether all teachers use the strategies in the future.

My classroom action research is value-laden and morally committed. Participants in action research perceive themselves as in relation with one another and everything else in their social context (McNiff & Whitehead, 2006). I adopted criteria used to address the validity of practitioner research, applicable to the British and Australian teacher-as-researcher, improvement-oriented-tradition (Stevenson, 1996):

1. I articulate the rationale for and educational significance of the study that connects to my value commitment and theoretical knowledge. The purpose is for me to establish the worthiness of the research.
2. I articulate and justify my intentions and beliefs. Asking me as the researcher to remain neutral in a research based on my commitment, intervention and action does not make much sense to me.
3. I genuinely respected Torres Strait Islander culture, collaborated with Torres Strait Islander students and assistant teachers, and include their perspectives in the research.
4. I did not abort the research before taking action to change the educational experience of Torres Strait Islander students learning science.
5. I attempt to present multi-perspective data sources in the research.
6. I articulate a constant dialectical interplay between my values and action, with values informing action and vice-versa.
7. The research was systematically conducted, and was responsive to my evolving understanding.

8. The research was transformative, leading to changes in my understanding.
9. The research results were made public so as to engage in dialogue. I presented the findings of this research at three international conferences, and published three papers in academic journals.
10. I supply rich descriptions of the context in this thesis so that others will be able to draw analogies to their situations.

Practitioner research serves to advance classroom understanding and practice. Action research is valuable when findings move beyond the value of individual development and move beyond the local context to contribute more broadly to education and societal improvement (Fischer, 1996; Zeicher, 1977). I made results of this study public by presenting at three international conferences and publishing three papers in academic journals. I also have plans to publish two more papers from this research, as well as writing this thesis.

4.9 My classroom action research plan

In this section, I highlight steps in my classroom action research plan. I encouraged Torres Strait Islander middle school students to employ science language used in the science concept descriptors by the Queensland Studies Authority *Science Years 1-10* (1999/2004) Level 4 and 5 learning outcomes. Prain and Waldrip (2008) write that in science learning, students are expected to learn a new literacy, consisting of scientific claims about their physical world, and are introduced to, and expected to use diverse representations. I wanted Torres Strait Islander students to realise that science concepts of energy and force can be identified and analysed to help understand and develop technologies, and to make predictions about events in the world (QSA, 2004). I sought to influence positively the learning outcomes of these students by:

(1). deliberately establishing a learning environment that implemented a socio-cultural learning model that sought to develop these students' representation and description of the concepts of energy and force.

(2). taking a "guided hands-on/minds-on scientific inquiry" approach which used hands on activities to provide the students the opportunities to look at, talk about, share and predict, define and characterise the big ideas and details of the concepts of energy and force. Engle and Conant (2002) define engagement in terms of students actively speaking, listening, responding, and working and high levels of on task behaviour. Disciplinary engagement expands to include scientific content and experimental activities. The aim was to provide Torres Strait Islander students with a genuine scientific experience as the research occurred during normal science lessons. Such an approach prescribed making certain that genuine scientific inquiry took place. The scientific inquiry consisted of the aim of the activity, hypothesis, prediction, method and results (QSA, 2004). Students were encouraged to present their work in the form of scientific reports in their science writing books.

(3). providing adequate resources by using simple science investigations and activities requiring equipment that were economic and easy to acquire. I wanted to improve the competence of handling apparatus and performing hands-on science activities by the students. Hanrahan (2001) suggests using activities which demystify some of the common genres of the science classroom.

(4). encouraging the students to work scientifically, that is, to investigate, understand and communicate scientific ideas on the concepts of energy and force (QSA, 2004).

(5). facilitating group work that promoted positive horizontal relationships between students, and between the students and me as their science teacher. I wanted my students to see me as a partner in the process of scientific inquiry and learning.

(6). encouraging students to cooperate, improve self control, act responsibly, be accountable to others and actively participate in the group by giving each student in the group a role. I encouraged them to communicate about their roles with others. Yunkaporta and McGinty (2009) suggest that Indigenous students, if well supported, can be self-directed and self-regulated learners, and do work well and cooperatively.

I put the classroom action research plans into action in February 2007 with two of my Grade 9 science classes at the College. I was confident that the plans were educationally sound, but not sure how they would be lived in the classroom, and the responses I would get from the group of Indigenous students.

Figure 2: Picture of students in my class which was published with an article I contributed to The Journal of the Australian Science Teachers Association, Volume 53 (2), Winter 2007. Photographed by Ludo Kuipers.

4.10 Section One

First research cycle

4.10.1 Acting and observing in the first cycle of data collection

Forty nine Torres Strait Islander middle school students in two grade 9 science classes agreed to participate in the first cycle of data collection which took place during the first semester of 2007. Three of them transferred from the school in the early stages of data collection. They were not considered as part of the analysis. The participating students attempted or completed pedagogical activities, which were designed to elicit the students' representations of the concepts of energy and force. Students were also encouraged to consult Torres Strait Islander word banks and dictionaries on how some science terminology translates from common Torres Strait Islander languages.

The science concepts on energy and force in the first cycle of data collection were:

a. Define a force as a push or pull with magnitude and direction, measured in Newtons (N).
b. Recall that there are different forces which affect the motion, shape, behaviour and energy of objects.
c. Define energy as the capacity to do work, measured in Joules (J).
d. Describe forms of energy (including Heat Energy, Light Energy, Sound Energy, Electrical Energy, Kinetic Energy, Gravitational Potential Energy, and Chemical Energy) and the effects and characteristics of these different forms (QSA, 2004).

The first cycle of data collection was guided and informed by these research questions:

- How did a group of Torres Strait Islander middle school students employ their everyday languages and formal science language when learning the concepts of energy and force?
- How did a group of Torres Strait Islander middle school students participate and communicate in science activities when learning science concepts of energy and force?

- How did a group of Torres Strait Islander middle school students apply and relate to science concepts of energy and force as described in Standard Australian English?

Aikenhead (2002) argues for science teaching frameworks that validate the ways of knowing that Indigenous students bring to school. I attempted to ground science learning in Torres Strait Islander ways of talking and knowing, to make heard the students' voices, and connect with lived experiences.

In pre-inquiry and brainstorming sessions, communication between Torres Strait Islander students was mostly in Creole languages (these are varieties of Torres Strait Creole) and the students used very few science words in English. Thirty nine students were observed as finding it difficult to articulate their prior knowledge and experience about the concepts of energy and force, and were reluctant to proactively take centre stage handling the science apparatus. Keys (2008) found when Indigenous students were asked to work as a group that they relied on one person to speak on their behalf. This was replicated in my classroom, where students nominated a peer to handle the science apparatus on their behalf, but would engage in watching hands-on science activities, and seemed to enjoy them. Yunkaporta and McGinty (2009) suggest that Indigenous students like to watch first, and join in for small parts, then take on larger parts when confidence grows.

Thirty nine students who were observed as finding it difficult to articulate their prior knowledge and experience about the concepts of energy did not feel comfortable to explain, present or discuss the science activities. As a result, most of these students' presentations were given in diagrammatical form or by direct action (which are gestures). They used few science English words to label their diagrams or express action. I will use the italicised voice for my reflections. At this stage of the research, *I realised that I had set conditions that continued to alienate these thirty nine students from actively participating in science learning.* I noticed that seven students who were competent speakers of English translated to their peers in their Creole language, *and, at this stage, seemed to be the students most empowered to learn classroom science.*

Using Venn diagrams to compare and contrast everyday and science ways of describing concepts of energy and force, most of the students continued to use very few science English words, except for seven of them who had facility with the English language. The seven students who had facility with the English language were starting to claim that they knew the science words prior to the hands-on science activities, but the evidence showed that they had used very few science words in their "pre-inquiry" and brainstorming session as their everyday ways of describing the concepts. *I suspected that the interface of knowledge* (see Nakata, 2002)*, which is the intersection of the indigenous and western science knowledge domains was expanding for the seven students. It seemed that they were starting to own the science language.* The "post-inquiry" concept maps were done similar to the Venn diagrams, with seven students who had facility with the English language using science words, and the rest of the students being unable or unwilling to use them. Most of these students' oral communication was conducted in their Creole language.

Students did not see the designing of science activities as a central part of science learning. Here is an extract of dialogue I had with four students (G8, G22 & B3) learning about procedure in a science experiment in March 2007:

> G8: What do you want us to do?
> Me: I want you all to follow the steps in a science experiment.
> G22: That is boring.
> Me: You need to read and follow the instructions.
> B3: Just tell us what to do and we will do the science.
> Me: I need you to follow the instructions and write what you observe.
> G8: Why do we need to write? Can't you see what we are doing?
> G22: Show us what to do and we can have a go. You can come and watch.

For most of the students, the designing of science activities seemed an unnecessary burden, as highlighted by student B3, who commented: "Tell us what to do, and we will do the science". *At this point, I realised that students were still looking forward to the "fun science"* (explained in Chapter One) *as the doing of science, and not focusing on either the process of scientific inquiry, or on the knowledge of underlying scientific principles, and were resisting reproducing scientific knowledge.*

Many students did not wish to write the steps of a fair test, and constantly asked for clarification or directions from me or from the seven students who had facility with English. Many of these students had difficulties with reading and following instructions. Student G22 commented, "Show us what to do and we can have a go". Once the instructional language was explained, however, most students would familiarise themselves with the steps, and attempt the science investigations, sometimes with much enjoyment doing the activities. At this stage, *I concluded that instructional process words in science were limiting many Torres Strait Islander students from participating meaningfully in science investigations.* These students relied on instruction words explained a number of times, illustrated or translated into direct action (gestures), and combined with a form of Creole language by their peers, who had facility with the English language.

The students were reluctant to collect, analyse and present information, and many did not see the point of collecting, analysing and presenting data. When I told them it was for assessment, student G8 responded, “Can’t you see what we are doing?” But most students were agreeable to presenting a number of drawings to represent their understandings, were keen to show off their drawings, and explained them using their Creole language and direct action, pointing and gesturing to show knowledge of the physical concepts of push and pull. Very few of these drawings were labelled correctly in English. This scenario presented a need to incorporate all possible literacy dimensions into the science classroom, so as to fruitfully engage all of the students. The reporting, presentation, analysis and explanations of the scientific process proved challenging to all but a few students because of the English language terms students were required to use. Students were able to communicate their science learning using their Creole language, direct action and drawings, but did not use English science language terms with facility as prescribed by the Queensland Studies Authority curriculum documents.

Most Torres Strait Islander middle school students defined a force as push or pull, using gestures (which I call direct actions). The magnitude of force was translated to mean the amount of force, and students illustrated big or small using direct action. Students had difficulty measuring the magnitude of a force, using the Newton unit. What appeared most challenging was conceptualising the magnitude of force as defined by the Newton unit. Harris (1990) suggests that Indigenous languages generally reflect the quality of things rather than their properties or quantities. Most students were able to illustrate diagrammatically these concepts, but could not employ ‘curriculum’ language to describe them. Contact forces were better illustrated, with diagrams and direct actions. The concept of non-contact forces proved challenging, even after hands-on experiences of attraction and repulsion forces, using magnets. Only seven students were better able to explain these concepts, using Standard Australian English. I wrote in my research journal: *What the seven students were able to do is what is captured and measured in state, national and international testing, and the thirty nine students were not able to do this.* Seven students who had facility with the English language were better able to describe the concept of energy using the Queensland Studies Authority *Science Years 1-10* (1999/2004) Level 4 and 5 learning outcomes.

Generally, students were able to describe the concept of energy as the capacity to do work, using direct action and examples. The concept of quantifying and measuring Energy using the unit Joule (J) also proved challenging, and students preferred to resort to “large”, “small” or “medium” when quantifying energy. The students preferred to recall heat, light, sound, and electricity, the concepts they were familiar with, but without applying the word “energy” as a suffix (i.e., “heat” not “heat energy”). They were more conceptually comfortable with kinetic energy (relating it to physical action), gravitational potential energy (relating it to falling bodies) and chemical energy (relating it to food and BBQ gas).

> Excerpt from research journal May 2007:
> The students did not want to have a science lesson on gravitational potential energy and kinetic energy. I told the students to move the furniture next to the wall to create room so we could play a popular game called ‘marbles’. To play marbles, you put the first marble on the ground and from a distance; you flick the second marble with your fore finger aiming for the first marble on the ground. If you hit the marble on the ground, you earn a point and the marble. As students were warming to the game the Deputy Principal (DP) walked into my room and here is an extract of dialogue with him:
> DP: You should stop playing marbles with students.
> Me: We will play for less than ten minutes.
> DP: I mean you are wasting students’ time, they come here to learn.
> Me: I am using the game to introduce the lesson.
> DP: That is not the way to manage Indigenous students. You need to have a firm grip; otherwise you will fail to manage the class.
> Me: Trust me, it will be alright.
> DP: I need to talk to you about behaviour management skills. (And walked away looking very worried)
>
> We played the ‘marbles’ game for a few more minutes, moved the furniture back and started working on a science experiment. This experiment investigated gravitational potential energy and how it is converted into kinetic energy. In this experiment, a marble is rolled down a ramp at different heights

> and the distance it travels is measured. Thirty minutes into the lesson, the students were busy performing the experiment and measuring the variables; they did not realise that the Deputy Principal was back standing at the door and checking on the class. He just shook his head and walked away, and he never talked to me about behaviour management skills.

I wrote in my research journal: I need to start with the familiar and focus on using students' cultural resources to improve engagement. When I used the marble game, which was a familiar and enjoyable game to the students, to introduce the experiment investigating gravitational potential energy and how it is converted to kinetic energy, the students who initially did not want to do the lesson got really engaged.

4.10.2 Reflecting on the first cycle of data collection

I consulted published works by Ray (2001) and Shnukal (1998) and found no direct comparison between the meta-concepts of energy and force as constructed in Queensland curriculum in Standard Australian English and the concepts as constructed in Torres Strait Creole. I discovered that there is no direct translation of the abstract concepts of energy and force from Standard Australian English into Torres Strait Creole. I could not find any Torres Strait Creole terms meaning energy, in the sense that energy is defined as the capacity to perform work, and is measured through its effects. There appears to be no direct translation of the terms "energy" or "force" (as an abstract meta-concept) from Standard Australian English to Torres Strait Creole. As a result, I found it extremely challenging to explore Torres Strait Islander middle school students' ideas effectively. I do not speak any of Torres Strait Islander students' diverse community and Creole languages. As a science teacher, monitoring the development of established scientific ideas, the conceptual extension of these ideas and explicit evaluation was hard to achieve because most of these students communicated in Creole languages. This created a dilemma because the science descriptors for Level 4 and 5 are formulated and articulated in English. It was not possible for me to effectively interpret and map the students' emerging ways of knowing energy and force, applying descriptors from the Queensland Studies Authority *Science Years 1-10* (1999/2004) syllabus documents. I believe, though, that I achieved some success challenging their everyday ways of knowing by exposing them to science ideas in the hands-on science activities in this first research cycle.

Most Torres Strait Islander middle school students had initial challenges with English science instruction words, but once the language was explained, the students were able to perform the science activities. The large majority of students needed to have the instructions explained in simple terms or, in some cases to see demonstrations first. Once one of seven students with facility in English got the idea, they would explain it to the other students in a Creole language and gestures (direct action). Most students would then proceed to perform the hands-on science activities. Students preferred short practical lessons, with few instructions, that repeated a concept in a number of ways to reinforce their understanding, and most students resorted to communicating in their Creole language. This might imply that Torres Strait Islander students were learning science using both English and their Creole languages. (I, too, never left my village language outside the classroom but used it to negotiate learning in English.) However, from my observations, the use of the English language as the only medium of instruction did limit most of my students' participation in hands-on activities. This is a significant pedagogical problem. How was I to encourage engagement when it appears that a lack of facility in English is holding the students back from participating fully?

A total of thirty nine students had problems spelling and pronouncing English science words. Torres Strait Islander people pronounce words differently from Standard Australian English. I pronounce words differently from Standard Australian English. I was in a dilemma. If I insisted that the students use Standard Australian English pronunciations (if there is any such thing), would that not imply that I was indicating that their way of talking is inadequate? By the same token, because I talk differently from mainstream Australians, is my way of talking inadequate? Would that not be against what I wanted to achieve in this study, mobilising and marshalling Torres Strait Islander students' cultural resources to engage with science learning? What form, level or standard of an English language can enable engagement with science concept descriptors formulated in Standard Australian English? A further dilemma was that I could not ascertain what level of acquisition of Standard

Australian English was required for science learning that is guided by a curriculum formulated, taught and accessed in Standard Australian English.

Most Torres Strait Islander middle school students in the study were prepared to participate is science learning, but the process was full of unexpected complexities. Here is an extract of a dialogue I had with three students (G12, B11 & B20) talking about earthquakes in May 2007:

> Me: The sun gives energy to the earth.
> G12: What is that earthquake thing the Principal was talking about at assembly?
> Me: This is a good question. Can you ask the whole class?
> G12: No Mister, you do it.
> Me: G3 is asking what causes an earthquake.
> B11: It is caused by angry spirits.
> Me: What do you mean?
> B11: It is them white fellas; they drill everywhere and make the spirits angry.
> Me: Remember, everyone, that in this science class we don't use spirits for explanations.
> B11: But that is what I have been told by my uncle.
> B20: Yah, it's our way, it's the way of black fellas.
> Me: But that is not a scientific explanation. In science we explain earthquakes in terms of energy building inside the earth and released as seismic waves.
> B11: But that is not the black fella way, are you not black, Mister?
> (I unconsciously looked at my dark skinned arm – and all students had a big laugh)

The notion of challenging Torres Strait Islander students' everyday or cultural ways of understanding, as prescribed by conceptual change learning models (see Hubber, 2005), appeared not to be very effective at a surface level. In this stage, some students did not take it kindly when I challenged their everyday or cultural knowledge. Student B20 commented, "It's our way; it's the way of black fellas", and student B11 asked me: "Are you not black, mister?" *I was pulled towards the notion of collateral learning which involves indigenous students taking in western science ideas that conflict with their everyday ways of understanding, and rationalising the two conflicting perspectives simultaneously in their long term memory* (see Jegede, 1995) *as a more human way of conceptualising Torres Strait Islander students learning science. I realised that challenging the students' cultural ways of knowing was not the most appropriate avenue to follow. I decided that these students can renegotiate their ways of knowing by themselves at a later stage, rather than directly confronting and challenging that cultural knowledge in a science class.* Cobern

(1996) advises that Indigenous students can close their minds to explanations that reject their own beliefs to the supremacy of western models, and this is wise advice.

The context of each individual student's experience was different. This was a challenge for me, the diversity students presented. They come from different islands and communities, and present different varieties of knowledge and Creole languages. Indigenous knowledge systems are recorded as local knowledge systems (see Aikenhead, 2005), and are highly place-based and sea-country orientated. As described by Hampton, Licona and Izquierdo (2005), a context based approach to science learning calls for interactive dialogue. With Torres Strait Islander students, this means a dialogue about local contexts for understanding the concepts of energy and force in Torres Strait languages and English. *I discovered that this approach can be most difficult with a diverse group of students. I struggle to conceptualise a dialogic approach to learning and teaching, and how it could work in practice with a group of indigenous students who come from diverse communities, and have diverse views and personal circumstances.* Such consideration led to the reformulation of the research after the first cycle.

Figure 3

Figure 4

Figures 3 and 4: Pictures of students in my class which were published with an article I contributed to The Journal of the Australian Science Teachers Association, Volume 53 (2), Winter 2007. Photographed by Ludo Kuipers.

4.11 Section Two

Second research cycle

4.11.1 Planning a process of change in the second cycle of data collection

I am not a native speaker of Torres Strait languages. I have taught myself to speak in some form of Creole to communicate with Torres Strait Islander students for the last seven years that I have taught at the school. In planning the second cycle of research, I realised that my lack of competence in Torres Strait languages made it difficult to mobilise the cultural resources of the students in the classroom to engage in science learning. I therefore invited five Torres Strait Islander assistant teachers working in the school to participate in the study, and all five accepted. It was not possible for them to attend all my science lessons because of their work commitments, but three of them attended about one third of my science lessons in the second and third data collection cycles, and joined in the class discussions. I consulted with the other two assistant teachers after working hours. I sought explicit assistance from the three assistant teachers during science classes on what cultural resources students can and could mobilise to engage with Level 4 and 5 QSA (2004) science learning outcomes. I encouraged the assistant teachers and students to consult Torres Strait Islander word banks and dictionaries to figure out how some science terminology can be translated to and from common Torres Strait Islander languages. It was necessary to encouraged all participants to use the dictionaries because students were presenting different versions of formal and informal Creole language words.

I added three research questions for the second and third research cycles:

- What language and cultural resources did a group of Torres Strait Islander middle school students draw on for developing their understandings of the concepts of energy and force?
- How did the structure of science curriculum constituted by the Queensland Studies Authority *Science Years 1-10* (1999/2004), enable or limit the learning agency of a group of Torres Strait Islander students?

- What pedagogical content knowledge enabled a group of Torres Strait Islander middle school students to learn, know and (re)produce knowledge of the concepts of energy and force?

The science concepts on energy and force in the second cycle of data collection were:

a. Explain balanced and unbalanced forces, action and reaction, contact and non contact forces.
b. Explain relationships between forces, motion and energy: push and pull, machines, floating, sinking, flight, space travel, gravity, electromagnetic and friction.
c. Explain energy transfer from one object to another: reflection and refraction of light, absorption and transmission, conduction and convection (QSA, 2004).

I provided all the new terminology as one set of cut-outs per group of three or four students to introduce science words in a non threatening way. I put non science words in black and formal science words in blue. Examples of non science words included: obtaining and use, particular purposes, discuss the consequences, different ways. Examples of formal science words included: chemical energy; energy transfer, reflection and refraction of light, absorption and transmission, conduction and convection, energy converters; fossil fuels, hydro-electric, geothermal, solar and nuclear energy. Keys (2008) describes how more emphasis for Indigenous students was placed on learning scientific terminology than on understanding scientific concepts (justified on grounds of improving indigenous students' literacy levels). I did not want students to crossing out and then rewriting the new words. *I realised that by providing one set of cut-outs per group, I had increased the chances of students in the group working together.* Increasing the chances of students working together was consistent with my socio-cultural approach. I provided a template of a fair test procedure for each student in the group. I took these steps to increase coaching and scaffolding the inquiry process for students.

Consistent with an approach that encouraged learning from and with others (Tobin, 2005; Murphy et. al., 2008), data collection in the second cycle also involved the assistant teachers, especially the three assistant teachers who attended my science classes. I engaged them to elicit cultural resources that the students can use to learn the science concepts of energy and force, and advise how some words used learning these concepts translate to and from Creole. I wanted to find common comparable Creole language words for those that constitute physical concepts in English so that we could use a mix of language resources (English and Creole) to support the students' learning.

4.11.2 Acting and observing in the second cycle of data collection

The second cycle of data collection took place during the second semester of 2007. Forty six Torres Strait Islander middle school students attempted or completed the pedagogical activities. Two students transferred during the semester. These two students had completed less than one third of the pedagogical strategies in the cycle, and were not considered in the final analysis (see Chapter Five). The students participated more actively than in the first cycle. Both the students and assistant teachers focused on telling other members of the group how they describe physical phenomena differently in their communities, but some students thought that these sessions were not relevant to their learning of science. They indicated that they already know what they do in their communities, and doubted whether discussions of activities in their community were part of the authentic learning of science. *They did not realise that what they already know is a springboard for learning.* During discussions, both students and assistant teachers communicated in their Creole languages and used very few science words. *The improved participation and communication by students could have been caused by the participation of the assistant teachers in the discussions* (see Keys, 2008)*, or from the students now being more experienced and confident than in the first cycle.*

In guided, group, hands-on/minds-on science activities, thirty seven of the students were observed to lack confidence in reading instructions, science texts and handling science apparatus. The students still wanted someone else, especially the seven students with facility in English, to take the lead or explain the English language instructions. Once instructions were explained and activities demonstrated, however, they would perform the activities. I noticed that the students and assistant teachers frequently referred to experiences and incidents that occurred in the sports field and hospitality outdoor cooking area. The assistant teachers had worked in these areas with the same students who participated in the study.

In Venn diagram and ‘post inquiry’, concept mapping sessions, only seven students were fully able to include scientific descriptions as part of their everyday ways of describing the concepts. Here is an extract of dialogue I had with student G9 while we were looking at her Venn diagram in August 2007:

> Me: You now have a large number of science words in the everyday ways of knowing section.
> G9: Yes what is wrong with that?
> Me: Actually it is good. When did these science words become part of your everyday ways of knowing?
> G9: I do not know, G13 isn’t it we always knew this?

These were science words and descriptions the students had encountered during the hands-on/minds-on activities. Student G 9 responded: “We always knew this”, and was claiming the knowledge. The seven students were starting to display a much richer interaction with the concepts. *The cultural interface visually represented by the intersection of the Venn diagram was expanding.* I took this as evidence of students starting to accept science ways of describing the concepts as part of their everyday ways of describing the concepts. The other thirty seven students seemed to mix up their everyday ways of describing the concepts with the science ways. *This might have been because the students were communicating mostly in variants of Torres Strait Creole, and starting to incorporate science concept descriptions into their talking and thinking.*

I monitored each student’s responses and attempted to make meaning of the responses, cognisant of their diversity. *I discovered that addressing the context of teaching science language, specifically instructional words in science learning, introducing few science words per lesson, using concrete materials and representations proved helpful to students. The students’ participation and communication in science learning had increased. I realised that by adjusting the language of science (oral / written) and encouraging use of variants of Torres Strait Creole, I had increased students’ engagement, participation and access to the language of formal science learning. Adjusting grammatical challenges through reducing logical connectives, lexical density and avoiding qualifying words and passive voice* (see Wellington & Osborne, 2001) *increased the students’ access to scientific language. I discovered that using short sentences, paraphrasing and* *repetition for emphasis improved engagement. My aim was not to dilute the curriculum, but to provide extra scaffolding effort and clarity.*

I observed that the majority of Torres Strait Islander boys were protective of their cultural ways. I asked them why they felt that their cultural ways should be kept separate from science learning. Student B9 responded, "Why should we change something that works for us?" Student B4 explained, "It works for us. It is our way". Student B11 commented, "It is the way of black people". These boys felt that eliciting their everyday ways of knowing during the 'pre inquiry' concept mapping and group brainstorming session was not part of legitimate science learning, and they did not need to be treated as serious in the activities. Here is an extract of dialogue I had with three other students (B13, B14 & G17) and assistant teacher T1, learning about wind and water energy in September, 2007:

> Me: How do you use wind and water waves back in the communities?
> T1: You mean like when we go out fishing Philemon.
> Me: Yes fishing or in a dingy.
> B13: But this is not science.
> B14: Yah, when are we going to start learning real science?
> Me: It is science alright. We all use a lot of science everyday in our communities.
> G17: Mister, they mean when are we going to blow them stuff, and learn them big words?

When student B 13 responded: "This is not science"; student B 14 asked, "When are we going to start learning real science?" and student G17 asked, "When are we going to blow them stuff?" it suggested to me that their understanding of science had to be challenged. *I realised that Torres Strait Islander students had been disenfranchised from using their cultural resources to engage science learning. The students needed to realise that the formal science curriculum would make more meaning to them if they could relate science to themselves.*

4.11.3 Reflecting on the second cycle of data collection

I came to the conclusion that doing science lessons in the classroom setting may be limiting the agency of Torres Strait Islander students. Though there was a significant improvement in participation in the second cycle, I sensed that students felt restricted to exercise their body movements to illustrate what they wanted to express using direct action. I decided to liberate my students by planning to have more than 40% of our science learning outdoors, where they might feel less restriction. Snively and Williams (2008) suggest that restricting the socio-cultural language dimensions of Indigenous students limits them in terms of engaging with science learning. However, when I encouraged them to feel free to express themselves, Student G3 argued, “We can not do that in a science class, it’s not allowed”. I asked who does not allow them to express themselves. Student G7 replied, “We have been told we can not do that, we should sit and watch, write or read”. I was puzzled, perhaps while trying to implement safety strategies in science classrooms, the students’ previous teachers might have encouraged them not to run around to avert disasters or their teachers did not do much science.

Limiting literacy to reading and writing denies multiple language dimensions of Indigenous students (see Aikenhead, 2006). Interpreting Bourdieu, this may be the equivalent of denying students the use of their cultural capital, their home ways of knowing the world. Nevertheless, when I encouraged students to use their Torres Strait Creole(s), they felt that they were not learning science. Student B3 asked, “When are we going to learn them big science words?” How could I liberate Torres Strait Islander students from the notion that they can only learn science using “them big science words”? I wanted them to understand that they could learn science in environments that allowed multiple language and cultural dimensions, but was this a rational desire on my part? Again I found myself in a dilemma. If Torres Strait Islander middle school students continue to use their community Torres Strait Creole learning science, at what point do science educators, especially the ones who impose state, national and international science literacy tests on these students, expect them to communicate science understanding in Standard English, and what is the justification? If the students are talking about science in Torres Strait Creole, and learning science in Torres Strait Creole, what right have science educators to deny the students such opportunity? What is the justification for such an approach? Is it not alienating science conceptualisation for the students? Also, why were some boys so resistant to my attempts to encourage bi-lingual learning?

When I ask students to use English as the medium for communication, they spend much of their time focused on writing the English words correctly. Their attention is not on learning the science concepts. I realised that I could not translate meanings of science instructional words (I discuss this further in Chapter Five). The meanings are not portable, so meanings have to be negotiated from what languages the students already know (Chigeza, 2008). I discovered that science terminology learning can be coached to students with limited facility in English: for some students, terms negotiated from Torres Strait Creole can build solid understanding. Students with facility in English – the cultural capital valued in the formal Australian science curriculum – had to explain concepts to students with limited facility in English, using Torres Strait Creole and gestures (direct action). I became convinced that I, too, had to use Torres Strait Creole words and direct action along with English instruction words to construct science meaning and understanding for the students.

It was during class discussions in this research cycle that the students with help from the assistant teachers, discussed activities like cooking the Kup Mauri, and playing the traditional drum and didgeridoo. Here is an extract of a dialogue I had with three students (G13, G19 & B9) and assistant teacher T2, learning about energy transfer, doing cultural dance practice in November 2007:

> T2: *Yupla* (you me fellas), one man talk. Listen to what Philemon is saying before I go.
> G13: Where are you going, T2?
> T2: I have a meeting about cultural dance practice.
> B9: Can I come with you? I want to be in your cultural dance practice group.
> Me: What are energy changes that take place when you are doing cultural dance practice?
> T2: You mean like when you are drumming and dancing?
> Me: Yes
> G19: We sing, too. You fellas also play the didgeridoo.
> Me: Can we get into our groups and discuss energy changes that will take place in the afternoon during cultural dance practice?
> (Students move into groups – T2 leaves the room)

I thought the Kup Mauri, the drumming and the didgeridoo were legitimate to science learning. I wanted the students to apply western science ways of knowing to their everyday experiences. This is one of the reasons I decided to take some of my science classes into the sports field and outdoor cooking areas in the third cycle of data collection. I wanted the students to realise that their experience in the sports field and outdoor cooking area were legitimate sources of scientific knowledge and objects for learning concepts.

I wished to include the multiple dimensions of old and emerging Torres Strait Islander cultures into science learning. My original focus in this cycle of data collection was on traditional cultural ways of knowing. I discovered, though, that some students were not very familiar with the traditional knowledge systems, and perhaps that inquiry is best suited directed to indigenous scholars and traditional elders in the communities. Students who had some traditional knowledge were embarrassed to share with their peers because they were mocked.

> Excerpt from research journal October 2007:
> We were discussing geological forces and the discussion turned to rock types and the rock cycle. Next lesson I brought samples of three rock types: igneous, sedimentary and metamorphic. I put the three piles of rock on my table and asked the students to get into their groups so I could give the samples of rock to the different groups of students to observe. Student B19 challenged why I had put the rocks in the three groups because it was wrong. He walked to my desk and rearranged the rock into two groups and here is a snippet of dialogue I had with the students:
> B19: That is how we use them rocks.
> B15: We have *man popa* (grandfather) in this class. (G13 imitates an old man – and students laugh).
> Me: B19 has classified the rock according to how they use them in their community. What he has done is good, and in science we classify rocks according to how they are formed.

I wrote this reminder in my research journal: What I need to focus on to promote socio-cultural dialogue in my science classes are the emerging ‘hybrid’ or ‘youth’ cultures, which is common knowledge all students are eager to explore, and not only focus on traditional knowledge, which is community based. Hanrahan (2001) proposes that learning activities can take place in an environment where students’ concerns and feelings are respected, where language, teacher – student relationships and curriculum practices are all transformed to some extent to produce a learning environment in which students become more actively involved in the curriculum and in their learning.

I decided to investigate the ‘footy field’ and how these students use their acquired cultural capital and community cultural wealth to engage with sports activities, the Kup Mauri (traditional sand oven), comparing and contrasting modern materials with traditional materials, and kinetic energy - (sound) transfer, using a traditional drum and didgeridoo. I am cognisant of potential contestations. Will the state, national or international assessment instruments respect the literacies that Torres Strait Islander students employ as legitimate scientific representations in the investigations and representation of science knowledge? Will the wider science community respect this as legitimate science learning and representations, or just “dumbing down” the science curriculum? Are there spaces in formal science curriculum for such approaches?

Figure 5

Figure 6

Figures 5 and 6: Pictures of students in my class which were published with an article I contributed to The Journal of the Australian Science Teachers Association, Volume 53 (2), Winter 2007. Photographed by Ludo Kuipers.

4.12 Section Three
Third research cycle

4.12.1 Planning a process of change in the third cycle of data collection

I decided to take to the sports field and outdoor cooking area to explore pedagogical matters arising from the second research cycle. In the Science On The Oval Project, Whitehouse (2007) advises science teachers to take advantage of facilities and spaces in school grounds. I made the decision because I realised that the learning agency of my students may be enhanced in the sports field and outdoor cooking area. Two of the assistant teachers in the study worked in the sports department and one in the hospitality department. Aikenhead (2002), reporting on the Rekindling Traditions Project (six middle school science units that incorporated Canadian Aboriginal knowledge), acknowledges that the strategy that made a real difference was teaching outdoors. Aikenhead says that Indigenous students in the study reacted very positively to science away from school buildings.

As with the second cycle, I explored the spoken and written language of the students, and how they participated, communicated, related to and applied science concepts when learning science. I divided science language into two categories: instructional words in science and science terminology. Instructional words in science learning include the terms observe, describe, compare, classify, analyse, discuss, hypothesise, theorise, question, challenge, argue, design experiments, follow procedures, judge, evaluate, decide, conclude, generalise and report (Lemke, 1990). Science terminology includes: technical terms (eg. conductor), theoretical entities (eg. conservation of energy), abstract idealisation (eg. frictionless surface) and mathematical words and symbols (Wellington & Osborne, 2001). Also in this data collection cycle, I continued to explore science concepts from the previous cycles, to recap on learning. I also introduced the following science concepts of energy and force:

a. Explain energy converters: appliances in homes, in industry, in the biological world (plants and animals)

b. Explain alternative ways of obtaining or harnessing energy: fossil fuels, hydro-electric, wind, geothermal, solar, nuclear
c. Explain alternative ways of using energy: generating electrical energy, heating, cooling (QSA, 2004).

4.12.2 Acting and observing in the third cycle of data collection

Forty four Torres Strait Islander students participated in the third cycle, and six of them transferred during the semester. However, they were included in the analysis (see Chapter Five) because they had attended more than 70% of the pedagogical activities. The same five assistant teachers as in the second cycle participated in the third cycle of data collection.

This cycle of data collection became increasingly concerned with students' participation and communication within science learning. Student participation was observed to improve significantly in the outdoor areas compared to the classroom situation. On the sports field, all students were more willing to actively participate to show their skills kicking balls, running and recording distances and times. In outdoor lessons, students voluntarily demonstrated how Indigenous sports personalities like Jonathan Thurston, and Mathew Bowen of North Queensland Cowboys (National Rugby League) kick the ball. I tried to use these moments for genuine scientific learning. The students demonstrated the 45˚ long range kick, the 90˚ vertical kick, 'the bomb', and the short, near-horizontal kick, 'placing the ball'. They measured average speed/velocity (that is, run 100 metres in, for example, 15 seconds), and we held conversations about the gravity and frictional drag acting on a football.

In the outdoor cooking area, students constructed a Kup Mauri or Kopa Mauri (Ray, 2001; Shnukal, 1992), a traditional sand oven used to cook food for feasting, and discussions were held on heat transfer: conduction, convection and radiation. During the outdoor science activities, most of the students were more engaged in hands-on learning activities than in the classroom situation. When we made the Kup Mauri, students presented four versions of how this was done differently in their respective communities. This prompted me to look more closely at differences between the students to inform my planning. I also considered the range of differences that they presented in using formal science words.

Classroom activities that generated significant levels of enthusiasm and participation from students were learning about vibrations (kinetic energy) and sound energy using a traditional drum and didgeridoo. The waveforms produced were displayed on an oscilloscope. Aikenhead (2006) suggests that Indigenous students react very positively and apply themselves to learning when they realise that their community is rich in knowledge, and that they are involved in exploring that knowledge. The learning activities were less structured than in the previous cycles and there was less demand for writing.

1. Science activities in the sports field: All students were familiar with the 45˚ long range kick, the 90˚ vertical kick, 'the bomb' and the short, horizontal kick. Students increased the angle of kick (from the horizontal kick) to the 90˚ vertical kick (the bomb), and measured the range (the horizontal distance the ball travels). They devised how to measure the angle of kick using a ramp, and levelling the kick against the ramp. They initially argued that they could put the same effort in the kicks (Impulse of force: Ft=mv), and kick at an accurate angle against the rump. After debates about accurate measurement of the angle of kick and controlling the impulse of force, they realised that using human senses was too subjective, and agreed on the need to use a measuring scale for reliability and accuracy. Most students' representations of force were still only in diagrammatic form; however, they were able to illustrate the forces acting on an air borne football, gravitational pull and frictional drag acting on a football.

Students measured speed in terms of time to run 100 metres, and to cycle 100 metres and calculated and compared the averages (distance travelled divided by time taken). Extension activities investigated the need to put more effort (force) to increase speed and related that to acceleration (rate of change of speed). This was an attempt at understanding Newton's second law of motion (F=ma).

2. Science activities in the outdoor cooking area: A Kup Mauri is a shallow hole in the ground with a layer of smooth rocks. You set a wood fire to heat the layer of

rocks to high temperatures. Heat energy transfers from the fire to the rocks. You wrap the food in coconut or banana leaves, or aluminium foil. Normally meat (e.g. pork) is put next to the hot rocks and vegetables at the top. Students explored the concept of heat energy transfer using Kup Mauri, including the rationale to cover the food with an insulating material (coconut or banana leaf) to explore how heat energy transfers through conduction and convection. They investigated physical properties of traditional materials used and modern material substitutes, and compared this traditional oven with conventional ovens in terms of energy efficiencies. Extension activities were related to the thermal flask (how we keep our coffee warm).

3. Science activities using traditional drum: When investigating vibrations (kinetic energy) using a traditional drum, students were keen to try different beats on the drum, and analyse the waveforms produced on the oscilloscope. Students investigated tightening the skin of the drum, and loosening the skin (using the sun or any heat source, in resulting expansion). They investigated how sound is produced (vibrating skin), and the air pressure created at the end of drum, using a barometer (compressions and rarefactions). Using a microphone (to pick up the sound wave produced), and connected to an oscilloscope (to display the sound wave), students explored the loudness and pitch of the sound waves. They were fascinated with the relation between the amplitudes and frequencies of the waveforms to the loudness and pitch. The investigations were repeated using the didgeridoo. They were eager to take turns in producing these waveforms and measuring the amplitudes and frequencies. Extension activities involved how we pick up sound (vibrating ear drums, vibrating loud speakers), and sound production from stringed musical instruments.

Unlike in the first and second cycles of data collection, the students were applying and relating to science concepts in the third cycle of data collection. Here is an extract of dialogue I had with two students (B16 & B9), on the sports field, exploring the concepts of speed and acceleration, in May, 2008:

> B16: So you mean if I run 100 metres in 15 seconds, and Bill here does 100 metres in 15 seconds on his push-bike, and you Mister drive your car 100 metres in 15 seconds, Is that the speed we were talking about in class?
> Me: Yes, that is how we measure speed.

B9: Aha! That will be the same speed; no one will win that race.

Students expressed disbelief that what they were doing in the outdoor activities was the science they had found difficult to comprehend in the classroom situation. In the above conversation, the two students displayed improved level of interaction with the concepts, in that they understood that in order to run faster, you need to put in more effort (force) and they relate that to acceleration, which is rate of change of speed, an attempt at conceptualising Newton's second law of motion (F=ma).

The students displayed a lot of purpose in the science activities in the third cycle. When investigating energy transfer in the Kup Mauri, student B1 commented, "So we can learn science when cooking Kup Mauri, that's cool". During classroom activities, learning about vibrations (kinetic energy) and sound energy using a traditional drum, student B3 told me, "I always knew there was something special about the skin on the traditional drums, the way my grandfather makes them. I think we should investigate that next week". Student B7 said, "I practice kicking my footy everyday; I know gravity is always pulling my football down; wind direction and speed also affect my kick. Do you think I should measure them everyday? What do we use again to do that?" And student B19, an enthusiastic football player, commented, "Now I have a good reason to ask for a second serving of lunch: I am a rugby player and I need the energy". Students were relating their everyday life experiences to learning science.

4.12.3 Reflecting on the third cycle of data collection

Three levels of participation and communication (lessons inside the classroom and outside the classroom) emerged from this study (these levels are discussed further in Chapter Five). The first was a group of five of the students who were observed as active participants, when learning the concepts of energy and force, when taught in English and along conventional classroom practice lines. These students used the English language with facility to demonstrate the concepts of energy and force. The second was a group of nineteen students who were recorded as more passive classroom participants in learning. The participation of these students increased significantly during outside classroom lessons, though they used the English language with limited facility. The third was a group of twenty students who were recorded as limited classroom participants. Taking them outside was good, as their participation improved, but the students in this group did not use the English language with facility in labelling their drawings to explain and demonstrate the concepts of energy and force. They did, however, show evidence of knowing how to apply the concepts both in the classroom setting (activities involving the traditional drum) and on the sports field and outdoor cooking area using direct action and Torres Strait Creole. Students in this category would fail to cope with a science curriculum that is wholly administered using Standard Australian English. They would be judged at risk of not being able to participate adequately in science learning in such a curriculum. Yet this group of students can participate and learn science when their cultural resources – their everyday languages, experiences and knowledge systems – are incorporated in science teaching and learning, especially when taken outdoors.

Three levels of employing everyday language and science language were recorded (these levels are discussed further in Chapter Five). The first was a group of nine students who could use scientific genre to explain and demonstrate the concepts of energy and force through speaking, writing, drawing and direct actions. The second level was a group of fifteen students who could use limited scientific genre to explain and demonstrate the concepts of energy and force in terms of direct action. The third level was a group of twenty students who did not use scientific genre to either describe or display by direct action their knowledge of energy and force. I discovered that when Torres Strait Islander students learn school science, they negotiate language challenges. If the school science curriculum is administered and measured using Standard Australian English concept descriptors, it is possible that such a curriculum might not adequately facilitate Torres Strait Islander students who have limited facility in Standard Australian English to negotiate from their vernacular languages into science. A science curriculum that accommodates the multiple language dimensions of old and emerging Torres Strait Islander cultures could possibly empower these students learning school science to develop the capacity to successfully negotiate the language and knowledge systems. These matters are more fully discussed in Chapter Six.

Common instructional words students encountered when learning the science concepts included: design, perform investigations, relationships, analyse situations, collect and present information, explain how, transferred, transformed, present, alternative, obtaining and use, particular purposes, discuss the consequences, different ways and obtain (QAS, 2004). Instructional words like these are unlikely to be translated directly into Torres Strait Creole (see Michie, 2002). I found out, however, that 'Creole language substitutes' with the help of gestures, which I call direct action, can be used to aid instructional words in science, not only to negotiate new meaning and understanding for Torres Strait Islander students, but to assess them. I found out that instructional words in science had more effect than science terminology on students' agency in science learning. I discuss this more fully in Chapter Six.

I failed to find common comparable abstract concepts on the meta-concepts of energy and force in Torres Strait Islander students' diverse and complex languages. The science words students encountered when learning the concepts of energy and force included: balanced and unbalanced forces; action and reaction forces, contact and non-conduct forces; machines, gravity, electromagnetic, friction, and static friction; energy is the capacity to do work, heat energy, light energy, sound energy, electrical energy, kinetic energy, gravitational potential energy, chemical energy; energy transfer, reflection and refraction of light, absorption and transmission, conduction and convection, energy converters; fossil fuels, hydro-electric, geothermal, solar, and nuclear energy (QSA, 2004). I concluded that these science words need to be taught in Standard Australian English, so that the intended 'universal' meaning of science is not distorted. I found it helpful to introduce just a few science words per lesson, and to use concrete materials and representations when engaging the students. I discuss this more fully in Chapter Six.

4.13 Summary

In the first part of this chapter, I have explained my agency - structure dialectical standpoint and how I have adopted a hybrid research approach from Kemmis and McTaggart's (2000) classroom action research, and McNiff and Whitehead's (2006) action research model of "lived experience". I have discussed the study participants in terms of their habitat, my research methodology, ethics consideration, validity of research, and my classroom action research agenda. In the second part of the chapter, I have described the three data collection cycles, and my reflections. The next chapter analyses the data collected in the three cycles.

Figure 7

Figure 8

Figures 7 and 8: Pictures of middle school students performing cultural dance published on the Indigenous College website. Photographed by Ludo Kuipers.

Chapter 5

My findings and interpretations from data analysis

5.1 Introduction

In this chapter, I present my findings and interpretations from data analysis. The analysis of data collected included analysis of students' documents and my research journal. I identify three categories of how Torres Strait Islander students were able to use science terminology, and participated in learning science. I then undertake a second analysis to categorise the forty-four students in terms of my recorded observations of their level of engagement and participation in the science classroom. I report that of the forty-four students who attempted or completed the pedagogical activities in this study, the large majority, (*n* =37, or 84%), had limited to severe difficulty communicating in English, and about half the class struggled to understand the formal terminology of the science classroom. Furthermore, students with facility in English used Creole language substitute words and direct action (gestures) to 'translate' the science instruction words for the benefit of students with limited to severe difficulty communicating in English. I also report how I failed to find common, comparable, abstract concepts on the meta-concepts of energy and force in Torres Strait Islander students' diverse and complex languages. Finally I suggest that using Torres Strait Islander knowledge systems was enabling for the students.

5.2 Data analysis

Analysis of data collected included scrutiny of students' documents, as artefacts and my observational field notes recorded in my research journal. I draw on Akerlind (2002) to analyse how a group of Torres Strait Islander middle school students employed everyday language and formal science terminology (in Standard Australian English) to explain and demonstrate the concepts of energy and force. I further analyse how the students employed everyday language and scientific genre in labelling their drawings and direct action (gestures) to explain and demonstrate the concepts of energy and force, how they participated when learning the concept of energy and force, how they applied and related to formal science terms and concepts, what cultural resources they drew on for developing their understandings and what pedagogical content knowledge enabled them to learn, know and (re)produce knowledge. The findings on employing formal science knowledge, their participation in science learning and their competence in Standard Australian English are summarised in Table 2, and are explained in detail in sections 5.3, 5.4 and 5.5. The findings on translation from Standard Australian English to Torres Strait Creole and on using Torres Strait Islander knowledge systems are described in sections 5.6 and 5.7 respectively.

My analysis focused on similarities and differences presented by the students to establish the attributes that distinguished them by category (see Coupland & Crawford, 2002), and how employing the structure of the Queensland Studies Authority science curriculum in a classroom enabled or limited the agency of these students. My analysis produced three categories of how they represented energy and force, through speaking, writing, drawing and direct action and three categories of how they participated in learning the concepts of energy and force. It concluded descriptions of students' competence in Standard Australian English, translation from Standard Australian English to Torres Strait Creole and employing Torres Strait Islander knowledge systems. The categories and descriptions represent the relationship between me (the researcher) and this data as I experienced the phenomena of doing my research. What emerges is a partial understanding that cannot be empirically tested. I tried to make sense of the data by highlighting the qualitatively different ways in which the students learn, know and (re)produce knowledge of the concepts of energy and force.

Table 2: Summary of findings from data analysis

		Girls	**Boys**
Employing formal science language	Category A	(5) G3, G4, G7, G8 and G9	(4) B9, B10, B16 and B17
	Category B	(12) G1, G2, G5, G6, G16, G17, G18, G19, G20, G21, G22 and G23	(3) B6, B7 and B8
	Category C	(6) G10, G11, G12, G13, G14 and G15	(14) B1, B2, B3, B4, B5, B11, B12, B13, B14, B15, B18, B19, B20 and B21
Participation in science learning	Category 1	(1) G9	(4) B9, B10, B16 and B17
	Category 2	(16) G1, G2, G5, G6, G16, G17, G18, G19, G20, G21, G22, G23, G3, G4, G7 and G8	(3) B6, B7 and B8
	Category 3	(6) G10, G11, G12, G13, G14 and G15	(14) B1, B2, B3, B4, B5, B11, B12, B13, B14, B15, B18, B19, B20 and B21
Competence in Standard Australian Enlish	Competent	(5) G3, G4, G7, G8, and G9	(2) B9 and B10
	Less Competent	(18) G1, G2, G5, G6, G10, G11, G12, G13, G14, G15G16, G17, G18, G19, G20, G21, G22 and G23	(19) B1, B2, B3, B4, B5, B6, B7, B8, B11, B12, B13, B14, B15, B16, B17, B18, B19, B20 and B21
Total		23	21

5.3 Employing formal science language

Bourdieu's sociology favours classification as a means of understanding order through ordering. Classification is an arbitrary cultural act, and, from the research cycles, I eventually deduced that there were three categories of how these students employed formal science terminology, and demonstrated knowledge of scientific concepts and processes. I identified three categories of how they were employing formal science terminology (in Standard Australian English) to demonstrate their understandings as this is what is actually measured in formal and standardised assessment procedures.

Category A were 9 students (20%) who could use scientific terminology (instructional words and science concept words) to explain and demonstrate concepts of energy and force through speaking, writing, drawing and direct actions. They were able to use scientific genre in speaking and writing to explain and actively demonstrate the concepts of energy and force; label diagrams correctly in Standard Australian English using appropriate terminology; and show evidence of phonic awareness and textual interaction (making meaning) employing the scientific terminology for Level 4 and 5 of the Queensland Studies Authority *Science: Years 1 to 10 Syllabus* (2004). Only nine out of 44 students (20%) were able to do this. These students were five girls (G3, G4, G7, G8 and G9) and four boys (B9, B10, B16 and B17). Students B16 and B17, though they had limited facility in English, were able to negotiate learning school science using a combination of instructional words in science, direct action (body language and gestures) and Creole language substitutes and body movements.

Category A students were able to:

- Use scientific genre in speaking and writing to explain and demonstrate the concepts of energy and force. They were able to articulate a string of sentences in Standard English, using level five instructional and science words from the *Science: Years 1 to 10 Syllabus* (QSA, 2004).

- Use scientific genre in labelling their drawings to explain and demonstrate the concepts of energy and force. They were able to use the level five instructional and science words from the *Science: Years 1 to 10 Syllabus* (QSA, 2004) to label their diagrams.

- Use scientific genre to demonstrate by direct action the concepts of energy and force. They were able to use body language to express their understanding of the level five instructional and science words from the *Science: Years 1 to 10 Syllabus* (QSA, 2004).

- Show evidence of phonic awareness and textual interaction (making meaning) with scientific words and concepts. They showed phonic awareness and textual interaction with the level five instructional and science words from the *Science: Years 1 to 10 Syllabus* (QSA, 2004).

All seven students who were categorised as competent speakers of English were among the nine students in Category A. Two other students in the group B16 and B17 had limited facility in English, but were able to demonstrate their understanding of science words and concepts in combination with Creole language substitutes. I concluded that they had grasped Level 5 concepts even though they did resort to explanations in Creole.

In Category B were fifteen students (35%) who could use limited scientific vocabulary to demonstrate by direct action their understanding of the concepts of energy and force, and could only marshal a limited set of terms with which to label their diagrams and drawings. They showed evidence of phonic awareness, in that they tried to pronounce the terms correctly according to Standard Australian English, but only demonstrated limited textual interaction (making meaning) with scientific words and concepts. They could demonstrate understanding in the context of hands-on activities (designed to elicit such), but their control of written vocabulary was limited. The fifteen students were twelve girls (G1, G2, G5, G6, G16, G17, G18, G19, G20, G21, G22 and G23) and three boys (B6, B7 and B8).
Category B students were able to:

- Use limited scientific vocabulary in their speaking and writing to explain and demonstrate the concepts of energy and force. The students were code switching (language switching) between English and Creole languages. As a result of this code switching, they used limited science terminology (instructional words and science words), and produced minimal formal writing. Harris (1990) explains that code switching or language switching is conscious and deliberate switching of chunks of language by an individual. The students managed the language negotiations employing a combination of instructional words in science, direct action and Creole language substitutes.

- Use limited scientific terminology in labelling their drawings to explain and demonstrate the concepts of energy and force. They preferred drawing to speaking and writing about the concepts. As a result, they produced a number of diagrams with limited use of science terminology, and used some Creole words in labelling these diagrams to reproduce their understandings.

- Use limited scientific language to demonstrate by direct action the concepts of energy and force. They used body language to code switch English with Creole language substitutes to demonstrate their understanding. This code switching resulted in students using less formal scientific terminology.

- Show evidence of phonic awareness and limited textual interaction (making meaning) with scientific words and concepts. While they attempted to pronounce most of the science terminology in Standard Australian English, they showed limited success in code switching and making meaning with the science concepts words.

In Category C were Torres Strait Islander students who did not use scientific terminology to label their drawings to explain and demonstrate the concepts of energy and force; they did not use scientific terminology to demonstrate their understandings using hands-on eliciting activities; they showed limited evidence of phonic awareness and no evidence of textual interaction (making meaning). These students found it difficult to describe concepts using Standard Australian English. This meant as teacher/researcher, I could not appropriately assess their levels of scientific understanding using eliciting activities, such as demonstrations and drawings, oral explanation or written work using Standard Australian English. Twenty of the forty four students (45%) were classified in this category, meaning that almost half the students in this study were unable to employ science terminology to demonstrate or represent their scientific understandings. The students were six girls (G10, G11, G12, G13, G14 and G15) and fourteen boys (B1, B2, B3, B4, B5, B11, B12, B13, B14, B15, B18, B19, B20 and B21). This does not mean that the students in this category did not understand the concepts, only that they could not express what they knew in the formal language of secondary science education, conducted and assessed in Standard Australian English.

Category C students:

- Did not use scientific genre in labelling their drawings to explain and demonstrate the concepts of energy and force at all. These students had severe communication problems in English, and preferred to use their Creole language. They also preferred to draw diagrams, and did not use science words to label the diagrams. When they attempted to use English science terminology, they code mixed (language mixed) between the English science words and Creole words. Harris (1990) explains that code mixing or language mixing is random mixing of bits (or units) of language. This meant that in some instances, the students could not distinguish between English and Creole language words.

- Did not use scientific genre to demonstrate by direct action, the concepts of energy and force. The students did a number of demonstrations in the outdoor science classes, but did not use science terminology. They would wait for others in the group to demonstrate, and they would imitate those students, meanwhile repeating the Creole language substitutes the students would have used.

- Showed limited evidence of phonic awareness and no evidence of textual interaction (making meaning) with scientific words and concepts. They avoided using or repeating the science terminology used, in case they pronounced them wrongly. The students would repeat Creole language substitutes, and showed no textual interaction with the science terminology since they avoided using the terminology.

Table 3: Main features of the categories of employing formal science language for the concepts of energy and force.

Category	Referential features	Structural features	Number
A	Students who could use scientific terminology to explain and demonstrate the concepts of energy and force through speaking, writing, drawing and direct actions.	Used scientific terminology in speaking and writing to explain and demonstrate the concepts of energy and force. Used scientific terminology in labelling their drawings to explain and demonstrate the concepts of energy and force. Used scientific terminology to demonstrate by direct action the concepts of energy and force. Evidence of phonic awareness (how the words sound) and textual interaction (making meaning) with scientific words and concepts	9 (20%)
B	Students who could use limited scientific terminology to explain and demonstrate the concepts of energy and force in terms of direct action. Students were code switching.	Used limited scientific terminology in the speaking and writing to explain and demonstrate the concepts of energy and force. Used limited scientific terminology in labelling their drawings to explain and demonstrate the concepts of energy and force. Used limited scientific terminology to demonstrate by direct action the concepts of energy and force. Some evidence of phonic awareness (how the words sound) and limited textual interaction (making meaning) with scientific words and concepts	15 (35%)
C	Students who could not use scientific terminology to neither describe in English nor display by direct action their knowledge of energy and force. Students were code mixing.	Did not use scientific terminology in labelling their drawings to explain and demonstrate the concepts of energy and force. Did not use scientific terminology to demonstrate by direct action the concepts of energy and force. Limited evidence of phonic awareness (how the words sound) and no evidence of textual interaction (making meaning) with scientific words and concepts	20 (45%)
		Total	44

Students in Category A were able to display their descriptions of energy and force by using their language capacity to listen, speak, read and illustrate the concepts by direct action. What distinguished the students in this category was that they were able to string together a number of sentences about the science concept they were investigating in mostly one language. They were able to use English scientific terminology to speak and write about the concepts of energy and force. They were able to decipher the phonic awareness (how the words sound with a Standard Australian English accent) and the textual interaction (making meaning) of the scientific words and concepts. Cleote (2010) writes that being at ease with the English language expands access to significant resources available in this language. Seven students had facility in English as a result of living on the mainland for some time.

These students were able to distinguish the everyday meaning of the concepts of energy and force from the scientific meaning, and used an 'acceptable' form of English language that presented structured, scientific knowledge, as defined by Level 4 and 5 learning outcomes of *Science: Years 1 to 10 Syllabus* (QSA, 2004). They represented energy as a property of the body, defined energy as capacity to do work, correctly identified sources of energy, and traced energy changes. They presented force as acting on a body, defined force as push and pull, demonstrated effects of a force, and represented the concept that a force has magnitude and direction. They were able to use their competence and facility in the English language to present labelled visual texts (pictures, drawings, concept maps, flow charts) and perform direct action with scientific language to illustrate their scientific knowledge of the concepts of energy and force.

Students in Category B described the concepts of energy and force using limited English science language. They presented visual text – pictures, drawings, concept maps – with fewer English science words labelled correctly, compared to students in Category A. They demonstrated an understanding, however, of the concepts by performing direct action (using gestures) and employing a mix of English science words and Creole language words. The students were code switching (language switching) between English and Creole, where switching is defined as conscious interchange of language (see Harris, 1990). While the code switching was a good strategy to employ to be able to negotiate the language challenges, it encouraged students to use less precise English science language as prescribed by Level 4 and 5 learning outcomes of the Queensland Studies Authority mandated science curriculum. Harris (1990) suggests that if a society does not use language extensively for particular kinds of scientific differentiation, then the language might not have words for those purposes.

Because the students did not use precise English science language, their scientific knowledge was not well structured, as set out by Level 4 and 5 learning outcomes of the Queensland Studies Authority mandated science curriculum. Students in this category said, “fruit is energy” and, “fuel is energy”, and not the precise scientific understanding which explains energy as a property of a body. They used these examples to illustrate conversion of energy as “fruit is energy when I eat it”, and “petrol is energy when a car uses it”. These statements, while they imply basic scientific understandings, do not represent conventional scientific understanding at Levels 4 and 5, which is generally expected for year 9 students in Queensland. Students in this category also illustrated the ideas of direction and size of a force and effects of a force, in their visual texts and using direct action, while code switching between English and Creole languages. As a result, these students’ descriptions had evidence of phonic awareness of the few science words they used, but less evidence of text interaction (making meaning of precise science understanding) with most science words and concepts.

Students in Category C displayed limited evidence of phonic awareness of scientific words and no evidence of text interaction with the scientific words and concepts. The students in this category were code mixing (language mixing) between English and Creole. They were able to produce visual texts in the form of drawings, and used direct action to demonstrate their understanding of the concepts. However, a reliance on code mixing two languages resulted in them confusing English science words and Creole words. Cummins (1986) argues that someone knowing two languages less than well is worse off than knowing one language very well. Students in this category produced a distorted understanding of the science concepts of energy and force, and could not reproduce any apparent evidence of scientific language and evidence of scientific knowledge as prescribed by Level 4 and 5 learning outcomes of the Queensland Studies Authority mandated science curriculum.

The problem of code switching and mixing was compounded because of the nature of my science classroom interactions, the habitus of the classrooms, where all participants (including me) were using a second, third or fourth language to learn the mandated science content and scientific processes. Being reflexive, I had to take into account my own position, my set of internalised structures, and how these were likely to affect my research study (see Denzin & Lincoln, 2003b). The evidence suggests that lack of facility in English is associated with an unwillingness to actively participate in classroom learning. Active, participatory learning is a highly desired pedagogy in the middle school science curriculum in Queensland. I set up many hands-on demonstrations and activities, and made detailed observations of how the students acted and conversed in formal lessons, in order to research the nexus between English language facility and willingness to engage with hands-on learning in year nine science.

I observed that the students were conceptualising science instruction words, using a combination of body action and Creole substitutes. Though we failed to directly translate the instruction words, using Torres Strait Islander dictionaries and word banks, the students were putting science instructional words into action, which is putting the science instruction words into body action, combined with Creole language substitutes. The quandary I found myself in was that if I discouraged my students from using Torres Strait Creole substitute words, was I not conveying to them that their language was inadequate or inappropriate to use? I realised that it would deny my students the use of their cultural resources that they have accumulated to learn science. This was against everything I stand for, and is the main purpose of this research, which was to mobilise these students' cultural resources when learning science. If I continued to allow or encourage them to use their Torres Strait Creole substitutes in their talking, writing and labelling of drawings, I then wondered, was I promoting a 'science language' that is not recognised by science educators, a 'science language' that would probably guarantee that my students would 'underachieve' in the state, national and international assessments? I made the following reflections: *Were the students able to hold productive learning conversations with me or with each other? Were they willing to take the lead and contribute to class discussions or* *did they hold back? Were they shy or reluctant or distractible, because of a lack of facility in Standard Australian English?*

5.4 Participation in science learning

I undertook a second analysis, and analysed the students in terms of my recorded observations of their level of engagement and participation in the classroom. Three categories captured levels of student confidence to engage in science learning in Standard Australian English. Only five students (11%) were categorised as Category 1 active learners. These were independent students who attempted to establish their own narrative, and compared their thinking with established scientific knowledge, used scientific terminology accurately, and understood and employed instructional words competently. Three of these students were identified as competent speakers of Standard Australian English. The students were one girl (G9) and two boys (B9 and B10). Two boys in this category, B16 and B17, were identified as having limited facility in English, but managed to participate actively in science learning, using a combination of direct action, English science words and Creole language substitutes. All five students were among the nine students in Category A, employing formal science language.

Category 1 students were:

- Active learners who seemed to be insiders in the generation of scientific knowledge. These students were active in both indoor and outdoor science activities. They took up leadership roles, and took the initiative in doing science activities and translating instruction words to their peers. Their behaviour was aligned with Queensland Studies Authority mandated syllabus guidelines and descriptors, which highlight the importance of knowledge, understanding and scientific ways of working, which includes investigating, communicating and reflecting (QSA, 2004).

- Independent learners who tried to give explanations of the scientific knowledge as their own narrative. These students were labelled as independent in the sense that they were attempting to bring the self into learning. They attempted to construct meaning, practised critical and creative thinking and problem solving, and demonstrated decision making capabilities (QSA, 2004).

- Learners who compared their thinking with the established scientific knowledge. They attempted to think out problems, and write down what they thought, before consulting the textbook or me for assistance.

- Learners who used scientific language: science words and instructional words in science. They attempted to use the instructional words and science words while participating in science learning.

Category 2 consisted of nineteen students (43%) who were passive participants in science activities on topics of energy and force. Four girls (G3, G4, G7 and G8) who were identified as competent speakers of English, and were among the nine students in Category A on employing science language, slipped to Category 2 on participation in science learning because they did not consider themselves as players in the generation of scientific knowledge, and sought explanations of scientific knowledge from me or textbooks. The four girls were not interested in doing science activities and learning about science independently. Student G4 commented, “Science is too hard; I do not really enjoy doing those experiments”. She complained that science was hard before attempting the learning activities. I attributed the attitude that G4 had towards science to her previous experiences. The four girls had the language capacity to engage with Level 4 and 5 learning outcomes of the mandated Queensland Studies Authority science curriculum, but chose not to utilise that resource. Even in the third cycle of data collection, during the outdoor science activities, these girls did not want to take up the initiative in science activities, and were happy to take the role of recording the measurements.

The students in Category 2 were sixteen girls (G1, G2, G5, G6, G16, G17, G18, G19, G20, G21, G22, G23, G3, G4, G7 and G8) and three boys (B6, B7 and B8).

Category B students were:

- Learners who were consumers, and did not consider themselves as players in the generation of scientific knowledge. They were slightly active in the indoor science activities and much more active in the outdoor science activities, but wanting to take up a secondary role like recording data, and not major players acting out the science activities. The students in Category B who code switched, I suspected, did so due to lack of confidence with using the English language, and were not sure if and when they should use their Creole language.

- Learners who sought explanations of scientific knowledge from the teacher or textbook. Their first step was to consult me or a textbook before attempting to think the issue through, unlike students in Category 1. They wanted me or the seven students with facility in English to think along with them, and constantly wanted confirmation that they were on the right track.

- Learners who used limited scientific language: science words and instructional words in science. These students were code switching most of the time, which meant that they were employing few English science words.

The fifteen students in Category B who used limited scientific language to explain and demonstrate the concepts of energy and force, were among the nineteen students in Category 2 on participation in science learning, who did not consider themselves as active generators of scientific knowledge, and sought explanations of scientific knowledge from me or from textbooks.

Category 3 consisted of twenty students (45%), who were minimal participants in science activities on topics of energy and force. The twenty students who were in Category C, who did not use scientific language to either describe in English or display by direct action their knowledge of energy and force, were the same twenty students in Category 3 on participation in science learning, who were minimal participants learning the science concepts of energy and force. The students were six girls (G10, G11, G12, G13, G14 and G15) and fourteen boys (B1, B2, B3, B4, B5, B11, B12, B13, B14, B15, B18, B19, B20 and B21).

Category 3 students were:

- Learners who seemed to be ‘outsiders’ in the learning of scientific knowledge. Most of them were not active during indoor science activities (except for science learning activities on the traditional drum and didgeridoo). Though students in this group used direct action (gestures and body movement) during outdoor science activities, they were classified as minimal participants because they were not able to interact with Level 4 and 5 science terms from the *Science: Years 1 to 10 Syllabus* (QSA, 2004). I realise that if these students were learning a science curriculum that recognised other literacy dimensions like the use of Creole, they might not be classified in this category.

- Learners who used very few scientific language, science words and instructional words in science. This group of students were code mixers, and achieved very few of the Level 4 and 5 learning outcomes of the *Science: Years 1 to 10 Syllabus* (QSA, 2004), and used very few science terminologies.

Table 4: Main features of the categories of participation when learning the concepts of energy and force.

Category	Referential features	Structural features	Number
1	Students who are active participants in the learning of the concepts of energy and force.	Active learners who are insiders in the generation of scientific knowledge. Independent learners who give explanations of the scientific knowledge as their own narrative. Compare their thinking with established scientific knowledge. Use of scientific language.	5 (11%)
2	Students who are passive participants in the learning of the concepts of energy and force.	Learners who are consumers and do not consider themselves as players in the generation of scientific knowledge. Seek explanations of scientific knowledge from the teacher or textbook. Limited use of scientific language.	19 (43%)
3	Students who are minimal participants in the learning of the concepts of energy and force.	Learners who seemed to be 'outsiders' in the learning of scientific knowledge. Use very few scientific terms.	20 (45%)

This categorical data indicates a possible relationship between a student's ability to use English with facility and their willingness to be active learners of science in the classroom. What I attempted in Table 5, where I have categories A1, A2, B2 and C3, was to combine the two categories that emerged from the study, to indicate a possible relationship between students' ability to use English with facility and their willingness to actively participate in science learning. I decided that I needed to distinguish them first, and then attempt to combine them for the specific purpose of attempting to ascertain a possible relationship.

Table 5: Summary of student categories

Categories	Number of students	Percentage of study group	Main structural features of competence in Standard Australian English and participation in learning science
A1	5	11%	Competent in Standard Australian English, able to demonstrate understandings, active learners
A2	4	9%	Competent in Standard Australian English, able to demonstrate some understanding, passive learners
B2	15	34%	Limited competence in Standard Australian English, able to demonstrate some understanding, passive learners
C3	20	45%	Not competent in Standard Australian English, demonstrated very limited understanding, minimal participants

This simple table of results suggests that if Torres Strait Islander students bring English language capital to the classroom, they are more willing and able to enact agency as independent learners. The key concern is that only five students in this study (11% of the total) possessed the cultural capital to participate in the classroom as competent and confident learners of science with the ability to employ technical and abstract terms and mathematical symbols productively. The students in Category A were active constructors of scientific knowledge because they managed to use English with facility, and the other two boys were able to negotiate the language system. The Queensland Studies Authority science curriculum states that forces and energy are identified and analysed to help understand and develop technologies, and to make predictions about events in the world. Scientific processes, called, "Ways of Working", require that students are able to identify problems and issues; plan investigations; research and analyse data; evaluate data, information and evidence; select and use scientific equipment and technologies; conduct and apply safety audits; draw conclusions and explain patterns; communicate scientific ideas using scientific terminology in appropriate formats; reflect on learning and on different perspectives, and *evaluate the influence of people's values and culture on the application of science* (QSA 2009b, italics mine).

For forty-five percent of my students, a limited facility in English proved a barrier to their active learning participation. The scientific processes called, "Ways of Working", as formulated (QSA, 2009b), limited Torres Strait Islander students with limited facility in English language from being active participants and constructors of scientific knowledge. This group of students relied on the language capital they brought to the classroom to negotiate learning. The students used Torres Strait Creole to discuss physical science concepts in class, and were either unable or unwilling to actively construct their understandings in written or spoken English. A teacher who must teach and assess in Standard Australian English cannot judge the extent of formal science learning when adolescents call on non-English languages to construct their understandings. I argue that the benchmarked state, national or international science assessment regimes, formulated in 'standard' English, cannot judge the extent of formal science literacy and understanding when Torres Strait Islander students call on Creole languages to organise their science ideas.

5.5 Competence in Standard Australian English

The Queensland Studies Authority mandated science curriculum is formulated and assessed in Standard Australian English, but of the forty-four Torres Strait Islander students who attempted or completed the pedagogical activities in this study, I discovered that the large majority, (*n* =37, or 84%), had limited to severe difficulty communicating in English, and about half the class struggled to understand the formal terminology of the science classroom. This means 84% of the group of my students were left ill equipped to access Level 4 and 5 materials from the Queensland Studies Authority mandated science curriculum and science textbooks. Science curriculum documents and science reading materials can be made to be sympathetic to the plight of Torres Strait Islander students who have limited facility in English: they can incorporate Torres Strait Creole language and cultural resources to explore these science learning outcomes. This is not the situation at present, however.

Only seven of these students (16%) spoke and wrote Standard Australian English with facility. These students were five girls (G3, G4, G7, G8, and G9) and two boys (B9 and B10). I explored the individual trajectories of these seven students prior to coming to boarding school. I discovered that though they were originally from the Torres Strait Islands, they had spent considerable amounts of time on mainland Australia. This means that they have been exposed to the English language or similar cultural habits to mainland Australia more than the other thirty seven students who spent most of their time in the Torres Strait Islands. These seven students had acquired the cultural capital which is highly valued in the school system and in the Queensland Studies Authority mandated science curriculum, which is formulated and accessed in Standard Australian English and other cultural habits from mainland Australia.

The other thirty seven Torres Strait Islander students in the group had spent most of their time in the Torres Strait Islands prior to coming for boarding school. They had acquired cultural capital and community cultural wealth prescribed by their Torres Strait Islander habitus. These students' cultural capital and community cultural wealth that they had accumulated needs to not only be recognised, valued and utilised by the science classroom teacher, but be incorporated into the Queensland Studies Authority mandated science curriculum. When Torres Strait Islander students learn science, classroom communication may not only be in Standard Australian English, but could utilise Torres Strait Creole languages and other possible literacy dimensions of their cultures.

A distinction exists between Indigenous Torres Strait Islander students from traditional and remote communities and Indigenous Torres Strait Islander students from urban and semi-urban communities (see Mellor & Corrigan, 2004). For equity and social justice, the Queensland Studies Authority mandated science curriculum could be sympathetic to the plights of the different groups of Indigenous students, especially those who struggle to conceptualise and communicate in Standard

Australian English. I propose here that it could do this if the curriculum and pedagogy incorporate their cultures' resources.

Currently, Standard Australian English is the language in which these students are expected to produce or reproduce scientific understanding and demonstrate their control of relevant terminology, which may partially explain the standardised testing results mentioned in Chapter Three. I discovered that Torres Strait Islander students may develop quite a good understanding of science concepts, as discussed with each other and expressed in their Creole language. The study has evidence of seven students with facility in English using Creole language substitute words and direct action to 'translate' the science instruction words for the benefit of students with limited to severe difficulty communicating in English. However, unless these same adolescents are highly able to translate both language and concepts accurately into English, they are likely to be judged as attaining only "low" levels of academic achievement. By contrast to Islander adolescents, students from urban areas, who speak and think in English as a first language, are distinctly advantaged by current standardized science assessment practices. All students from remote areas, whose first language is not English, face similar challenges in terms of demonstrating what they do know about the world in the taken-for-granted culture of mass assessment.

5.6 Translation from Standard Australian English to Torres Strait Creole

I found no direct comparison between the meta-concepts of energy and force as constructed in the Queensland Studies Authority science curriculum in Standard Australian English and the concepts as constructed in Torres Strait Creole. I failed to find common comparable abstract concepts on the meta-concepts of energy and force in Torres Strait Islander students' diverse and complex languages. This was not unexpected, given "the idea that culture, through language, affects the way we think, especially … our classification of the experienced world" (Gumperz and Levinson, 1996, p. 1). I am not a linguist but a science educator, versed in the complexities of student understandings of physical science concepts. I discovered that there is no direct translation of the abstract concepts of energy and force from Standard Australian English into Torres Strait Creole. There appears no direct translation of the term “energy” (as an abstract meta-concept) from Standard Australian English to Torres Strait Creole.

Indigenous Australian languages, both new and old, are subtle, supple and highly context-specific languages. Energy and force, as constituted in the junior science curriculum, are abstracted notions, both terms being shorthand for a constellation of practical applications in specific contexts. I could not find any Torres Strait Creole term for energy, in the sense that energy is defined as the capacity to perform work and is measured through its effects. There are words such as *inzin* meaning engine; *wok* = work; *nokop* = stop working; *aute* = switch off; *opene* and *prese* = switch on; *lektrik* = electricity. But the meta-category energy, as constituted by Queensland Studies Authority science curriculum documents, is ‘untranslatable’.

Many Torres Strait Creole terms are linguistically derived from English, but this remarkable Creole reproduces and reflects Islander ways of thinking and knowing, not western ways. I discovered that recorded Torres Strait Creole (Shnukel, 1988) has no term for force as it is understood in English. Neither is the term “force” directly ‘translatable’ from Standard Australian English to Torres Strait Creole. I did find transitive verbs in Torres Strait Creole to describe the actions of force, but these terms do not and, in all likelihood, cannot capture the meta-category meaning of the term “force” such as *poke*, meaning to poke, prod or jab; *puse* and *pusem*, meaning to push; *prese*, to press, switch on; and *pule* (var. *puli*) meaning to pull (out or up). Students, in discussion with each other in the research classroom, commonly used such Torres Strait Creole language terms, particularly *pusem* and *poke*. This created a dilemma to me during classroom discussions, if I should encourage Torres Strait Islander students to use English science words and abandon Torres Strait Creole substitutes in their talking, writing, labelling of drawings and direct action. My research was always focused on how these students can use their cultural resources to better their learning in school science.

Searching through dictionaries of Torres Strait Creole languages (Shnukal, 1988; Ray, 2001), I found verbs relating to force, acting in specific contexts, including *mube* meaning to move; *asmape* meaning to hoist, lift, lift up; *kaumdaun* meaning to descend*; poldaun* meaning to fall off or fall over; *poldaun daun* meaning to fall down; *spidmape* meaning to accelerate, increase speed; *uke* (var. *uki*) meaning to hook and pull in a fish; *amare* meaning to hammer or knock; *apu* (var. *apo*, *apowe*) meaning to piggyback or carry; *bange* meaning strike or hit; *ploke* meaning to hit with a stick or other object; *paspas* meaning to get stuck (be unable to pass); *slu* meaning to turn; *slu raun* meaning to tack into the wind; and *pose* meaning to directly force something to move when it is stuck. Students, in discussion with each other, used a range of these words. Note that *pose* is a verb, and cannot be substituted for the concept noun "force" in English. While Torres Strait Creole is linguistically derived from English, this remarkable language reproduces and reflects Islander ways of thinking and knowing. It doesn't reproduce western curriculum categories, but it does have a multitude of terms for force(s) in action.

I wondered whether the action verbs for science inquiry skills could be reasonably translated to Torres Strait Creole. This is the limit of what I found: "observe" might approximate *luk, lukraun*; "compare with" might approximate *olsem*; "hypothesise" might approximate *kole,* which is translated by Shnukal (1988) as meaning "to claim"; decide might approximate *gad main*; evaluate might approximate *ting* and *ting baut*. I couldn't find any Creole terms equivalent to what is meant in the science curriculum for design experiments, follow procedures, judge, conclude, generalise, theorise, classify, describe and report. Yore (2008) points out that theoretical notion of causality within western science do not sit neatly alongside indigenous ontological and epistemological perspectives, particularly in relation to relationships between the observer and the observed, the categories used to make claims about reality and explanations about cause. There can be epistemological differences in how knowledge claims come to be known, the methods and procedures used to study phenomena, and the types of evidence used to justify and explain a knowledge claim or event. This being acknowledged, does it mean translations for the scientific process skills taught in middle school are improbable?

I was left in a dilemma, should I continue to 'allow' use of the Torres Strait Creole language in my science classroom? This is a language that is not recognised by the Queensland Studies Authority science curriculum in its formulation and assessment criteria. English is the medium of expression of 'science language'. Use of Creole would disadvantage my students from achieving in the state, national and international assessments. Linguistic standardisation has happened in many parts of the world. I propose that, in this context, linguistic standardisation between old and emerging indigenous Australian languages with Standard Australian English is mandatory. Linguistic standardisation would reduce my dilemma or similar dilemmas which teachers who teach Indigenous Australian students can encounter. I suggest that the Queensland Studies Authority mandated science curriculum could make provisions for old and emerging Indigenous languages in its formulation and assessment criteria, but, again, this is politically unlikely in the short term. Then, should Indigenous languages and knowledge systems be 'disciplined' by western frames? Nakata (2007) writes that differences at epistemological and ontological levels mean that, in academy, it is not possible to bring in Indigenous knowledge and drop it in the curriculum unproblematically, as if it is another data set for Western knowledge to discipline and test. Indigenous systems and Western knowledge systems work off different theories of knowledge that frame who can be a knower, what can be known and what constitutes knowledge.

I discovered that most Torres Strait Islander students in the study either did not know or did not wish to speak the traditional Kalaw Lagaw Ya (a related dialect of Kalaw Kalaw Ya) and Meriam language systems very well. They told me, "It is not cool to talk island Kalaw Lagaw Ya in a science class" (field notes from research journal, April 2007). It was the equivalent of teaching the students a new subject, Indigenous knowledge and language systems. As explained in Chapter Two, the Queensland Studies Authority launched a statement in April 2008, acknowledging the importance of understanding, maintaining and promoting the diverse Australian traditional Indigenous languages, and assisting schools and communities to work in partnership, and to recognise and value local, traditional, Indigenous languages and knowledge systems. I suspect that this approach can limit Torres Strait Islander students' agency when learning science if it is not intelligently implemented. The approach can be seen as teaching Indigenous students another subject, traditional language and knowledge systems and not school science knowledge. Traditional knowledge systems are localised knowledge systems (see Synott & Whatman, 1998). Torres Strait Islander students' ways of knowing are shaped by structures from these traditional knowledge and language systems (see Martin, 2008), in the sense that the Creole languages students are more familiar with are derived from traditional languages and knowledge systems. I discovered that the students seemed to agree on language terms when using Creole languages (far more than traditional languages), and I realised that Creole was the language system I needed to concentrate on to encourage classroom dialogue. This was not an easy endeavour because Creole languages have few direct comparison words with terms we used in classroom science learning, as formulated in the science curriculum. Indigenous people do not habitually use language extensively for science instructional purposes (see Harris, 1990). It was not surprising that Creole languages may not readily be used to teach classroom science in a way that fosters academically purposeful learning. Nevertheless, Creole languages, which until recently have been oral languages, can be further developed in terms of terminology for academic instruction, to empower and enable those Creole-thinking students, particularly given that Torres Strait Creole is a highly adaptable language, as I argued in Chapter Three.

The students were learning about instruction words in science, and using Creole substitutes for these instructional words, though these terms could not be directly 'translated'. I discovered that the key to understanding these words for the students was to use science instructional words with actions, which is putting the science instruction words in body action, combined with Creole language substitutes. There was evidence of students with facility in English translating and demonstrating what the science word meant. An example is when student G9 attempted to translate and demonstrate: " *yupla this kind*", while demonstrating the actions of collating data. Initially it was students with facility in English, but later it was most of the students who did this. Two students, B16 and B17, were able to move at ease between instructional words in science and Creole language substitutes in combination with body action. These two boys, B16 and B17, had limited facility in English, and had limited experience learning science from their community schools, but seemed to cross the language negotiations easily, using a combination of instructional words in science, direct action (body language and gestures) and Creole language substitutes. Phelan and colleagues (1991) suggest that a group of students, potential scientists and smart students, can have a manageable transition, though the languages and cultures they negotiate may be different.

By employing a socio-cultural lens, I was able to 'see' the learning dynamics of the students in my science class. Before the study, the students' expectations about science learning were translated to 'Blowing up stuff' or 'Learning them big words'. This notion of science was so intrinsic with students' expectations of what should be happening when they learn science. Some of the students thought science would only interest them or be fun if they 'blew things up'. They did not recognise other components of learning science, such as ways of working and construction of conceptual understanding. A limited expectation of learning science was problematic when I asked students to do science learning related activities that did not bubble or explode. The students had taken the literal meaning of 'blowing up stuff' to mean science learning, or 'learning them big words' to represent learning science. My research and learning framework employed a socio-cultural approach which promoted learning from and with others. It afforded me the opportunity of listening and learning from my students about their science learning experiences and expectations. The students' prior learning experiences and expectations had focused on making science a lot of fun, and caused misunderstandings of what science learning is and can be about.

5.7 Using Torres Strait Islander knowledge systems

My foray through Torres Strait Creole dictionaries (Ray 2001, Shnukal 1998) revealed that some effective translations are possible when considering learning the concepts of energy and force through specific contexts. It is also an easy task to teach concepts using familiar terms. When learning about energy transfer, I used the Kup Mauri, also known as a Kopa Mauri, a traditional sand oven used to cook food for feasting. Students used their communal knowledge of how to properly build a Kup Mauri, in which vegetables and meat are cooked together, to explore how heat energy is transferred from one object to another, and compare the properties and energy efficiencies of traditional oven materials and modern convection ovens, using scientific terms. Here is an extract of dialogue I had with four students (B1, B2, B3 & G1), learning about energy transfer with the Kup Mauri in March 2008:

> Me: Why do you put pork at the bottom and vegetables at the top?
> B1: It's hotter, so you put pork. If you put vegetables it burns.
> Me: So we can learn about heat distribution in the Kup Mauri oven.
> B1: Mister, we can learn science when cooking Kup Mauri, that's cool.

B3: No, science is them big words; I hate them.
Me: Yes, we can learn science when cooking Kup Mauri, and today we will use two science words: conduction and convection to describe how heat follows.
G1: My aunt says if you are slack and not cover the Kup Mauri, the food burns. (Students laugh)
B2: I was told that, why so, mister?
Me: What do you think?
G1: Aunt says wind make food burn.
Me: What in the wind will make the food burn?
B1: Aha! Oxygen, mister, *Yupla* (you me fellows) that experiment, when you cover, the fire stops, and when you open, you have fire.
Me: How can we test this?
[Conversation interrupted by Dean of Students entering room to make a sports announcement]

This conversation fascinated me most because it was the turning point of my classroom activities. I recorded in my research journal that the students had started to realise that their traditional and everyday knowledge systems had an abundance of opportunities to explore an authentic scientific inquiry, able to generate authentic scientific knowledge. An argument emerges that science curriculum and pedagogical frameworks that embrace old and emerging dimensions of Torres Strait Islander students' cultures can enrich year 9 science learning in the same way the Western ways of knowing have enriched dimensions of Torres Strait Islander culture.

I introduced the traditional drum and didgeridoo to investigate kinetic energy and sound transfer. This, too, proved popular. The students were eager to try different beats on the drum or didgeridoo and analyse waveforms on an oscilloscope. One student commented that he always knew there was something special about the skin on the traditional drums, the way his grandfather makes them, and he wanted to investigate those possibilities further. I introduced the marbles game when learning about gravitational potential energy and kinetic energy. The students enjoyed the marble activity and asked to repeat it several times. I took the class to the sports field to explore concepts of speed, acceleration, gravitational pull and friction drag force. They were eager to take turns performing the activities, recording and calculating the different speeds. What amazed me was that during indoor science activities, students asked for calculators to do the calculations for speed, but during outdoor hands-on activities, the same students were encouraging each other to do the calculations mentally.

Students' participation, engagement and application of concepts improved significantly during outdoor hands-on activities.

I observed how employing learning strategies that recognise and celebrate Torres Strait Islander ways encouraged the students, generating enthusiasm, engagement and the all-important 'shining eyes, smiling faces' outcome (see Whitehouse, 2007). With careful and creative thought, it is quite possible to position indigenous students as knowledge creators, capable of controlling their own learning. Osborne and Tait (2002) suggest that it is time for teachers to test at classroom level framings that reflect social justice as well as curriculum justice. I propose here that the classroom level framings Osborne and Tait suggest can and do imply pedagogical content knowledge, which was defined in section 1.4 as "teachers' interpretations and transformations of subject matter knowledge in the context of facilitating students' learning" (Van Driel, Verloop & de Vos, 1998, p. 674). These thoughts are discussed more fully in the next chapter.

5.8 Summary

In this chapter, I presented my findings and interpretations from my data analysis and the connections between a student's ability to use English with facility and their willingness to be active learners of science in the classroom. The categories of how students were able to use science terminology, participate in learning science and their level of engagement in the science classroom suggests that if the students bring English language capital to the classroom, they are more willing and able to enact agency as independent learners and a limited facility in English proved a barrier to their active learning participation. The findings also indicate that when Torres Strait Islander students with limited facility in English learn science, their classroom communication may not be in Standard Australian English, but could utilise Torres Strait Creole languages. I have argued that science curriculum and pedagogical strategies that embrace old and emerging dimensions of Torres Strait Islander students' cultures can enrich year 9 science learning in the same way that the Western ways of knowing have enriched dimensions of Torres Strait Islander culture. The next chapter reflects on these findings.

Chapter 6
The need for pedagogical strategies

6.1 Introduction

In this section I discuss my thinking about the findings from data analysis and pedagogical strategies with Torres Strait Islander students learning the physical science concepts of energy and force around six themes that emerged from the study. In section 1.4, I explained that pedagogical content knowledge implies how I transform physical science subject matter knowledge of the concepts of energy and force from the Level 4 and 5 learning outcomes of the Queensland Studies Authority science curriculum; how I relate that transformation to my Torres Strait Islander middle school students; and how I use the students' cultural resources to transform the physical science subject matter. The first theme takes into account the students' competence in speaking, reading and writing Standard Australian English with facility. The second theme explores how Torres Strait Creole can be used as a resource for learning western science concepts more productively in the classroom. The third theme takes into account the interactivity of language and knowledge systems when these students engage in learning the physical science concepts of energy and force. The fourth theme recognises that most Torres Strait Islander middle school students from remote communities in North Queensland are multi-lingual/cultural. They deal with multiple language systems even before they engage with language challenges in science learning. The fifth theme calls for the rethinking of science literacy and classroom discourse with these students. The sixth theme concerns ontological issues that arise at conceptual content level (Nakata, 2007). I argue that the Queensland Studies Authority science curriculum as it is currently constituted makes little real concessions to Indigenous ways of knowing, and that general concerns about equity, in terms of assessment of learning in science, have real substance, as this study has shown.

6.2 Speaking, reading and writing Standard Australian English with facility

My formal training as a science teacher did not equip me with pedagogical frameworks that suit Torres Strait Islander middle school students in a middle school science class with limited competence in speaking, reading and writing Standard Australian English. Prain and Waldrip (2010) write that challenges can arise in relation to science teachers' own understandings of the complex relationship between key concepts and their co-ordinated representation, as well as pedagogical strategies.

Reflecting on pedagogical content knowledge, the elements here concern me as a science classroom teacher transforming knowledge of representations of the concepts of energy and force, and understanding and relating to Torres Strait Islander middle school students' learning challenges (see Shulman, 1986). Only nine students (20%) in this study showed the capacity to be competent and confident learners of science, able to employ technical and abstract terms and mathematical words and symbols effectively to demonstrate their knowledge of physical science concepts and position themselves as active constructors of scientific knowledge. Seven of these students spoke and wrote Standard Australian English with facility. I suggest that the ways Level 4 and 5 learning outcomes of *Science: Years 1 to 10 Syllabus* (QSA, 2004) are formulated are suited for the 20% of students in this study with facility in the English language. This implies that the majority of the students (80%) could not adequately 'access' these Level 4 and 5 learning outcomes. Pedagogical strategies with learning outcomes and experiences, using Standard Australian English as the only science concept descriptors, might assist 20% of Torres Strait Islander students' negotiations from Standard Australian English into science, and might not adequately facilitate 80% of these students' negotiations from their vernacular languages into science.

The second category employing formal science language (see Section 5.3) had fifteen students (35%) who used limited scientific terminology, and could only marshal a limited set of terms to demonstrate their understanding of the science concepts. The students consciously switched between English and Creole. The ways that the Level 4 and 5 learning outcomes of *Science: Years 1 to 10 Syllabus* (QSA, 2004) are currently formulated does not recognise the language switching of Torres

Strait Islander students with limited facility in Standard Australian English. Yet, the language switching is the immediate vehicle these Torres Strait Islander students can employ to learn school science. I have experienced this predicament as a student and English language learner. I switched languages (Shona and English) in my science classes when I learnt a science curriculum formulated in a similar fashion. I also taught Indigenous students in Zimbabwe, southern Africa, who were switching languages (Shona/Ndebele and English), before teaching this group of Indigenous Torres Strait Islander students.

Some educators have emphasised that Indigenous students should become competent in English literacy, as supported by Australian literacy initiatives, so as to engage with Australian curricula, which are formulated and assessed in Standard Australian English. However, to emphasise that Torres Strait Islander students become competent in Standard Australian English so as to engage with the Queensland Studies Authority *Science: Years 1 to 10 Syllabus* (QSA, 2004) as currently formulated denies these students the opportunity to learn science using their cultural resources. In this study, I assumed that these students would have been taught in Standard Australian English (as prescribed by the mandated Queensland Studies Authority curricula) for the past seven or eight years, in their community schools, prior to coming to boarding school, but, as data showed, a majority of the students have not as yet acquired facility with the English language sufficiently to achieve the Level 4 and 5 science learning outcomes (QSA, 2004). Furthermore, there is no guarantee that these students will acquire facility with the English language in the near future. This means that these students' formal learning of the school science concepts set out by the Queensland Studies Authority science syllabus may not happen in their immediate life time. I think this raises serious equity concerns.

I became most concerned with twenty students (45%) in the group (Category C for employing formal science language – see Section 5.3) for whom a limited facility in English proved a 'barrier' to participation in the formal discourses of science education in secondary school. These students unconsciously mixed languages (see Harris, 1990) between English and Creole, and sometimes could not distinguish words of one language system from another. Many Torres Strait Creole terms are linguistically derived from English (see Shnukel, 1988), but reflect Islander ways of thinking and knowing and not western ways. These students used Torres Strait Creole to discuss physical science concepts in class and were unable or unwilling to formally demonstrate their understandings in written or spoken English. These students' "cultural capital" (see Bourdieu 1986) in terms of what they can do and know, can not be captured in a situation where they are to be wholly taught and assessed in Standard Australian English. To quote Malcolm (2002, p. 131):

> The school context may confront Aboriginal and Torres Strait Islander students not only with modes of expression and interaction which are unfamiliar to them, but also, at least by implication, with messages that deny their own identity. The standard English which is used without question … is not neutral to people to whom it has always been the language of the "outsider" …The exclusion of Aboriginal and Torres Strait Islander languages and Aboriginal English from classroom communication is a symbolic exclusion of the identity and perspectives of those who speak them … It forces a choice upon Aboriginal and Torres Strait Islander students either to suspend or deny their identity, or to accept the status of "outsiders" to the education system.

This research was conducted in a wholly Indigenous school where Aboriginal and Torres Strait Islander identities are explicitly celebrated, and half the students in the study struggled to engage with the compulsory school science curriculum. What does it mean for a middle school Indigenous adolescent, who may know how to identify problems, plan, research, analyse, evaluate and explain patterns, but can not communicate their scientific ideas in the required language? What if you thought in Creole, but could not communicate the complexity of your thinking in a different language? I sometimes think in Shona, while having to communicate in a second and third language. I have continually switched between different language and knowledge systems in my teaching career with indigenous students. I observed my Torres Strait Islander students attempting to do this, too, that is think in Creole and then attempt to write and speak English with a different degree of willingness depending on the difficulty of the learning task. How would you recognise yourself, or perform as an active learner in such a differentiated cultural field? One finding from the research is that Torres Strait Islander students and Indigenous students are disadvantaged, they participate in school science curricula that do not value their specific cultural ways of knowing and doing and their language attributes. There are implications for how science educators view pedagogy in the Indigenous classroom.

How would a teacher implementing a constructivist approach or the 5Es learning approach as articulated in the *Primary Connections* Indigenous perspective model (see Chapter Three), capture the resources that Indigenous Torres Strait Islander students, who think in their home or Creole languages, bring to the classroom? Malcolm (1998, p. 125) is very clear that “when Torres Strait Islander students come to school with the ability to understand or speak an [Indigenous] language they possess a significant resource … of linguistic and cultural knowledge … that demonstrate they have a ‘track record’ as successful learners in experiential contexts”. I suggest that pedagogical content that can empower and enable these students, needs to focus on linguistic and cultural knowledge that the students demonstrate in experiential contexts. Formal schooling can complement students’ prior learning experiences, and most science educators who are persuaded towards the constructivist learning and teaching approach would agree. The problem is at a systemic level, where mandated science curricula relentlessly treat the standard language of instruction and assessment as neutral, when clearly it is not. This study’s data raises many questions which I struggle with on culturally responsive pedagogy. In the next sections I discuss how Torres Strait Creole dimensions could be used as a resource for learning school science concepts more productively in the classroom, and express my current concerns about equity and assessment in middle school science.

6.3 How Torres Strait Creole dimensions can be used more productively

In the previous section, I suggested that forty five percent of Torres Strait Islander middle school students in the study, with limited facility in English, were constrained by the structure of the formal and state mandated science curriculum to engage meaningfully with science learning. These students are effectively ‘denied’ the opportunity to mobilise and marshal their linguistic cultural capital to enhance their learning of science in a curriculum formulated, taught and assessed using only Standard Australian English concept descriptors. The study shows that there is a need to develop pedagogical strategies that may empower and enable these students by employing Torres Strait Creole language and cultural dimensions more productively in the science classroom.

Consideration of Torres Strait Islander students' everyday oral and written languages and how they create new meaning and understanding can be the starting point. In this study, I adopted a socio-cultural learning to investigate actual classroom practice, and from my data analysis three distinct groups emerged who had different capacities in terms of how students employed formal science language and participated in science learning. The different capabilities can and do imply different needs in terms of supporting students required to formally learn science. To enhance conceptual learning, this support needs to focus on two groups of words used in talking and writing science, which are science terms and instruction words in science. As described in Chapter Four, science terms include technical terms, theoretical entities, abstract idealisations and mathematical words and symbols. I failed to identify common comparable Creole language equivalents for most of the science terms and concluded that these needed to be taught in English (see Chigeza, 2008). Science terms are associated more with established content knowledge of science subject matter, and concern the students learning about science knowledge that other people have generated. The *Science: Years 1 to 10 Syllabus* (QSA, 2004. p. 1) suggests that, "scientific knowledge is a set of explanations made by communities of scientists... Like scientists of the past and present, students understand and appreciate that current scientific knowledge has been built up over time and has been organised into disciplines and fields." Because of this, any attempt to change the science terms changes the intended 'universal' meaning of the science subject.

The situation is not the same for instructional words in science learning, which I suggest can have a more direct influence on the agency of the learner. Examples of instructional words in science learning include observe, describe, compare, classify, analyse, discuss, hypothesise, theorise, question, challenge, argue, design experiments, follow procedures, judge, evaluate, decide, conclude, generalise and report. While maintaining 'universal' meaning and implication for instructional words in science is necessary for communicating science ideas, these instructional words play a central role concerning the learner generating their own knowledge (see Chigeza, 2008). I suggest that Torres Strait Islander students can construct knowledge for themselves by bringing new insights into the meanings, interpretations and implications of these instructional words in science. The study has evidence of these students making meaning of these words by using direct action (body movement) in combination with Creole language substitute words (a result of 'code switching' between English and Creole).

Pedagogical strategies can include a more systematic approach that manages this type of meaning negotiation by different groups of Indigenous students in a more positive and informed way, and can be implemented in classroom situations with Indigenous students to reflect a more 'universal' scientific approach. I have thought long and hard about using animations and Smartboards for this purpose. Nathan (2000) suggests that the historical, Indigenous alienation from the written word – perceived as a one-way communication system, quite discontinuous from Indigenous forms of communication – is not sustained in the interactive network environment. The online, interactive, network environment has reconstituted the balance between visual, oral and textual modes of presenting information, in ways that can support Indigenous people's cultural perspectives. The online environment helps "destroy the myth that meaning is really contained in text, by highlighting the inter-dependence of documents and showing that meaning arises from the relationship between texts and from our interactions with them" (Nathan, 2000, p. 41). At the time of writing this thesis, I was teaching myself animation, and exploring its possibilities for negotiating the meaning of instruction words in science learning.

Torres Strait Islander students negotiate meanings and understandings of instructional words in science learning from their everyday languages, body movement and experiences. The study shows evidence of students in all the three categories talking about science in their Creole languages, with students with facility in English, attempting to 'translate' instructional words to those with limited facility in English, using body movement and 'code switching' between English and Creole, and students with limited facility in English attempting to conceptualise the 'translated' instructional words. I observed that Creole language substitute words can be used to aid instructional words in science to negotiate and construct new meaning and understanding, and even to assess these students. The study has evidence of students who had facility in English attempting to assess and judge the comprehension of those with limited facility in English. I argue for developing pedagogical strategies with teaching and learning frameworks that accommodate these students' 'code/language switching' and everyday ways of talking and knowing in science teaching and learning. Torres Strait Islander students, especially those categorised as having limited facility in English, can thereby be encouraged to talk about science in both Creole and the English language, to enhance not only their understanding of school science, but a two-way flow of language and cultural understandings. Researchers, teacher educators and classroom teachers might wish to further explore how these languages and knowledge systems can be validated and recognised in the school science curriculum, and improve linguistic and cultural diversity in the Queensland and Australian education systems. Not that this is an easy task.

Interchanges between Torres Strait Islander students' cultural and everyday ways of knowing and talking and school science ways of knowing and talking can be established, as I have shown in this study. The human mind is a pattern recogniser and builder, and the world is infinitely full of potentially meaningful patterns in many domains (see Golatti, 2004). Gee (2005) suggests that socio-cultural practices and settings guide and norm these patterns. I suggest that animation can be part of the socio-cultural practice in science classrooms. This means that students' socio-cultural practices and settings can guide and norm how they think, act, value and interact in a science classroom. Negotiating meaning by the students involves more than just reading and writing in Standard Australian English. Negotiation of meaning must involve how they interpret information received through their five senses and how they are guided by their socio-cultural practice. The task for both education researchers and classroom practitioners is to develop pedagogical strategies within appropriate frameworks to build conceptual linkage between Indigenous students' perspectives and formal school science. The conceptual linkage can be made to adequately facilitate these students' negotiations and 'code switching (or language switching)' from their vernacular languages into science.

6.4 The interactivity of language and knowledge systems

I do not advocate that direct translation of the different language and knowledge systems is the solution, as I agree with Michie's (2002) position that attempts at direct translation may lead to a rewrite of meaning. Direct translation is not a general solution to the overall problematic situation of field negotiations. This does not mean, however, that attempts at direct translation of Creole should be excluded from the classroom. I argue that the opposite should be true: functional substitutes with respect to instructional science terms, derived from the students' everyday languages and experiences, can be adopted in the science class discussions to enhance the students' agency. I have run a successful teaching career for twenty years working in English and sometimes thinking in Shona. I suggest here that I have developed my personal pedagogical framework, which enables me to work in English while thinking in Shona (or work in Shona while thinking in English). I want to argue that using old and emerging language and knowledge resources of Indigenous Torres Strait Islander students would assist their conceptual learning in English. They construct meanings and understandings when learning science from their linguistic cultural capital, knowledge, skills and experiences, and these can become central in a culturally appropriate pedagogy designed for the students.

The research provided many instances where observations were made of students talking and explaining science to each other using a combination of direct action and a variety of Creole languages. This formative learning by Torres Strait Islander students is not equally valued in a curriculum formulated, taught and assessed using only Standard Australian English concept descriptors. Torres Strait Islander people have an elaborate sign language (see Martin, 2008), one that can be captured and expressed through animation. There is no reason why pedagogical strategies, with rich, social and cultural resources of Torres Strait Creole, cannot be marshalled in a science classroom, and those students can be encouraged to use their language resources (Torres Strait Creole and Standard Australian English) and other social and cultural resources to advance their science learning.

I discovered that Torres Strait Islander people have not as yet developed their language vocabulary to include those terms commonly used in science learning. Christie (1985) suggests that Indigenous languages are preoccupied with maintaining and expressing culture rather than promoting academic gains which could be transferable to English. There is no reason why linguists should continue to 'ignore' this language dilemma that Indigenous Torres Strait Islander students encounter on a daily basis in school. Teachers and linguists can develop Creole language capacities. Developing Creole language capacities will not only benefit pedagogical strategies with Indigenous students, but enrich all languages and cultures by opening interchange between them. Tobin (2009) advises educators to tune into others' voices, and radically listen, learn from difference, and escape oppression, so as to understand others' text in terms of their standpoint. Tobin encourages science educators to listen to the voices of those Indigenous students who have been labelled as 'underachievers' (described in Chapter Three) by the larger society, to gain insight of what is actually happening at the classroom level. Tobin's insight is that Indigenous students have been systematically harmed by the very institutions that were set up to help them improve their lives. Teaching models and curriculum materials that work from a deficit model must be disregarded, and in their place there can be pedagogies that empower and enable Indigenous students by opening up language and culture interchange. As McTaggart and Curro (2009) suggest, the language and culture interchange can resonate right through the Key Learning Areas (KLAs).

Indigenous students encounter tensions and challenges within language systems even before coming to the science classroom to learn science (see Nakata, 2002). In school, they encounter challenges learning Standard Australian English, and are expected to be competent in the use of it so as to engage Australian curricula. In addition, when learning formal science as prescribed by the state syllabus, year 9 Indigenous students are required to use English science terminology. This means that Indigenous students are introduced to more language challenges, with more science vocabulary and grammatical demands made on them, including the struggle to understand logical, qualifying words, objectification, lexical density and nominalisation (see Wellington & Osborne, 2001).

A more coherent understanding of pedagogical strategies can recognise at least two types of language negotiations that Indigenous students encounter when they are learning science in school. The first language negotiation involves moving these Torres Strait Islander students from their everyday use of home language to communicate to becoming competent in the use of Standard Australian English. The second involves moving these students from the everyday use of English language ways of talking, thinking and doing to becoming competent in school science English ways of talking, thinking and doing. Learning science for Australian Indigenous students can consist of staged complex negotiations as modelled.

Model 1: Language negotiation at the cultural interface for Indigenous students learning school science

An Indigenous student's everyday ways of talking and knowing		Scientific ways of talking and knowing
An Indigenous student from a community where the traditional home language is the commonly used language, and English is used only in schools.	An Indigenous student from a community where English or dialects of Indigenous people's English is the community and school language	An Indigenous student becoming competent in school science ways of talking, thinking and doing
Legend ↔ language negotiation at the cultural interface		

An Indigenous student from a community where Standard Australian English (including dialects of Indigenous people's English) is the community and school language will need to negotiate the language challenges when learning science, including vocabulary and grammatical challenges. An Indigenous student from a community where the traditional home language is the commonly used language will need to negotiate into Standard English or a dialect of Indigenous people's English first, before negotiating the vocabulary and grammatical challenges in learning science. Further research needs to explore how pedagogical strategies can facilitate smoother negotiations to reduce potential tension between the different language and knowledge systems.

6.5 Torres Strait Islander students are multi-lingual/cultural

Torres Strait Islander middle school students from remote communities in North Queensland are multi-lingual/cultural. Most Indigenous students from remote communities in northern Queensland are multi-lingual/cultural (see Crowley and Rigsby, 1979). They speak their traditional languages when communicating with people from their respective communities, Creole languages when communicating with Indigenous peoples from other communities, and the English language to be able to communicate and function within wider Australian communities. They also construct their own emerging youth languages and dialects. In the classroom situation, these Indigenous students traverse these intersecting knowledge and language systems on a daily basis, responding, interacting, taking positions and making decisions (see Nakata, 2002). Languages such as Aboriginal English or Creole may sound like English but are very different from Standard Australian English (see Shnukal 1998). I discovered that though the differentiated languages (traditional languages, Creole languages and different forms of the English language) have porous boundaries (see Ray 2001), there haven't been recorded attempts to translate them for instructional purposes. A pedagogical strategy, which attempts to integrate subject matter content, student characteristics and the environmental context of learning (see Cochran et al, 1993) can take advantage of the porous boundaries of Creole and English. Many Torres Strait Creole terms, though they reflect Torres Strait Islander ways of thinking and knowing are linguistically derived from English (see Shnukal 1998).

Yore and Treagust (2006) suggest that every student learning the language of science – regardless of their home language's alignment with the language of instruction – faces similar problems as a second language learner, navigating and negotiating the 'border crossings' between home, school, and science education discursive fields. The problem is compounded when one's home languages are accorded much lower status than the language of instruction (see Malcolm 1998). In such a situation, small moves become significant. Across Australia, science educational experiences afforded Indigenous students are not equal with students who have English as a first language and/or are from western backgrounds. One means of redress is to mobilise the existing cultural capital of these students in the classroom. Science educators can develop pedagogical strategies that awards equal recognition to the cultural resources that Indigenous students bring with them to school. When Indigenous students' cultural resources are ignored in science learning - as is unfortunately rather common - it becomes much more difficult for them to participate in class on an equal basis. Normalising cultural diversity in classroom science improves student participation and engagement. I employed learning strategies that recognised and celebrated Torres Strait Islander ways, and this simple act generated greater enthusiasm and engagement in the science classroom.

It seems reasonable to develop pedagogical strategies that draw upon Torres Strait Islander students' cultural resources to promote and enhance science learning in the classroom. Functional cultural substitutes for concepts, and instructional science terms derived from home languages, can be adapted to English language classrooms. Mitchie (2002) makes a strong case for multilingual learning, certainly in informal peer discussions and hands-on learning activities; I documented many instances of students talking and explaining science to each other in varieties of Creole and English. I taught science concepts using familiar objects and activities. While Torres Strait Creole is an unequally valued language compared with Standard Australian English, I see no reason why its nuanced conceptual resources cannot be marshalled for the project of learning science in middle school.

A pedagogical strategy that accommodates Indigenous students' experiences and everyday ways of speaking and knowing seems a reasonable approach that can also get around the problematic situation explored by Yore (2008), in that using or not using appropriate scientific language (in English) does not alone guarantee that students have fully conceptualised scientific ideas. Words, symbols, and terms are labels that may have no direct association with an underlying idea, or may have different meanings than the same label in another discourse community, discipline, or social context. Correct spelling (or pronouncing) of the word does not ensure conceptual understanding of the signalled idea, when the student is also negotiating differentiated languages and ontology. Marshalling the nuanced richness of Creoles and other home languages may be of considerable value in developing authentic, contextual, scientific understandings with middle school indigenous students. Klenowski (2009) calls this "culturally responsive pedagogy". There is still much work to do on this idea. Also, whatever gains are made with respect to classroom practice, what remains are the problematic issues of the nature of knowledge reproduced through state mandated curriculum, and the problem of standardised assessment of achievement in science, used to constitute evidence of "the gap" in Indigenous and non-Indigenous student achievement.

While a science class can be a dynamic, cultural field, where various potentialities exist, in this scenario, it transforms into a site of struggle, when the linguistic cultural capital, knowledge, skills and experiences of Torres Strait Islander students are excluded from science classroom discourse. Gee (2005) acknowledges that students' culture, lived experiences and home language are foundations for academic learning and must be recognised, respected and utilised to anchor abstract concepts. The science classroom becomes a site where Indigenous students are left ill-equipped in the struggle to acquire the cultural capital valued in science learning. The formulation of teaching materials, actual teaching and assessing of the science curriculum, must recognise, respect and utilise these students' culture, lived experiences and home languages as foundations for them to advance their acquisition of science cultural capital.

As science educators in Australia, how prepared are we to deal with Indigenous students' language challenges in science learning: vocabulary and grammatical challenges? (see Wellington & Osborne, 2001). Furthermore, as science educators who have explored constructivist learning approaches, we can agree to start from where our students are. I realise that my training as a science teacher has not adequately prepared me to deal with situations I have encountered with some of my Torres Strait Islander students who have limited facility in English. If I am to start where my Torres Strait Islander student are, how can I effectively do so if I do not have pedagogical strategies that starts where the students are? How can we walk the journey (both the students and me as the science teacher) until we arrive at our destination, the Level 5 learning outcomes of the mandated science curriculum? I argue that the current Queensland Studies Authority science syllabus does not provide curriculum elaborations that enhance the agency of Indigenous students or a framework to support Indigenous students walking the journey. The curriculum does not provide a framework teachers can use to formatively assess the students while walking that journey. The curriculum materials do not prescribe a yard stick to measure the indicators of success for Indigenous students with limited English language facility walking the journey. Where is the pedagogical strategy that supports and enhances Indigenous students walking the journey to effectively engage with science learning?

I used Model 1, which represents language negotiation of Indigenous students learning science to formulate Model 2, which attempts to represent possible language negotiations of students who have English as First Language (EFL). Neathery (1997) suggests that ethnicity is not a predictor of science achievement, but competency in the literacies involved with science learning and student's attitudes towards science. The Queensland Government Department of Education, Training and the Arts: *Towards a 10-year plan for science, technology, engineering and mathematics (STEM)* 2007 report highlights a large achievement 'gap' in literacy, numeracy and science between poorer and more affluent students, and between schools with large proportions of either poorer or more affluent students in Australia. Socio-cultural dimensions affect measured achievement in science to a significant degree in Australia.

Model 2: Language and knowledge negotiation at the cultural interface for English as First Language (EFL) students

<table>
<tr><td colspan="2">English as First Language (EFL) students' everyday ways of talking and knowing</td><td>School science ways of talking, thinking and doing</td></tr>
<tr><td>Students from low socio economic backgrounds</td><td>Students from high socio economic backgrounds</td><td>Students becoming competent in school science ways of talking, thinking and doing</td></tr>
</table>

Legend

↔ language negotiation at the cultural interface

The *STEM* (2007) report also highlights that students whose home language is English showed significantly higher levels of proficiency than those whose home language is not English. I interpreted this to mean that if school science teaching is done in Standard English, and achievement is measurement using Standard English benchmarks, then students from high social, economic backgrounds have Standard English, the language of power and social mobility in Australia, among other advantages to help them achieve in school science.

Most Torres Strait Islander students in my class come from economically disadvantaged backgrounds, and Standard Australian English is these students' second, third or even fourth language. This implies that these Indigenous students have more disadvantages as compared to students from high social economic backgrounds who have English as First Language or similar habits to mainland Australia. Torres Strait Islander students must overcome social and economic challenges and language negotiation challenges. Clearly this calls for a science pedagogical framework that is sympathetic to the plight of these students. Such a sympathetic learning framework can recognise and utilise these students' multiple language dimensions, and mobilise and marshal these students' cultural resources to engage with science learning.

I used Models 1 and 2 to conceptualise possible language and knowledge negotiations an Indigenous student who is an English language learner can encounter when they engage with science learning in a mainstream science class. Here, my thinking is assuming that socially and economically disadvantaged Indigenous students from remote communities, who are English language learners, are in the same class with Indigenous students who have facility in English and students who are English as First Language learners from low and high socio-economic backgrounds from mainstream Australia. Model 3 represents students' cultural dispositions and possible language and knowledge negotiations at the cultural interface when Indigenous students who are English as Second Language (ESL) learners and students from mainstream Australia who are English as First Language (EFL) learners can encounter in the mainstream school system. It is important to realise that the model can give the false impression that these language and knowledge negotiations at the cultural interface are linear, in reality, they are not. As Nakata (2002) suggests, the cultural interface has so many woven, competing and conflicting discourses.

Model 3: Language and knowledge negotiations at the cultural interface in the mainstream school system

English as Second Language (ESL) students' everyday ways of talking and knowing		English as First Language (EFL) students' everyday ways of talking and knowing		School science ways of talking, thinking and doing
Students from remote communities (where the traditional home language is the commonly used language, and English is used mainly in the schools)	Students from urban and semi-urban communities (where English, including dialects of Indigenous people's English is the community and school language)	Students from low socio-economic backgrounds	Students from high socio-economic backgrounds	Students becoming competent in school science ways of talking, thinking and doing

Legend

↔ language negotiation at the cultural interface

In a science curriculum wholly formulated and assessed in Standard Australian English, English as Second Language (ESL) students, especially Indigenous students from remote communities where the traditional home language is the commonly used language, have a series of language and knowledge negotiations before negotiating the language and knowledge challenges in science learning, as compared to English as First Language (EFL) students, especially students from high socio-economic backgrounds. If school science achievement continues to be measured using only Standard English benchmarks, it adds to other advantages that English as First Language (EFL) students have, especially students from high socio-economic backgrounds over the other groups of students. Assessment instruments using Standard English benchmarks are designed to measure the student's negotiations from Standard English into science. They do not adequately measure the Indigenous student's negotiations from their vernacular language into science. As science educators, we need to address this socio-cultural anomaly by developing pedagogical strategies that sanctions Indigenous students' lived languages, experiences and knowledge in their learning.

This approach to science learning and teaching can bring a lot of challenges for most teachers. The challenges arise because the science teacher should not only be equipped with pedagogical strategies that targets the different groups of students, but should be able to identify which group the individual students operate from, as well as being able to make transitions smoothly within the groups. This capacity is a big ask from science teachers who might not have received training for it and need professional support to be able to effectively teach the different groups of students. Science educators can draw from a project in Haiti (Vilsaint & Heurtelou, 1996). A bilingual English/Haitian Creole dictionary has been successfully implemented to provide teachers and students with Haitian Creole equivalents for English terms used in science. The dictionary contains over 3000 English terms used in science and science related disciplines with Haitian Creole equivalents. It provides clarifications of terminology and instructional materials for teachers. Australian science educators can emulate a similar program to empower Indigenous students learning school science to develop the capacity to successfully negotiate the language and knowledge systems.

I realise that this approach has significant political implications in Australia where English is assumed to be a neutral language in school curriculum documents formulated, taught and assessed in Standard Australian English. This approach can be viewed not only as a challenge to Standard Australian English, the language of 'power' and social mobility in our communities, but as a proposition to 'dumb down' the science curriculum. I challenge those educators to develop an alternative framework that enhances science learning for these marginalised Indigenous students.

6.6 Science literacy and classroom discourse

I propose that Indigenous students who have limited facility in English need explicit coaching in language challenges encountered in a science class, in order to stand a better chance of achieving school science outcomes (see Bennett, 2003). Language challenges can alienate Indigenous students with limited facility in English from achieving in school science. Traditionally, learning achievement in school science has been positioned as the ability to understand and discuss scientific matter and science literacy as a development of talking, writing, listening and reading abilities in science lessons, making language a core constitution of science (Norris & Phillips, 2003). This means that English language development in talking, writing, listening and reading plays a central in science lessons. As argued in the previous section, Indigenous students with limited facility in English can be marginalised from science learning if Standard English becomes the only medium of communication in the classroom. I suggest that as science classroom teachers, we 'listen' to the 'little voices' of Indigenous students on their perception and experience of the difference between their life world and the science classroom. We need to hear these 'little voices' being conveyed through multiple forms of Indigenous students' language and cultural dimensions. This means that we have to extend classroom discourse beyond the use of Standard English to communicate. Learning and acquisition of Standard English should not be used as the 'gatekeeper' to disadvantage Indigenous students learning and achievement in school science.

Pedagogical strategies can look at an Indigenous student's language and culture as a way of coming to grips with their external world, and developing a symbolism to represent it, so it can be talked and thought about and celebrated (see Nettle & Romaine, 2000). In pedagogical frameworks that encourage these students to get more engaged with science learning, science classroom teachers can encourage use of the multiple language dimensions of their students. Science classroom teachers need to realise that these culturally sensitive, pedagogical frameworks can be part of the everyday schooling of Indigenous students. Teachers can also explore pedagogical frameworks that create smoother language negotiations for Indigenous students who constantly move between different language and knowledge systems.

As science educators, we need to rethink science literacy and classroom discourse. I argue we need to rethink how we can acknowledge and accommodate the culturally different styles of communicating and representing knowledge of the Indigenous students in our classrooms. Communicating and representing the knowledge of Indigenous peoples includes storytelling, ceremony, songs, ritual and sharing a diversity of languages and dialects – what Martin (2008) describes as multiliteracies. We cannot continue to restrict science literacy to print-based forms of reading and writing and deny Indigenous students' socio-cultural, oral, gestural and spatial language dimensions (see Snively & Williams, 2008; Martin 2008).

From my viewpoint, a middle school science pedagogical strategy that accommodates the multiple language dimensions of Indigenous peoples is conceivable and practical. I continue to worry that existing systemic constraints continue to sideline Indigenous languages, knowledge, skills and experiences in the science classroom. Theobald has called being at school, "twelve years of institutionalised life that demands the most unforgiving brand of conformity" (1997, p. 132). Schooling is presently endowed with an instrumentality "that has become even more refined and pronounced", where schools are now viewed as the mechanism designed to give the corporate liberal state what it needs: workers capable of doing their jobs well and a certain group of elite maths-science performers who will carry the torch forward toward [national] domination in the global economic market" (Theobald 1997, p. 133). My purpose in conducting this research was to look beyond the rhetoric of "the gap", to look beyond policy, and investigate pedagogical strategies, when learning and teaching science in a real classroom situation with Indigenous students.

As proposed in the previous section, science educators and researchers can do more to develop appropriate pedagogical strategies that facilitate smoother negotiations for the many Indigenous students who constantly move between different language and knowledge systems. Klenowski (2009) argues that such work is necessary on equity grounds alone given the systemic obsession with standardised assessment of a narrowed and uniform science curriculum in Australia. National benchmarking assessment is done using written text, yet the many and varied Indigenous cultures present on the Australian continent are predominantly oral and visual cultures. Historically, the Torres Strait Islander ways of knowing did not include codifying concepts in writing. Knowledge was and is passed from one person to another in oral form. Indigenous students are asked to demonstrate scientific understandings in a language not their own, conveyed in a non traditional form (in writing), and they must negotiate knowledge that is inimical to their well established cultural ways of being in the world. A socio-cultural view of knowing acknowledges cultural differences in the nature of learning, what is valued as knowledge and the ways in which Indigenous students in secondary school draw on their cultural legacies to learn as well as they can, the disciplines of western knowledge systems that inhabit Australian school curriculum (see Murphy and Hall 2008, Williamson and Dalal, 2007).

One fifth of Australian Indigenous students did not meet the lowest international TIMSS benchmark in science (Commonwealth of Australia, 2007). My research conducted in wholly Indigenous classrooms suggests that what is being assessed in benchmarking achievement tests in Australia is a student's facility to represent concepts in Standard Australian English. Nearly half of the Torres Strait Islander students in my study did not have the cultural resources to formally express physical science concepts in the language of assessment. Klenowski (2009) argues that equity in relation to assessment is a socio-cultural matter rather than a technical matter.

6.7 Ontological concerns that arise

As I thought through the research findings and read more widely, a larger ontological consideration raised its questioning head. The science curriculum, as it is constituted at both state and national levels, makes little real concession to Indigenous ways of knowing. The Queensland Studies Authority website advises, "The QSA is currently developing a range of materials to support the inclusion of Australian

Indigenous perspectives into the school curriculum. [Some] materials are available now, and more are in development" (QSA 2009c). On this website are a beautiful Torres Strait Islander seasonal events calendar, a seasonal star calendar and a Zugubul star map. Such materials can be integrated into existing curriculum, but the ontological structure of the curriculum remains untroubled by this "inclusion". Mr Ernie Grant (n.d. p. 51-52), a Dijirabal Elder from far north Queensland, sets out the problem this way:

> Indigenous communities have a holistic view of their world, which incorporates a vital link between Land, Language and Culture. This view is considerably different from what is considered the norm in western society. Many academics, over the years, have recognised and noted its success in passing on information accurately for centuries …there is a significant difference between western and indigenous approaches to the application and acquisition of knowledge. Western thinking generally adopts a more holistic approach to the wider issues, while its approach in more localised issues is compartmentalised. The end result is that most information in schools and institutions - whether it be oral or written – is organised and presented in a way that reflects this. On the other hand, largely because of the people's dependence on the spoken word and observation for sharing knowledge about their own world, the Indigenous approach is quite the opposite. Aboriginal and Torres Strait Islander people look at the whole picture and identify relationships and links within it, whereas their western counterparts often focus on the detail of the individual parts without considering their possible interaction with others. This apparent conflict can be confusing and frustrating for all those involved in sharing the knowledge.

Grant advocates a holistic approach to knowing and teaching Indigenous studies, to create "the total picture" encompassing consideration of Land, Language and Culture by contextualising Time, Place and Relationships. Together, Grant proposes, "these six components provide a flexible framework for organising and presenting information on a range of topics". The standardised science curriculum in the state of Queensland and the newly proposed national curriculum make no explicit reference to any of these elements. As it is constructed through formal curriculum discourses, scientific knowledge stands outside of Place and Time. Knowledge doesn't, of course, but the way science is presented in state-sanctioned curriculum statements makes it very difficult to recognise the place of Place and the time of Time. No direct mention is made of Land - the central organising concept of Australian Indigenous ways of knowing - nor is there formal mention of Culture. There is little, if any, recognition of the many and different cultures of Indigenous Australians. Certainly nothing is said concerning Language; the unquestioning default position being Standard Australian English, is neutral in a continent with a multitude of unique and now disappearing Indigenous tongues.

More worryingly is the new national science curriculum in its current draft iteration which proposes that, "Science knowledge refers to facts, concepts, principles, laws, theories and models that have been established by *scientists over time*" (emphasis mine). There is no recognition of old, established Indigenous forms of knowledge, or newer emerging forms. It seems that within what Nakata (2007, p, 215) calls the "very contested knowledge space" of the disciplines, the intense political tussle over what constitutes the science curriculum in Australia has managed to exclude proper (or is that properly exclude?) consideration of the old sciences of wind and water, of people, ecology and place that made for the original habitation of Australia and its islands. It's not that Australian educators aren't hotly contesting the present constitution of the national science curriculum – they are, and on many fronts, including from Indigenous standpoints and from sustainability standpoints – but it is disappointing to see how little formal attention is actually being paid to Indigenous ways of knowing, beyond the policy statements. As one of my academic colleagues remarked, "What books haven't they [curriculum developers] been reading?"

6.8 Summary

This chapter has reflected on my thinking about the findings from the data analysis and pedagogical strategies around the themes that emerged from the study. I have argued that school students' competence in speaking, reading and writing Standard Australian English can affect their learning agency. For example, the ways the learning outcomes of *Science: Years 1 to 10 Syllabus* (QSA, 2004) are formulated are better suited for students who speak and write Standard Australian English with facility. I have expressed concerns for the 45% of students in the study with limited facility in English over their inability to engage meaningfully with science learning. I have suggested how Torres Strait Creole can be used as a resource for learning western science concepts more productively in the classroom, and the need to pay attention to the interactivity of language and knowledge systems when these students engage in learning science concepts. Most Torres Strait Islander students from remote communities in North Queensland are multi-lingual, and deal with multiple language systems even before they engage with the English language challenges in science learning. I have argued for science educators to rethinking on science literacy and classroom discourse and how the science curriculum can make some real concessions to Indigenous languages and ways of knowing. The next chapter reflects on the limitation, strengths and recommendations from the study.

Chapter 7
Learning from my classroom action research

7.1 Introduction

In this chapter, I reflect on the limitations, strengths, recommendations and directions for further research. I discuss the limitations of my study, which come from the fact that the research project was limited to Torres Strait Islander middle school students and Torres Strait Islander assistant teachers in one school, and a further concern that the study was my learning personal history and cannot relate a 'whole picture'. I discuss the strengths of the study, which involve exploring individual and social experiences that real Torres Strait Islander middle school students bring to real science classrooms, and that I am an expert field negotiator, and bring a more informed insight on how Torres Strait Islander middle school students negotiate learning science in English as a second or third language. I then discuss the recommendations arising from the study: (1) professional development for teachers and pre-service teacher education to renew an approach that is culturally sensitive, (2) the explicit recognition and utilisation of the cultural resources Indigenous students bring to the science classrooms, and (3) revisiting the science curriculum documents to facilitate Indigenous students' agency. Finally, I discuss the three areas which need further research, which include negotiation of the meaning of science concepts by Australian Indigenous students, the agency of Australian Indigenous students when negotiating language and culture in science classrooms, and the ontological and epistemological concerns that arise between Indigenous knowledge and western science.

7.2 Limitations of the study

Inquiry, like any other human activity is always incomplete (Stringer, 2007). Limitations of this study come from the fact that the research project was limited to Torres Strait Islander middle school students and Torres Strait Islander assistant teachers at one Indigenous College, from the first semester in 2007 to the first semester in 2008. Torres Strait Islander students and Torres Strait assistant teachers from schools in different contexts to this study may have been able to give different perspectives to this study. Only students at the Indigenous College who consented to be part of the study, and whose parents also consented to their participation were involved in this action research study. There is concern that aspects of learning at the Indigenous College may have been left out of the study because of lack of consent from students, their parents or guardians. Stringer (2007) writes that it is not usually possible to include all the people who should be included "to deal with all the contingencies that arise" (p. 179).

Participants in this study were not randomly selected in terms of space and time. Nor can my teaching and learning personal history illuminate the 'whole picture'. Anfara and Mertz (2006) suggest that no practical or theoretical framework provides a perfect explanation of what is being studied, and Kemmis and McTaggart (2000, p. 580) write "It is an illusion that research methods and techniques provide secure paths to truth and certainty." My classroom was selected as the study site because it was my place of work with a group of Indigenous students. To choose a science classroom and a group of Indigenous students at random for a study focused on transforming my classroom practice did not make much sense to me. As suggested by McNiff and Whitehead (2006), action research is a form of research that enables practitioners to learn about their specific contexts, and how they can improve practice, individually and collectively.

I was not able to explore the language experiences of the group of Torres Strait Islander students in their community schools prior to their coming to the College. Nor can I know the language dynamics of the students in their respective communities and homes. Knowledge of these language experiences could have valuably informed the study, which assumed as accurate the results of research conducted for the Queensland Indigenous Education Consultative Body in 2002 and the Catholic Diocese of Townsville in 2003. These studies identified that very few indigenous students from remote communities (including those from the Torres Strait) spoke English as a first language. However, against the aims of this classroom action research study, which were to understand and improve the pedagogical content knowledge of how a specific group of Indigenous Torres Strait Islander middle school students learn science concepts in my science classroom at the College, these limitations can be overlooked. My primary research attention was and is always focused on improving my classroom practice.

Any focus on improving classroom practice can be a limitation to the study. Kemmis and McTaggart (2000) suggest that the privileging of teachers' knowledge in classroom action research masks the assumption that significant improvement in classrooms can be accomplished in the absence of broader patterns of community support and social change. They also question if change can occur without theoretical resources of traditions of critical theory and other such discourses. Against this concern, I took into account the relationship between my science classroom practice and my students' lived and accumulated cultural resources (from their respective social trajectories) to inform their learning. I also invited five Torres Strait Islander assistant teachers working in the school to participate in the study, and adopted a reflexive and dialectical approach (see Carr & Kemmis, 1986).

7.3 Strengths of the study

My research is unique, practical and applied, generated from a real classroom situation with real Indigenous students, and not conceptualised from the abstracted or imagined situations. Kemmis and McTaggart (2000, p. 578) state that "research is a process of learning from action and history – a process conducted within action and history, not standing outside it in the role of recorder or commentator, or above it in the role of conductor or controller." This study takes into account individual and social experiences that real Torres Strait Islander middle school students bring to real science classrooms. As discussed in Chapter Two, human development occurs on at least three levels: personal, interpersonal and cultural/institutional (Rogoff, 2003), and these three levels were inherently interwoven in my classroom research activities with participating students. I explored the concept of capital that Indigenous students bring to the science classroom from the individual, social and community (Bourdieu's, 1986; Morris, 2004; Yosso, 2005), which I conceptualise as cultural resources. I argued that cultural resources informed the agency of the students learning science in the classroom. I was able to provide research evidence that if the students' cultural resources are incorporated into a science classroom, improved engagement, participation and enjoyment of learning takes place.

Another strength of this study comes from the fact that I am an expert field negotiator, and bring 'inside' experience and knowledge of the problematic issue of field negotiations. Carr and Kemmis (1986) call for insights from insiders and applying the insight to practice. I learnt science using English as a second language. I also taught science to Indigenous students in southern Africa and North Queensland for twenty years, using English as my second language. These experiences informed this study and helped me to develop research insights into pedagogical strategies that consider science classrooms as cultural fields and learning science as cultural enactment (Tobin, Elmesky & Carombo, 2002). Employing a socio-cultural analytical lens enabled me to listen to the 'little voices' of Indigenous students about their experience when learning science in a second or third language. As explained in Chapter One, I have always used my first language Shona to think and conceptualise and I observed my students doing a similar thing, thinking in their Creole language and then attempting to speak in English in the science classroom. I believe that my experience as a teacher and researcher, who used English as a second language, brought to the study informed insight on how the students negotiated learning science in English as a second or third language.

7.4 Recommendations from the study

Recommendations arising from the study focus on: (1) professional development for teachers and pre-service teacher education to renew an approach that is culturally sensitive, (2) the explicit recognition and utilisation of the cultural resources Indigenous students bring to the science classrooms and (3) revisiting the science curriculum documents to facilitate Indigenous students' agency.

The first recommendation suggests teachers will need professional development on culturally sensitive pedagogy to be able to teach Indigenous students with limited facility in Standard Australian English more effectively. The features of a culturally sensitive pedagogical framework which have been developed in this study for helping Torres Strait Islander students include: recognition and celebration of Indigenous way, activities which engage these students that draw on the students' cultural resources to promote and enhance science learning in the classroom, creating functional cultural substitutes and utilising multiple language dimensions, and accommodating Indigenous students' experiences and everyday ways of being. McTaggart and Curro (2009) suggest that educators must realise that most Indigenous students will not be proficient in Standard Australian English, and are entitled to teaching strategies based upon sound knowledge of English as a Second Language.

The second recommendation calls for the cultural resources of Indigenous students to be recognised and effectively utilised in classroom science learning and teaching. I have suggested that these elements of cultural resources are tools that the students use to engage with learning science. Gee (2005) suggests that various literacies that students bring to class can and do need to be used to engage with learning, and science educators need to draw on this 'fund of knowledge' to adopt culturally responsive pedagogy. Bourdieu's cultural sociology views agency and structure as dialectical – structure influences human action, and humans are capable of changing the social structures they inhabit. I have suggested in this study that teachers can attempt to help the Indigenous students negotiate from their: 1) cultural disposition to move towards a more scientific disposition, 2) community cultural wealth as contexts of experience to scientific contexts, and 3) acquired cultural capital to acquire scientific capital. The recommendation encourages educators to build connections between Indigenous students' cultural resources learned through cultural practice and those central to science.

The third recommendation calls for the Queensland Studies Authority science curriculum documents to be re-framed and concept elaborations that facilitate Indigenous students' agency included, to facilitate learning of Indigenous students with limited facility in Standard Australian English. For example, this study used the Kup Mauri as a context when learning about heat transfer. This context attempted to use the Indigenous students' cultural resources to transform the physical science subject matter. McTaggart and Curro (2009) suggest that Australian Indigenous ways of knowing and languages awareness needs to permeate right through the Key Learning Areas, the curriculum in teacher education and educational research practice.

There is a need to recognise and appreciate the tension that can arise when Indigenous students negotiate between Indigenous and western languages and knowledge systems (Nakata, 2002). Physical science concepts themselves, no matter what language we use to discuss them, are the same. For example, Newton's laws are laws of how objects behave on the earth's surface. In this study, I found a number of Creole words for specific applications of force, but there seem to be no words for the meta concept 'force'. Creole words for 'energy' were a bit more problematic because concepts of energy are more technical, one example is the concept of mechanical energy. I explored the Physics strand in this study, and not the Biology, Chemistry and Geology strands. I suggest that there is going to be greater or lesser opportunity for incorporating Indigenous understanding, depending on the science strand. Classroom science teachers can develop pedagogical frameworks to minimise the tensions between Indigenous and western languages and knowledge systems, and focus their teaching on knowledge of English as a Second Language. They can thus draw on their Indigenous students' cultural resources, and create space for negotiation of language and culture in their science classrooms. I suggest that these dimensions can enhance the learning of school science by Indigenous students.

7.5 Directions for further research

This thesis raises three areas which need further research. The three areas which need further research are: (1) negotiation of the meaning of science concepts by Australian Indigenous students, (2) the agency of Australian Indigenous students when negotiating language and culture in science classrooms, and (3) the ontological and epistemological concerns that arise between Indigenous knowledge and Western science.

There is very little research literature to inform the negotiation of the meaning of science concepts and the scientific literacy of Australian Indigenous students (see Keys, 2008). Michie, Anlezark and Uido (1998) suggest that only fragmented approaches, which do not look at deeper understandings, have been researched. The research literature available focuses on the technology of teaching, and policy issues and what the 'experts' say about Australian Indigenous education, but not on what the Australian Indigenous students say about their learning. More case study research on the actual science classroom experiences of Australian Indigenous students is needed.

There is very little research on the agency of Australian Indigenous students when they negotiate language and culture in their science classroom (see McTaggart & Curro, 2009). Case study research approaches can explore how Indigenous middle school students' competence in speaking and writing Standard Australian English with facility can be improved. They can also explore how the Queensland Studies Authority mandated science curriculum, which is formulated and assessed using Standard Australian English concept descriptors, can be made to more fully align and adequately facilitate Indigenous students' negotiations from their vernacular languages into science. This is essential for Australian Indigenous students who consciously 'language switch' between English and Creole languages when learning science, because of limited facility with English, and those Australian Indigenous students who 'language mix' between English and Creole because they have severe communication problems in English. Research can explore pedagogical frameworks that accommodate Indigenous students' everyday ways of talking and knowing in science teaching and learning. Further, it can explore how outcomes of the *Science: Years 1 to 10 Syllabus* (QSA 2004) can be improved to promote the 'language switching and mixing' by these students, as this can be the immediate vehicle that the students can employ to learn school science.

It is too easy to acknowledge that Indigenous knowledge and Western science do not sit well in terms of their epistemological and ontological perspectives. The most pronounced issue is the theoretical notion of causality in western science, which does not sit neatly with Indigenous ontological and epistemological perspectives (Yore, 2009). Indigenous scholars and science educators need to explore the potential epistemological and ontological dilemmas that arise between Indigenous knowledge systems and western science. The scholars and educators need to realise that Indigenous students are dealing with these dilemmas on a daily basis (Nakata, 2007), without their 'guidance'. What can be done about the dilemmas? How can Indigenous students deal with these dilemmas in the science classroom? Research is needed on how Australian Indigenous students can encounter and deal with these potential dilemmas when they attempt to engage with the science curriculum. It is an area of fruitful future classroom research.

7.6 Summary

In this chapter, I have reflected on the limitations of the study, that the research project was limited to Torres Strait Islander students and Torres Strait Islander assistant teachers at one school, and a concern that the study was my learning personal history and cannot relate a 'whole picture'. I have reflected on the strengths of the study, investigating what real Torres Strait Islander students bring to science learning, and how as an expert field negotiator, I bring a more informed insight to the study. I have discussed the recommendations from the study, which include the need for professional development for teachers and pre-service teacher education to teach a new approach that is culturally sensitive, the need to effectively utilised cultural resources of Indigenous students in the classrooms, and the need to reframe the science curriculum documents to include concept elaborations that facilitate Indigenous students' agency. Finally, I discussed the three areas needing further research, which include negotiation of the meaning of science concepts by Australian Indigenous students, the agency of Australian Indigenous students when negotiating language and culture in science classrooms, and the ontological and epistemological concerns that arise between Indigenous knowledge and Western science. The next chapter summarises my study.

Chapter 8

Summary

8.1 Introduction

This chapter summarises my study. Firstly, I start by reviewing the study and then discuss how I engaged in extensive reading around many topics in school science education, and, during research cycles, how I was involved with planning, implementing, observing, reflecting and replanning my research (Kemmis & McTaggart, 2000). Secondly, I discuss my conclusion that learning experiences using Standard Australian English did not adequately facilitate Torres Strait Islander students' negotiations from their vernacular languages into science, and that a teaching and learning framework that accommodates the multiple language dimensions of old and emerging Indigenous cultures is possible. Thirdly, I discuss my learning and development as a science teacher, my learning to do action research, and how this research encourages me to develop an educational practice that improves pedagogical strategies for disadvantaged and marginalised Indigenous students. I finally discuss my own learning as a teacher researcher and how I presented results of this study at conferences, and published papers in academic journals, and how this experience has resulted in my increased self knowledge, self awareness and confidence.

8.2 Review of the study

This research was a prolonged learning process for me, and I call on other science educators to critique my experience. Leading to this research, I engaged in extensive reading around many topics in school science education. I examined my philosophical standpoint which informed my methodology and research methods. I explored a number of research paradigms to determine if they aligned with what I wanted to achieve in this study. I learnt that no one theory can illuminate all aspects of practice, and that by choosing one theory, it meant I was illuminating certain aspects of my practice (Denzin & Lincoln, 2003b).

I have argued why my science classroom with Indigenous students who have English as a second or third language can be a dynamic and interactive socio-cultural environment. The idea was taken a step further to explore why it is imperative to value and acknowledge the cultural resources that the students bring to the classroom. The ways of thinking about language and literacy in socio-cultural practice were discussed; and the definitions of science literacy and a proposal to improve Indigenous students' second language skills were explored. Three learning models: constructivism, conceptual change and context-based learning models were examined to find how useful they can be effectively employed in classrooms with Indigenous students who have Standard Australian English as a second or third language.

I discussed how science awareness is important in Australia and underachievement on benchmarked science assessment by Indigenous students. I have argued why year 9 science classrooms can be considered as a cultural field able to be researched using a socio-cultural analytical lens. The ideas were taken further to explore Indigenous knowledge and western science knowledge, and how it aligns with my socio-cultural analytic lens. I explored the accessible cultural resources Torres Strait Islander students bring to the science classroom, and how they align with science discourses and science activities. A position emerged that Indigenous students use their cultural resources to interact with classroom science organisational structures in a dialectical relationship, as they produce and reproduce science. I then adopted this dialectical relationship as my practical and theoretical standpoint.

I discussed my agency - structure dialectical standpoint and how it aligns with Kemmis and McTaggart's (2000) classroom action research, and McNiff and Whitehead's (2006) action research model of "lived experience". I discussed the study participants in terms of their habitat, my research methodology, ethics consideration, validity of research, and my classroom action research agenda. I then discussed the three data collection cycles, and my reflections.

I presented my findings and interpretations from data analysis and the connections between a student's ability to use English with facility and their willingness to be active learners of science in the classroom. The categories of how students were able to use science terminology, participate in learning science and their level of engagement in the science classroom suggests that if the students bring English language capital to the classroom, they are more willing and able to enact agency as independent learners, and a limited facility in English proved a barrier to their active learning participation. The findings also indicate that when Torres Strait Islander students with limited facility in English learn science, their classroom communication may not be in Standard Australian English, but could utilise Torres Strait Creole languages and other possible literacy dimensions of their cultures. I argued that science curriculum and pedagogical strategies that embrace old and emerging dimensions of Torres Strait Islander students' cultures can enrich year 9 science learning in the same way that the western ways of knowing have enriched dimensions of Torres Strait Islander culture.

I reflected on my thinking about the findings from the data analysis and pedagogical strategies around the themes that emerged from the study. I argued that school students' competence in speaking, reading and writing Standard Australian English can affect their learning agency. For example, the ways the learning outcomes of *Science: Years 1 to 10 Syllabus* (QSA, 2004) are formulated are better suited for students who speak and write Standard Australian English with facility. I expressed concerns for the 45% of students in the study with limited facility in English over their inability to engage meaningfully with science learning. I suggested how Torres Strait Creole can be used as a resource for learning western science concepts more productively in the classroom, and the need to pay attention to the interactivity of language and knowledge systems when these students engage in learning science concepts. Most Torres Strait Islander students from remote communities in North Queensland are multi-lingual and multi-cultural, and deal with multiple language systems even before they engage with the English language challenges in science learning. I argued for science educators to rethinking on science literacy and classroom discourse, and how the science curriculum can make some real concessions to Indigenous languages and ways of knowing.

I then reflected on the limitations of the study, that the research project was limited to Torres Strait Islander students and Torres Strait Islander assistant teachers at one school, and a concern that the study was my learning personal history and cannot relate a 'whole picture'. I also reflected on the strengths of the study, investigating what real Torres Strait Islander students bring to science learning, and how as an expert field negotiator, I bring a more informed insight to the study. I then discussed the recommendations from the study, which include the need for professional development for teachers and pre-service teacher education to teach a new approach that is culturally sensitive, the need to effectively utilised cultural resources of Indigenous students in the classrooms, and the need to reframe the science curriculum documents to include concept elaborations that facilitate Indigenous students' agency. Finally, I discussed the three areas needing further research, which include negotiation of the meaning of science concepts by Australian Indigenous students, the agency of Australian Indigenous students when negotiating language and culture in science classrooms, and the ontological and epistemological concerns that arise between Indigenous knowledge and Western science.

8.3 My learning and developing as a science teacher

This classroom action research was undertaken with the aim of improving practice and influencing positively the educational experiences of Indigenous students. Stringer (2007) writes "The end product of action research is a harmonious and productive sense of social life. It seeks to move people to cooperative, consensual ways of living that provide peace of mind and contribute to the pursuit of happiness." I sought to improve the engagement and participation of these students when learning classroom science. I provided supporting evidence that the changes I made to my practice improved the engagement, participation and enjoyment when learning science by the group of Indigenous students. I consider my research findings to be tentative and always subject to further refinement. McNiff and Whitehead (2006, p. 253) advise action researchers "to avoid closure of any kind", a situation in which the researcher believes they have found a final answer. Remaining open to the quest is an outlook that can contribute to my continual growth and development as a reflective science educator.

I hold the view that by doing this classroom action research, I provided Indigenous students with a more democratic and librating educational experience that momentarily improved their participation in their science education. Aikenhead (2002) suggests that when western science is taught in the context of local Indigenous knowledge, Indigenous students become more interested in their science learning, and take ownership of that knowledge. I attempted to promote educational experiences in my science classroom that valued cultural diversity. Stringer (2007, p. 215) writes: “Action research seeks to produce empathetic, evocative accounts that embody the significant experiences embedded in people’s everyday lives”, and I propose that the research process enabled the participating students to celebrate their ways of knowing, take ownership of that knowledge, and encourage other students to be knowledge creators and not recipients of other people’s knowledge.

I have argued that the quality of educational experience afforded Indigenous students is not equal with their counterparts who have English as a first language or similar habits to mainland Australia, if their cultural resources (their ways of knowing about their worlds) are not mobilised and marshalled into the science curriculum. Educational research can explore the question of “the need for democratic, creative, and liberating ways of conceiving and organising human activity” (Springer, 2007, p. 215). I explored whether a pedagogical strategy that sought equal status and recognition of Indigenous language and knowledge systems, and that did not only privilege western perspectives, was actually possible and probable, drawing from McNiff and Whitehead (2006, p. 257), who think that “practitioners can produce their own theories of living practice, which, like the practice, are transformational and developmental.” Accordingly, if Indigenous students’ cultural resources are ignored by science educators and policy makers in science learning, it can become problematic for Indigenous Australian adolescents to participate on an equal basis with their non-Indigenous counterparts, whose cultural resources are part of the science curriculum.

Since completing the research cycles, incorporating Indigenous students’ cultural resources, when learning classroom science, has become a key principle of my practice. Stringer (2007) suggests that the legitimacy of action research comes from its ability to be meaningfully applied to problems and issues in people’s everyday lives. I hold the view that this research has encouraged me to develop an educational practice that improves on situation of disadvantaged and marginalised Indigenous students. In my educational practice, I am now very conscious of conditions where potential denial of Indigenous students to gainfully participate in science learning is likely to occur, and signals the need for pedagogical strategies of learning that gives Indigenous students possibilities of mobilising and marshalling their cultural resources. My educational practice creates space within my classroom for Indigenous language and knowledge, provides room for negotiation of language and culture, and values Indigenous cultural identity. Aikenhead (2002) suggests that approaches that value Indigenous cultural identity are likely to increase self esteem of Indigenous students. Approaches that value cultural identities give Indigenous students more confidence to approach formal school education.

I hold the view that science educators, supported by policy makers, can seek to create educational experiences for Indigenous students that will be positive, emancipatory and life-improving, as supported by Springer (2007, p. 215) who writes that “action research suggests the need to liberate and empower people through collaborative and caring processes of investigation and action.” Such an endeavour can resuscitate values of social justice and equality in educational policy and curriculum design, to provide socially emancipatory educational practice. Creating space for more positive and librating educational experiences (Klenowski, 2009) can be the focus of middle school science educators. In this research, I made significant steps to celebrate the legitimacy of Torres Strait Islander languages and cultural values. I propose that this researched and emergent pedagogical framework can be implemented in junior secondary science schooling, to promote life improving experiences for Indigenous students.

8.4 My learning to do action research

This thesis is an account of my learning journey as a classroom action researcher. My classroom research was a self study and I was an active agent taking responsibility for the research process. Springer (2007, p. 215) writes: “Outcomes of action research are increased clarity and understanding that provide the basis for resolving the problem on which the study focused”. I learnt a great deal about how my students were learning science and the experience informed the development of my pedagogical content knowledge. I take responsibility for putting together this research, and for my interpretations and thinking. McNiff and Whitehead (2006) argue that by considering the possibility of doing action research, the researcher hangs onto their own sense of vision that there is another way. I suggested in Chapter One that there was another way, a ‘plan’ to engage Indigenous students in classroom science. I implemented the ‘plan’ described in Chapter four in two of my grade 9 science classes at the College and have provided research evidence of improved practice and educational experience for the students. From this effort emerged my new understanding and a pedagogical framework that attempts to mobilise and marshal Torres Strait Islander middle school students’ cultural resources in their classroom science learning. This classroom action research experience enhanced my personal and professional understanding of my science classroom practice with Indigenous students. This experience has resulted in my increased self knowledge, self awareness and confidence. Additionally, I suggest that self development still occurs during moments of critical reflection, as I continuously examine my new understandings of my classroom practice.

I learnt that my provisional findings and implications were a historical and social action of a particular group of Torres Strait Islander students at a particular moment. These provisional findings and implications might not be repeatable, and might not provide a generic model which applies to a different group of Torres Strait Islander students. Kemmis and McTaggart (2000) write that what we call “truth” is always and only provisional, that knowledge is always fallible, that it is always shaped by particular views and material-social-historical circumstances, and that it can be approached only inter-subjectively. Though my provisional findings and implications are unlikely to be repeated, this incredible learning journey I describe in this thesis has the potential to inform other teachers in similar situations, as well as policy makers and curriculum designers. I suggest that my learning and the improvement of my practice at the micro-level of my classroom research has had significant repercussions at the macro-level, in terms of the conferences and workshops where I have presented on this work. McNiff and Whitehead (2006) suggest placing accounts of learning in the public domain, and show how new learning can inform new practices to influence sustainable forms of social growth. I have presented the results of this study at the Australasian Science Education Research Association (ASERA), in Brisbane in July, 2008, at The Third Forum of Cultural Studies of Science Education (CSSE), in San Diego in April, 2009 and at The 82nd National Association of Research in Science Teaching (NARST), in Garden

Grove, California in April, 2009. I was also invited by the Australian Curriculum Assessment and Reporting Authority (ACARA) in Melbourne, in November, 2009, to participate in workshops on embedding Indigenous perspectives in the national science curriculum. In all these sites, I contributed my research learning to generate fruitful discussions.

The learning curve also meant that I had to publish papers on my research findings in academic journals. I have published three articles on this work, and plan to publish two more articles on sociolinguistic perspectives in Indigenous science classrooms and this thesis, which will be available from James Cook University library. The first paper is titled: ‘Indigenous students in school science”, and was published in 2007, in the *Journal of Australian Science Teachers’ Association,* Vol 53, No 2, pages 10-15. The second paper is titled: ‘Language negotiations Indigenous students navigate when learning science’, and was published in 2008, in the *Australian Journal of Indigenous Education*, Vol 37, pages 91-97. The third paper is a chapter I co-authored with my supervisor titled: ‘Australian Torres Strait Islander students negotiate learning school science in Standard Australian English: A tentative call for also teaching and assessing in Creole’, and was published in 2010 in Deborah Tippins, Michael P. Mueller, Michiel van Eijck & Jennifer Adams (Eds), *Cultural Studies and Environmentalism: The Confluence of EcoJustice, Place-based (Science) Education, and Indigenous Knowledge Systems,* Springer Forum Series Book. McNiff and Whitehead (2006) suggest that people working in person-centred communities of practice need to publish their accounts to create a new body of knowledge. I hope that these articles, which focus on my classroom action research findings, interpretations and thinking, can be part of Indigenous, classroom, science, education, research literature that other scholars and educators can use to advance their learning.

8.5 Conclusion

This chapter has summarised my study. I started by reviewing the study, how I was engaged with planning, implementing, observing, reflecting and replanning during the action research cycles, and then discuss my conclusion that learning experiences using Standard Australian English did not adequately facilitate Torres Strait Islander students’ negotiations from their vernacular languages into science, and that a teaching and learning framework that accommodates the multiple language dimensions of old and emerging Indigenous cultures is possible. I then discussed my learning and development as a science teacher, my learning to do action research, and how this research encourages me to develop an educational practice that improve on Indigenous students' agency in science learning. Finally, I discussed how presenting and publishing results of this study has resulted in increased self knowledge, self awareness and confidence.

References

Aikenhead, G. S. (1996). Science education: Border crossing into the subculture of science. *Studies in Education*, Vol 27, pp 1-52.

Aikenhead, G. S. (1998). Many students cross cultural borders to learn science: Implications for teaching. *Australian Science Teachers Journal*, Nov, Vol 44, No 4, pp 9-12.

Aikenhead, G. S. (2000a). "Rekindling traditions: Cross-cultural science & technology units" project. Retrieved 13/2/06 from http://capes.usask.ca/ccstu

Aikenhead, G. S. (2006). *Science education for everyday life: Evidence-based practice.* New York: Teachers College Press.

Aikenhead, G. S., & Jegede, O. J. (1999). Cross-cultural science Education: A cognitive explanation of a cultural phenomenon. *Journal of Research in Science Teaching*, Vol 36, pp 269-287.

Aikenhead, G. S., & Otsuji, H. (2000). Japanese and Canadian science teachers' view on science and culture. *Journal of Science Teacher Education*, Vol 11, pp 277-299.

Akerlinds, G.S. (2002). Principles and practice in phenomenographic research. Proceedings of the international symposium on: Current issues in phenomenography, held in Canberra, Australia, November.

Alloway, N., Freebody, P., Gilbert, P., & Muspratt, S. (2002). *Boys, literacy and schooling: expanding the repertoires of practice.* Canberra: Curriculum Corporation and Commonwealth Department of Education, Science and Training.

Anfara, V. A., & Mertz, N. T. (Eds). (2006). *Theoretical Frameworks in Qualitative Research*. London: Sage Publication.

Anzaldua, G. (1990). *Haciendo Caras/making face, making soul: creative and critical perspectives by woman of color*. San Francisco, CA: Aunt Lute Press.

Archer, M. S. (1996). *Culture and agency: The place of culture in social theory*. Cambridge: Cambridge University Press.

Ashcroft, K., & Lee, J. (Ed). (2000). *Improving Teaching and Learning in the Core Curriculum*. London: Falmer Press.

Australian Academy of Science. (2006). *Primary Connections: Plants in action.* Canberra: Australian Academy of Science.

Australian Bureau of Meteorology: *Indigenous Weather Knowledge* website: (http://www.bom.gov.au/iwk/)

Australian Curriculum and Reporting Authority. (2010). English curriculum: Draft consultation version 1.1.0 Available from http://www.australiancurriculum.edu.au/Home

Australian Education Council. (1994). *Statement of Science for Australian Schools*. Carlton, Victoria: Curriculum Corporation.

Australian Government: Department of Education, Training and Youth Affairs. (2001). *The Status and Quality of Teaching and Learning of Science in Australian Schools*. A Research Report prepared for the Department of Education, Training and Youth Affairs. Canberra: DETYA.

Australian Science Teacher's Association. (1985). *Science in Australian Schools: Today's problems and tomorrow's challenges*. Canberra: ASTA.

Baker, D. (1996). Does Indigenous Science really exist? *Australian Science Teachers' Journal*, March, Vol 42, No 1, pp 18-20.

Barber, M. (2000). A comparison of NEAB and Salters A-Level Chemistry: Student views and achievements. Unpublished MA Thesis, University of York.

Barnhardt, R., & Kawagley, A. O. (2005). Indigenous knowledge system/ Alaska knowing. *Anthropology and Education Quarterly*. Vol 36, No 1, pp 8-23.

Bauman, Z. (1973). *Culture as Praxis*. London: Routledge & Kegan Paul.

Bennett, J. (2003). *Teaching and Learning Science: A guide to recent research and its applications*. London: Continuum.

Bennett, J., Hogarth, S., & Lubben, F. (2003). A systematic review of the effects of a context-based and science-technology-society (STS) approach in the teaching of secondary science. *Research evidence in education library*. London: Continuum.

Berber-Jimenez, L., Montelongo, J., Hernandez, A. C., Herter, R., & Hosking, D. (2008). Helping students write better conclusions. *Science Teacher*, Vol 75, No 3, pp 56-61.

Biggs, J. (2003) *Teaching for Quality Learning at University*. Buckingham: Open University.

Bisanz, J., Zimmerman, C., & Bisanz G. L.(1998). Everyday scientific literacy: Do students use information about the social context and methods of research to evaluate news briefs about science. *Alberta Journal of Education Research*, Summer, Vol 44, No 2, pp 188-196.

Black, P. (1993). Formative and summative assessment by teachers. *Studies in Science Education*, Vol 21, pp 49-97.

Blenkin, G. M., & Kelly, A. V. (Eds). (1983). *The Primary Curriculum in Action: A Process Approach to Educational Practice.* London: Harper & Row.

Bourdieu, P. (1979). *Algeria 1960*. Cambridge: Cambridge University Press.

Bourdieu, P. (1984). *Distinction: a social critique of the judgement of taste*. Cambridge, MA: Harvard University Press.

Bourdieu, P. (1986). The forms of capital. In J.G. Richardson (Ed.) *Handbook of theory and research for the sociology of education.* New York: Greenwood Press.

Boykin, A. W. (1994). Afrocultural expression and its implications for schooling. In E. R. Hollins, J. E. King & W. C. Hayman (Eds.), *Teaching diverse populations: Formulating a knowledge base* (pp. 243-256). Albany, NY: State University of New York Press.

British Education Resource Association (BERA). (2004).

Brook, J., & Brook, M. (1993). *The case for a constructivist classroom*. Alexandria, VA: ASCD.

Brown, B. A., & Ryoo, K. (2008). Teaching Science as a language: A context first approach to science teaching. *Journal of Research in Science Teaching*, Vol 45, No 5, pp 529-553.

Brown, B. A., & Spang, E. (2008). Double talk: Synthesizing everyday and science language in the classroom. *Science Education*, Vol 92, No 4, pp 708-732.

Brown, D.S. (2003). A group approach to concept mapping. *The American Biology Teacher*, March, Vol 65, No 3, pp 192-197.

Bull, R (2008). *Small Study – Big Success Story. Primary Connection Incorporating Indigenous Perspectives Pilot Study Report.* Canberra: Australian Academy of Science.

Burns, R. B. (2000). *Introduction to Research Methods* 4th Ed. Australia: Longman.

Bybee, R. W. (1997). *Achieving Science Literacy: From Purpose to Practical Application*. Portsmouth, NH: Heinemann.

Calhoun, C., LiPuma, E., & Postone, C. (1993). *Bourdieu: Critical Perspective*. Cambridge: Policy Press.

Campbell, D. T., & Stanley, J. C. (1963). *Experimental and quasi-experimental designs for research.* Chicago: Rand McNally.

Carr, W., & Kemmis, S. (1986). *Becoming Critical. Education, knowledge and action research.* Lewes: Falmer.

Carruthers, P., & Bouchers, J. (1998). *Language and thought: Interdisciplinary themes*. Cambridge: Cambridge University Press.

Catholic Education, Diocese of Townsville. (2003). *Right Talk Right Place: A resource book for teachers of Aboriginal & Torres Strait Islander students in North Queensland schools as a companion to Making the Jump.*

Cavallo, A. (2008). Experiencing the nature of science: An interactive, beginning of semester activity. *Journal of College Science Teaching*, Vol 37, No 5.

Cheng, Y. C. (2000). A paradigm shift in science learning and teaching. *Asia-Pacific Forum on Science Learning and Teaching,* Vol 1, Issue 2.

Chigeza, P. (2007). Indigenous students in school science. *The Journal of the Australian Science Teachers Association*, winter, Vol 53, No 2, pp 10-15.

Chigeza, P. (2008). Language negotiations Indigenous students navigate when learning science. *Australian Journal of Indigenous Education*, Vol 37, pp 91-97.

Chigeza, P., & Whitehouse, H. (2010). Australian Torres Trait Islander students negotiate learning in Standard Australian English: A tentative case for also teaching and assessing in Creole: In D. Tippins, M. P. Mueller, M. van Eijck & J. Adams (Eds), *Cultural Studies and Environmentalism: The Confluence of EcoJustice, Place-based (Science) Education, and Indigenous Knowledge Systems.* Netherlands: Springer.

Chinn, P. W. U., Hand, B., & Yore, L. D. (2008). Culture, Language, Knowledge about Nature and Naturally Occurring Events, and Science for All: She says, He Says, They Say. *L1 – Educational Studies in Language and Literature*, Vol 8(1), pp 149-171.

Chittleborough, G., Hawkins, C., & Treagust, D. (2001). Brainstorming to concept maps: Developing ontological categories for Energy. A paper presented at the Australian Association for Research in Education. International Education Research Conference, Fremantle, Australia, December 2-6. Retrieved 21/10/2005 from: http://www.aare.edu.au/01pap/chi01532htm

Christensen, P., & James, A. (2000). *Research with children: Perspectives and practices*. London: Falmer Press.

Christie, M. (1994). Grounded and excentric knowledge: Exploring Aboriginal alternatives to western thinking. In J. Edwards(Ed), *Thinking: International interdisciplinary perspectives*. Hawker: Brownlow Education.

Christie, J. M. (1985). *Aboriginal perspectives on experience and learning: the role of language in Aboriginal education*. Victoria: Deakin University Press.

Christie, M. (1997). Notes on ethno-science and knowledge production: Learning from Australian indigenous scientists. *Science Teacher Association of the Northern Territory Journal*, Vol 16, pp 7-12.

Clarkson, P.C. (2002). Bilingual students learning mathematics in Australia: In H.S. Dhindsa, I. Cheong, C. Tendencia & M.A. Clements (Eds), *Realities in Science, Maths and Technical education* (pp 266 – 275). Brunei Darassalam: Universiti Brunei Darussalam.

Cloete, E. (2010). (in press). Going to the bush: language, power and the conserved environment in southern Africa. *Environmental Education Research.*

Clutterbuck, P. (2003). *Understanding Science, Upper Primary*. NSW: Blake Education.

Cobb, P. (1994). Where is the mind? Constructivist and Socio-cultural perspectives on mathematical development. *Educational Researcher*, Vol 23, No 7, pp 13-20.

Cobern, W. W., & Loving, C. C. (2001). Defining “science” in a multicultural world: Implications for science education. *Science Education*, Vol 85, pp 50-67.

Cobern, W. W., & Aikenhead, G. S. (1998). Cultural aspects of learning science. In B. J. Fraser & K. G. Tobin (Eds), *International handbook of science education* (pp 39-52). Dordrecht, Netherlands: Kluwer Academic Publishers.

Cobern, W. W. (1993). Contextual constructivism: The impact of culture on the learning and teaching of science. In K. Tobin (Ed), *The Practice of constructivism on science education* (pp 57-70). Hillsdale, NJ: Lawrence Erlbaum Associates Publishers.

Cobern, W.W. (1996). Worldview theory and conceptual change in Science Education. *Science Education*, Vol 80, pp 579-610.

Cochran, K. F., DeRuiter, J. A., & King, R. A. (1993). Pedagogical content knowledge: An integrative model for teacher preparation. *Journal of Teacher Education*, Vol 44, pp 263-272.

Committee for the Review of Teaching and Teacher Education. (2003, October). Main Report. Canberra, Department of Education, Science and Training: CRTTE.

Costa, V.B. (1995). When science is “another world”: Relationships between worlds of family, friends, school and science. *Science Education*, Vol 79, pp 313-333.

Cothron, J. H., Giese, R. N., & Rezba, R. J. (1989*). Students and Research: Practical strategies for science classroom and competitions*. Dubuque, Iowa: Kendall/Hunt Publishing Co.

Coupland, M., & Crawford, K. (2002). Researching complex systems of activity. Papers presented at the conference: Current issue in phenomenography, Canberra, Nov.

Crowley, T., & Rigsby, B. (1979). Cape York Creole. In T. Shopen (Ed.), *Languages and their status*, Cambridge: Winthrop Publishers.

Cummins, J. (1986). Empowering minority students: A framework for intervention. *Harvard Educational Review*, Vol 56 (1).

Curry, K., Moore, J., & Sumrall, W. J. (2007). Extra! Extra! Learn all about it. *Science Scope*, Vol 31, No 3, pp 40-45.

Cuttance, P. (2001). School Innovation: Pathway to the knowledge society. Canberra: *Department of Education, Training and Youth Affairs, Commonwealth of Australia.*

Dearborn, T. (2002). *Science experiments, Upper Primary*. NSW: Blake Education.

Dempster, E. R., & Reddy, V. (2007). Item readability and science achievement in TIMSS 2003 in South Africa. *Science Education*, Vol 91, No 6, pp 906 – 925.

Denzin, N. K., & Lincoln, Y. S. (2003b). *The landscape of qualitative research*, 2nd Edition. Thousand Oaks, CA: Sage Publication.

Descombe, M. (2003). *The good research guide*, 2nd Edition. Open University Press.

Downey, E. (2002). *Heinemann achieve science two. Alternative outcome based worksheets*. Heinemann: Harcort Education.

Driver, R., & Bell, B. (1986). Students' thinking and learning of science: A constructivist view. *School Science Review*, Vol 67, No 240, pp 443-456.

Driver, R., & Erickson, G. (1983). Theories in action: Some theoretical and empirical issues in the study of students' conceptual framework in science. *Studies in Science Education*, Vol 10, pp 37-60.

Dumbleton, M., & Lountain, K. (1999). *Addressing Literacy in Science: A Middle Resource*. Victoria: Curriculum Corporation.

Eade, D. (1997). *Capacity building: An approach to people-centred development.* Atlantic Highlands, NJ: Humnaities Press International.

Enger, S.K. (1998). Students' conceptual understanding: Qualitative evidence in concept maps. Paper presented at the 27th Annual Meeting of the Mid-South Educational Research Association, New Orleans, November 4-6.

Engle, R. A., & Conant, F. R. (2002). Guiding principles for fostering productive disciplinary engagement: Explaining an emergent argument in a community of learners classroom. *Cognition and Instruction*, Vol. 20, pp 399 -483.

Erickson, F. (1986). Qualitative research methods on teaching. In M. C. Wittrock (Ed), *Handbook of research on teaching* (pp. 119-161). New York: Macmillan.

Evidence for Policy and Practice Information and Co-ordinating Centre (EPPI-Centre). (2005). Social Science Research Unit (SSRU), Institute of Education, University of London, August. Retrieved 8/12/05 from http://eppi.ioe.ac.uk/EPPIWebContent/reel/review-groups/

Fischer, J. (1996). Open to ideas: Developing a framework for your research. In G. Burnaford, J. Fischer, & D. Hobson (Eds), *Teachers doing research: Practical possibilities* (pp. 33-50). Mahwah, NJ: Lawrence Erlbaum Associates.

Fleer, M., & Hardy, T. (2001). *Science for children: Developing a personal approach to teaching*, 2nd Edition. NSW: Pearson Education.

Florence, M. K., & Yore, L. D. (2004). Learning to write like a scientist: Co-authoring as an enculturation task. *Journal of Research in Science Teaching*, Vol 41, pp 637-668.

Foshay, A. W. (1994). Action research: An early history in the U.S. *Journal of Curriculum and Supervision*, Vol 9, pp 317-325.

Fraser, S., Lewis, V., Ding, S. et al (2004). *Doing research with children and young people*. London: Sage Publications.

Freebody, P. (2007). *Literacy education in school: Research perspectives from the past, for the future.* Camberwell, Vic: ACER Press.

Freire, P. (1970). *Pedagogy of the oppressed*. New York: Seabury.

Frigo, T. et al (2003). *Supporting English Literacy and Numeracy for Indigenous Students in the Early Years*, ACER Research Monograph No. 57, Vic: ACER.

Garcia, O. (2000). Bilingual Education. In F. Coulmas (Ed), *The Handbook of sociolinguistics.* Oxford: Blackwell Publishers.

Gardner, A. L., Mason, C. L., & Matyas, M. L. (1989). Equity, excellence and just plain good teaching. *The American Biology Teacher*, Vol 51(2), pp 72-77.

Gee, J. P. (2001). Reading as situated language: A sociocognitive perspective. *Journal of Adolescent & Adult Literacy,* Vol 44(8), pp 714 – 725.

Gee, J. P. (2005). *An Introduction to Discourse Analysis: Theory and method*, 2nd Edition. NY: Routledge.

Gee, J. P. (2008). *Social linguistics and literacies: Ideology in discourses*, 3rd Ed. NY 10016, Routledge.

Gentner, D. (2003). Why we are so smart. In D. Gentner & S. Goldin-Meadow, (Eds), *Language in mind* (pp 195 – 235). Cambridge, MA: MIT Press.

Geswell, J. W. (2003). *Research designs*: 2nd Edition. Thousand Oaks, California: Sage Publications.

Giddens, A. (1979). *Central Problems in Social Theory*. London: Macmillan.

Glassersfeld, E. V. (1993). Questions and Answers about radical constructivism. In K. Tobin (Ed). *The practice of constructivism in science education* (pp 23-38). Hillsdale, NJ: Lawrence Erlbaum Associates Publishers.

Glynn, S., & Muth, K. D. (2008). Methods and strategies: Using drawing strategically. *Science and Children*, Vol 45, No 9, pp 48-51.

Goodrum, D., Hackling, M., & Rennie, L. (2001). The status and quality of teaching and learning of science in Australian Schools: A research report, Department of Education, Training and Youth affairs, Canberra.

Gough, A. (2003). Students' attitudes, interest and motivation to science – what literature says. Retrieved 7/12/05 from http://www.scienceinschools.org/research/research03.htm

González, N., Moll, L., and Amanti, C. (2005). Funds of Knowledge: Theorizing Practices in Households, Communities, and Classrooms. New Jersey: Lawrence Erlbaum Associates Publishers.

Grant, E. (2002). My Land, My Tracks: A framework for the holistic approach to indigenous studies. In *Aboriginal and Torres Strait Islander Studies Handbook for the Senior Syllabus 2001.* Brisbane, QLD: Queensland Board of Senior Secondary School Studies, pp. 50-67.

Grabinger, S., Aplin, C., & Ponnappa-Brenner, G. (2007). Instructional design for socio-cultural learning environments. *E-Journal of Instructional Science and Technology*, October, Vol 10, No 1.

Graziano, A. M., & Raulin, M. L. (2004). *Research Methods: A Process of inquiry*, 5th Edition. Boston: Person Education.

Greene, S., & Hogan, D. (2005). *Researching children's experiences: Approaches and methods*. London: Sage publications.

Gruber, O., & Goschke, T. (2004), Executive control emerging from dynamic interactions between brain system mediating language, working memory and attention processes, *Acta Psychologica*, Vol. 115, pp 105 – 121.

Gumperz, J.J., & Levinson, S.C. (Eds.). (1996). *Rethinking linguistic relativity*. Cambridge, UK: Cambridge University Press.

Hackling, M. W. (2006). *Primary Connections: A new approach to primary science teaching and to teacher professional learning.* Australian Council for Educational Research.

Hampton, E., Licona, M., & Izquierdo, E. (2005). Learning science in multilingual settings. In A. Huerta-Macias (Ed), *Working with English language learners: A guide to successful practice*. Kendall Hunt Publishers.

Hanrahan, M. U. (1999). Rethinking science literacy: enhancing communication and participation in school science through affirmational dialogue journal writing. *Journal of Research in Science Teaching,* Vol 36(6), pp 699-717.

Hanrahan, M. U. (2001). Literacy learning as involving both skills and relationships: Implications for the development of science literacy. Paper presented at Australasian Science Education Research Association, 11-14 July, 2001, Sydney, NSW.

Hanrahan, M. U. (2005). Highlighting Hybridity: A Critical Discourse Analysis of Teacher Talk in Science Classrooms. Published online in *Wiley InterScience* (www.interscience.wiley.com). DOI 10.1002/sce.xxxx

Happs, J. C. (1994). *Level 3, Science in Focus, Energy and Change*. Victoria: Learning Solutions.

Happs, J. C. (1996). *Level 4, Science in Focus, Energy and Change*. Victoria: Learning Solutions.

Harker, R. (1990). Bourdieu – Education and reproduction. In R. Harker, C. Mahar & C. Wilkes (Eds), *An introduction to the work of Pierre Bourdieu: The practice of theory*. London: Macmillan Press.

Harris, S. (1990), *Two-way Aboriginal schooling: Education and cultural survival*. Canberra: Aboriginal Studies Press.

Hatano, G., & Wertsch, J. V. (2001). Socio-cultural approaches to cognitive development: The constitutions of cultural mind. *Human Development*, Vol 44, pp 77 – 83.

Henderson, D. G., Fisher, D. L., & Fraser, B. J. (1998). Learning environment and student attitudes in environmental science classrooms. Proceedings Western Australia Institute for Educational Research Forum. Retrieved 7/11/05 from http://education.curtin.edu.au/waier/forms/1998/henderson.html

Hitchcock, G., & Hughes, D. (1989). *Research and the teacher: A qualitative introduction to school based research*. London: Routledge.

Hitchcock, G., & Hughes, D. (1995). *Research and the classroom teacher.* London: Routledge.

Hodson, D. (2000). Toward universal scientific literacy. *Orbit*, Vol 31, No 3, p 13.

Holme, J. (2000). *An introduction to pidgins and creoles*. Cambridge: Cambridge University Press.

Holmes, A. (1983). *Counters of a world view*. Leicester: Intervarsity Press.

Holmes, R. M. (1998). *Fieldwork with children*. London: Sage Publications.

Hooley, N. (2003). Pragmatic science: Establishing non-racist, non-hegemonic learning from a Deweyan and Bourdieuian perspective: Conference of NZARE and AARE Educational Research, Risk and Dilemmas, 29 Nov to 3 Dec, Auckland, New Zealand. Retrieved 12/1/06 from http://www.aare.edu.au/03pap/hoo03266.pdf.

Hubber, P., & Tytler, R. (2004). *Conceptual Change Models of Teaching and Learning: The art of teaching science*. Sydney: Allen and Unwin.

Hubber, P., Tytler, R., & Haslam, F. (2008). Year 7 students' understanding of force as a representational issue: Insights from a classroom video study. Paper presented at the conference of the Australasian Science Education Research Association (ASERA), Brisbane, July 3-5.

Hubber, P., Tytler, R. & Haslam, F. (2010). Teaching and learning about Force with a Representational Focus: Pedagogy and Teacher Change. *Research In Science Education,* Vol 40 (1), pp. 5-28.

Huitt, W. (2003). Constructivism. *Educational Psychology interactive*. Valdosta, GA: Valdosta State University. Retrieved 5/11/05 from http://chiron.valdosta.edu/whuitt/col/cogsys/construct.html

Jegede, O. J. (1995). Collateral learning and the eco-cultural paradigm in science and mathematics education in Africa. *Studies in Science Education*, Vol 25, pp 97-137.

Jegede, O. J., & Aikenhead, G. S. (1999). Transcending cultural borders: Implications for science teaching. *Research in Science and Technological Education*, Vol 17, pp 45-66.

Jegede, O. J., Aikenhead, G., & Cobern, B. (1996). Cultural studies in science education. Paper presented at Mito Meeting, 23-27 September. Retrieved 11/1/06 from http://teleman.edu.ibaraki.jp/jrp/report/129Agenda.

Jenkins, E. (2001). Research in science education in Europe: Retrospect and prospect. In H. Behrendt; H. Dahncke; R. Duit; W. Graber; M. Komorek; A. Kross & P. Reiska (Eds), *Research in science education- past, present and future*. Dordrecht: Kluwer Academic Publications.

Jenkins, R. (2002). *Pierre Bourdieu: revised edition*, New York: Routledge.

Kawagley, A. (1990). Yupiaq ways of knowing. *Canadian Journal of Native Education*, Vol 17, pp 5-17.

Kawagley, A. O. (2000). Integrating indigenous knowledge, ways of knowing and world views into the Education System in Rural Alaska. Retrieved 12/1/06 from http://www.taiga.net/arctic2000/abstracts/kawagley.html

Kawasaki, K. (1990). A hidden conflict between Western and Traditional concepts of nature in science education in Japan. *Bulletin of the School of Education Okayama University*, Vol 83, pp 203-214.

Key, P. M. (2008). Teaching Indigenous students science. Paper presented at Australian Association for Research in Education. Retrieved 10/2/10 on http://aare.edu.au/08pap/key

Kemmis, S., & McTaggart, R. (1988). *The action research planner,* 3rd Edition. Geelong: Deakin University Press.

Kemmis, S., & McTaggart, R. (2000). Participatory action research. *Handbook of Qualitative Research,* 2nd Edition. CA, Thousand Oaks: Sage Publication.

Kemmis, S., & McTaggart, R. (2005). Participatory action research. *Handbook of Qualitative Research,* 3rd Edition. CA. Thousand Oaks: Sage Publication.

Klein, M. (1994). The politics of active involvement: Problematising constructivist pedagogy, action research and in – school experience in pre-service teacher education. Paper presented at the Australian Association of Research in Education. Retrieved 30/11/2009 on http://www.aare.edu.au/94pap/kleim94185.txt

Klein, M. (2004). Action Research. ED5190/ED5290, Introduction to Educational Research. Module 2: Approaches to Educational Research. School of Education, James Cook University, Queensland, Australia.

Klein, M. (2007). Engaging pedagogies in early mathematics education: fostering autonomy or the cruellest regulation? Paper presented at the Australian Association of Research in Education 2006, International Education Research Conference, 26 – 30 Nov, Adelaide, Australia. Retrieved 10/8/09 from http://www.aare.edu.au/06pap/kle06329.pd.

Klein, P. (2006). The challenges of science literacy: From the viewpoint of second-generation cognitive science. *International Journal of Science Education*, Vol 28(2-3), pp 143-178.

Klenowski, V. (2009). Australian Indigenous students: Addressing equity issues in assessment. *Teaching Education*, Vol. 20, No. 1. pp 77-93.

Kvale, S. (1996). *Interviews: An introduction to qualitative research interviewing*. London: Sage Publications.

Labov, W. (1970). *The study of non-standard English*. Washington, DC: Centre for Applied Linguistics.

Lemke, J. L. (1990). *Talking science: Language, learning and values*. Norwood, NJ: Ablex.

Lewis, A., & Lindsay, G. (Eds). (2000). *Researching children's perspectives.* Buckingham: Open University Press.

Lewis, V., Kellet, M., Robinson, C. et al (2004). *The reality of research with children and young people*. London: Sage Publications

.

Linkson, M. (1999). Some issues in providing culturally appropriate science curriculum support for indigenous students. *Australian Science Teachers' Journal*, March, Vol 45, No 1, pp 41-48.

Liu, M. (2005). Motivating students through problem-based learning. *The University of Texas at Austin Dept. of Curriculum & Instruction*. Retrieved 7/11/05 from http://center.uoregon.edu/ISTE/uploads/NECC2005/KEY-6778393/Liu-NECCOS.

Lovat, T. (Ed). (1987). *People, Culture and Change. Communicating All Around*. NSW: Social Science Press.

Luke, A. (2009). On Indigenous education. *Teaching Education*, Vol 20, No 1, pp 1-5.

Luke, A., Freebody, P., & Land, R. (2000). *Literate futures: Report of the literacy review for Queensland state schools.* Brisbane: Education Queensland.

Luykx, A., Lee, O., & Edwards, U. (2008). Lost in translation: Negotiating meaning in a beginning ESOL Science Class. *Education Policy*, Vol 22, No 5, pp 640-674.

Mahar, C., Harker, R., & Wilkes (1990). The basic theoretical position. In R. Harker, C. Mahar & C. Wilkes (Eds). *An introduction to the work of Pierre Bourdieu: The practice of theory.* London: Macmillan Press.

Malcolm, C. K. (1995). *There's an emu in the sky*. Melbourne: Curriculum Corporation.

Malcolm, I. (1998). “You gotta talk the right way” Language and Education. In G. Partington (Ed). *Perspectives on Aboriginal and Torres Strait Islander Education.* Australia: Social Science Press.

Malcolm, I.G. (2002). *Aboriginal English genres in Perth*. WA: Edith Cowan University.

Martin, K. (2008). The intersection of Aboriginal knowledge, Aboriginal literacies and new learning pedagogy for Aboriginal students. In A. Healey (Ed.) *Multi-literacies and Diversity in Education* (pp. 59-81). South Melbourne: Oxford University Press.

Masters, G. N. (2009). *A Shared Challenge: Improving Literacy, Numeracy and Science Learning in Queensland Primary Schools*. Victoria: Australian Council for Educational Research.

McConvell, P. (1990). Understanding language shift: A step towards language maintenance. In P. McConvell (Ed), *Can Aboriginal languages survive?* St Lucia, Queensland: University of Queensland Press.

McKinley, E. (2005). Locating the global: Culture, language and science education for indigenous students. *International Journal of Science Education*, Vol 27, pp 227-241.

McNiff, J., & Whitehead, J. (2006). *All you need to know about Action Research*. London: Sage Publications.

McTaggart, R., & Curró, G. (2009). Book Language as a Foreign Language – ESL Strategies for Indigenous Learners. Report of research commissioned by the Queensland College of Teachers.

Mellor, S., & Corrigan, M. (2004). *The case for change: A review of contemporary research on indigenous education outcomes*. (Australian Education Review). Melbourne, Victoria: Australian Council of Educational Research.

Michie, M., & Linkson, M. (1999). Interfacing western science and indigenous knowledge: A Northern Territory perspective. Paper presented at the 30th Australian Science Education Research Association Conference; held at Rotorua, Aotearoa, New Zealand, July. Retrieved 12/1/06 from http://members.ozemail.com.au/mmichie/interfacing.html

Michie, M. (2002). Why indigenous science should be included in the school science curriculum. *Australian Science Teachers Journa*l, June, Vol 48, No 2, pp 36-40.

Michie, M., Anlezark, J., & Uibo, D. (1998). Beyond bush tucker: Implementing indigenous perspectives through the science curriculum. *Natsiew: Indigenous perspectives across the curriculum: A resource guide* (pp 101-110). Retrieved 27/10/2005 from: www.natsiew.nexus.edu.au/lens/perspectives/index.html

Millar, R., & Osborne, J. (1998). Beyond 2000. Science Education for the Future: Report of a seminar series funded by the Nuffield Foundation. London, King's College, School of Education.

Ministerial Council on Education, Employment, Training & Youth Affairs. (2004). *National Year 6 Science Assessment Report,* p. xi. Melbourne: MCEETYA.

Mirolli, M., & Parisi, D. (2006). Talking to oneself as a selective pressure for the emergence of language. In A. Cangelosi, A. Smith & K. Smith (Eds), *The Evolution of language: Proceedings of the 6th International Conference on the Evolution of Languages* (pp. 214 – 221). World Scientific Publishing.

Morris, J. (2004). Can anything good come from Nazareth? Race, class and African American schooling and community in the urban south Midwest, *American Educational Research Journal*, Vol 41, No 1, pp 69 -112.

Moore, F. M. (2007). Language in science teaching as a gatekeeper to learning, teaching and professional development. *Journal of Science Teacher Education,* Vol 18, No 2, pp 319-343.

Mueller, M. P. & Tippins, D. J. (2009). van Eijck and Roth's utilitarian science education: why the recalibration of science and traditional ecological knowledge invokes multiple perspectives to protect science education from being exclusive. *Cultural Studies of Science Education.* DOI 10.1007/S11422-009-9236-z. http://www.springerlink.com/content/5810rsg417998045/

Mullins, S. (1995). *Torres Strait: A history of colonial occupation and cultural contact (1864 – 1897).* Rockhampton, Queensland: Central Queensland University Press.

Murphy, P., & Hall, K. (2008). *Learning and practice: Agency and identities*. London: Sage.

Murphy, C., & Sherwood, S. (1995). The tutoring process: Exploring paradigms and practices. In C. Murphy & S. Sherwood (Eds). *The St. Martin's sourcebook for writing tutors*, pp 1-17. NY: St. Martin's.

Nakata, M. (2001b). Changing Indigenous Perspectives in curriculum areas. Paper presented at Aboriginal and Torres Strait Islander Education symposium: Successful futures, Cairns, Queensland, 2-12 April.

Nakata, M. (2002). Indigenous knowledge and the cultural interface: Understanding issues at the intersection of knowledge and information systems. *IFLA Journal*, Vol 28. pp. 281-291.

Nakata (2007), *Disciplining the savages, savaging the disciplines*. Canberra: Aboriginal Studies Press.

Nathan, D. (2000). Plugging in Indigenous knowledge: connections and innovations. *Journal of Aboriginal Studies,* Vol 2, pp. 39-47.

National Curriculum Board. (2009). The shape of the Australian curriculum, Available from http://www.acara.edu.au

Nazzi, T., & Gopnik, A. (2001), Linguistic and cognitive abilities in infancy: Where does language become a tool for categorization? *Cognition*, Vol 80, pp 303 – 312.

Neathery, M. F. (1997). Elementary and Secondary students' perception towards science: Correlations with gender, ethnicity, ability, grade and science achievement. *Electronic Journal of Science Education*, Vol 2, No 1. Retrieved 8/12.05 from http://unr.edu/homepage/jcannon/ejse/ejsev2nl.html

Nesmith, R. (2001). Four practical applications to improving the teaching of Science. *Educare News*, October, pp 51-52.

Nettle, S. P., & Romaine, S. (2000). *Vanishing voices*. New York: Oxford University Press.

Novak, J. D., & Gowin, D. B. (1984). *Learning How to Learn*. Cambridge: Cambridge University Press.

Novak, J. D. (1990). Concept Mapping: a useful tool for science education. *Journal of Research in Science Teaching*, Vol 27, No 10, pp. 937-949.

Norris, S., & Phillips, L. (2003). How literacy in its fundamental sense is central to scientific literacy. *Science Education*, Vol 87, pp 224-240.

OECD Program for International Students Assessment (PISA). (2006). Paris: OECD.

Ogawa, M. (1986). A preliminary study on a key concept "nature" involved in science education. *The bulletin of the Faculty of Education, Ibaraki University (Educational Sciences*), Vol 35, pp 1-8.

Ogawa, M. (1995). Science education in a multi-science perspective. *Science Education*, Vol 79, pp 593-605.

Olson, M. W. (1990). The teacher as researcher: A historic perspective. In M. W. Olson (Ed), *Opening the door to classroom research, (*pp. 1-20). Newark, DE: International Reading Association.

Osborne, B. & Tait, S. (2002). Listen. Learn. Understand. Teach. Social Justice and Teaching Torres Strait Islander and Aboriginal Students, In Gary Partington (Ed), *Perspectives on Aboriginal and Torres Strait Islander Education*. Australia: Social Science Press.

Parson, R. D., & Brown, K. S. (2002). *Teachers as reflective practitioner and action researcher*. Belmont, USA: Wadsworth/Thomas Learning.

Palmer, D. (1999). *Attention grabbing science, Book 2*. NSW: Emerald City Books.

Partington, G. (2003). Aboriginal children and mathematics. *Quadrant,* Vol XLVII, No 11.

Peccei, J. S. (2004). Language and age. In I. Singh & J. S. Peccei, (Eds). *Language, Society and Power* (pp. 113-130). London: Routledge.

Pendley, B. D., Bretz, R. L., & Novak, J. D. (1994). Concept maps as a tool to assess learning in chemistry. *Journal of Chemical Education*, Vol 71, No 1, pp 9-15.

Phelan, P., Davidson, A. L., & Cao, H. T. (1991). Students' multiple worlds: Negotiating the boundaries of family, peer, and school cultures. *Anthropology & Education Quarterly*, Vol 22, No 3, pp 224-249.

Pomeroy, D. (1994). Science education and cultural diversity: Mapping the field. *Studies in Science Education*, Vol 24, pp 49-73.

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Towards a theory of conceptual change. *Science Education*. Vol 66 (2), pp 311-227.

Prain, V., & Waldrip, B. (2008). Using representations for teaching and learning in science. . Paper presented at the conference of the Australasian Science Education Research Association (ASERA), Brisbane, July 3-5.

Prain, V. & Waldrip, B. (2010). Represeting Science Literacies: An Introduction. *Research in Science Education,* Vol 40 (1), pp. 1-3.

Prime Minister's Science, Engineering and Innovation Council. (1999). Raising Awareness of Importance of Science and Technology to Australia's Future: Paper prepared by an independent working group for PMSEIC, Agenda 3, Fourth Meeting, 26th November, Canberra.

Queensland Government Department of Education, Training and the Arts. (2007). *Towards a 10-year plan for science, technology, engineering and mathematics (STEM) education and skills in Queensland, Discussion paper,* October.

Queensland Indigenous Education Consultative Body. (2002). *Standard Australian English and languages for Queensland Aboriginal and Torres Strait Islander students*.

Quinn, M., & Schaak, M. (2004). *MYZONE Science. Forces in action*. Victoria, Heinemann: Harcourt Education.

Ray, S. H. (2001). *Dictionary of the Torres Strait languages*. Queensland: Rams Skull Press.

Rockow, M. (2008). This isn't English class! Using writing as an assessment tool in Science. *Science Scope*, Vol 31, No 5, pp 22-26.

Rogoff, B. (2003). *The cultural nature of human development*. New York: Oxford University Press.

Rose, D., & Read, T. (2003). Learning to listen to indigenous voices: dialogue and dilemmas. Retrieved 12/1/06 from http://www.aare.edu.au/03pap/irv03664.pdf.

Ross, K., Lakin, L., & Callaghan, P. (2000). *Teaching Secondary Science: Constructing Meaning and Developing Understanding*. London: David Fulton Publishers.

Roth, M-W., & Tobin, K. (Eds.). (2006). Announcing Cultural Studies of Science Education. *Cultural Studies of Science Education*, Vol 1, No 1, pp 1-5.

Russell, D., & Russell, P. (1999). The importance of science education for indigenous students. Paper presented at the 48th Annual Meeting of the Australian Science Teachers' Association, Adelaide, South Australia, July.

Sensevy, G., Tiberghien, A., Santini, J., Laube, S., & Griggs, P. (2008). An epistemological approach to modelling: Case studies and implications for science teaching. *Science Education*, Vol 92, No 3, pp 424-446.

Sewell, W. H. (1999). The concept(s) of culture. In Bonnell, V. E., & Hunt, L. (Eds). *Beyond the cultural turn: New directions in the study of society and culture.* Berkeley: University of Califonia Press.

Shaeffer, F. A. (1976). *How should we then live? The rise and decline of western thought culture*. Westchester: Crossway books.

Shamos, B. M. H. (1995). *The Myth of Scientific Literacy*. New Brunswick, NJ: Rutgers University Press.

Sharwood, J. (Ed). (2005). *Science Edge 3*. Southbank, Victoria: Thomas Nelson.

Sharp, N. (1993). *Stars of Tangai: The Torres Strait Islanders*. Canberra, ACT: Aboriginal Studies Press.

Shnukal, A. (1996). *Broken: an introduction to the Creole language of Torres Strait*. Canberra: ANU Printing Service.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, Vol 15, pp. 4-14.

Singh, I. (2004). Language, thought and representation. In I. Singh & J. S. Peccei, (Eds). *Language, Society and Power* (pp. 17-33). London: Routledge.

Sire, J. W. (1997). *The universe next door: A guide to worldviews*, 3rd Edition. Leicester: Intervarsity Press.

Skamp, K. (1998). *Teaching primary science constructively*. Sydney: Harcourt.

Smith, R. (1993). Potentials for empowerment in critical education research. *Australian Education Researcher,* Vol 20(2), pp 75-93.

Snively, G., & Corsiglia, J. (2001). Discovering indigenous science: Implications for science education. *Science Education*, Vol 85, No 1, pp 6-34.

Snively, G. J., & William, L. B. (2008). “Coming To Know”: Weaving Aboriginal and Western Science Knowledge, Language, and Literacy into Science Classroom. *L1 – Educational Studies in Language and Literature*, Vol 8 (1), pp 109-133.

Snook, I. (1990). Language, truth and power: Bourdieu's ministerium. In R. Harker, C. Mahar & C. Wilkes (Eds), *An introduction to the work of Pierre Bourdieu: The practice of theory*. London: Macmillan Press.

Somonelli, R. (1994). Sustainable science: A look at science through historic eyes and through the eyes of indigenous people. *Bulletin of science, technology & society,* Vol 14, No 1, pp 1-12.

State of Queensland, Queensland Studies Authority: *Science Syllabus Years 1 to 10* (2004).

Stevenson, R. (1996). What counts as good action research? Paper presented at the Ethnography in Education Research Forum, Philadelphia.

Stringer, E. T. (2007). *Action Research,* 3rd Edition, NY: Sage Publications.

Sutherland, D.L. (2003). The case for capacity building as a pedagogical goal in the science classroom. In D. L. Sutherland & L. Sokal (Eds). *Resiliency and capacity building in inner-city learning communities,* Winnipeg, Manitoba, Canada: Portage & Main Press.

Sutton, C. (1992). *Words, science and learning*. Buckingham: Open University Press.

Smyth, J. (2007). Towards the Pedagogically Engaging School: Listening to Students. In D. Thiessen & A. Cook-Sather (Eds). *International Handbook of Student Experience in Elementary and Secondary School*, Netherlands: Springer.

Synott, J., & Whatman, S. (1998). United to the sea and land: Cultures, histories and education in the Torres Strait. In G. Partington (Ed), *Perspectives on Aboriginal and Torres Strait Islander education* (pp 55-74). Katoombe, NSW: Social Science Press.

Taylor, P. C. (1998). Constructivism: Value added. In B. J. Fraser & K. G. Tobin (Eds). *The international handbook on science education* (pp 1111-1123). Great Britain: Kluwerb Academic Publishers.

Taylor, P. T. (2005). An Illuminative Participatory Evaluation of the Response of Queensland Schools to Indigenous Literacy Policies. Unpublished PhD Thesis, James Cook University, Queensland.

Theobald, P. (1997). *Teaching the commons: Place, pride and sense of community*. Boulder: Westview Press.

Thomas, L. (2004). Attitudes to language. In I. Singh & J. S. Peccei, (Eds). *Language, Society and Power* (pp. 193-208). London: Routledge.

Tobin, K. (2005). Urban Science as a Culturally and Socially Adaptive Practice. In, K. Tobin, R. Elmesky & G. Seiler (Eds), *Improving Urban Science Education: New roles for teachers, students and researchers*. New York: Rowman & Littlefield.

Tobin, K. (2009). Turning into others' voices: radical listening, learning from difference, and escaping oppression. *Cultural Studies of Science Education*, Vol 4, pp 505-511.

Tobin, K., Elmesky, R., & Carombo, C. (2002). Learning environments in Urban Classrooms: Contradictions, Conflicts and Reproduction of Social Inequality. In, S. Chiew Goh & M. Swe Khine (Eds), *Studies in Educational Learning Environments: An International Perspective.* Singapore: World Scientific.

Todd, A. (1999). *Concept Science*. Victoria: Learning Solutions.

Todd, A. (1999). *Energy, A step by step guide*. Victoria: Learning Solutions.

Tripcony, P. (2000). English literacies: Indigenous Australian Context. *Indigenous perspectives support materials,* Brisbane: Queensland Studies Authority. Retrieved on August 1, 2009, from http://www.qsa.qld.edu.au/learning/3035.html

Tytler, R. (2007). Re-imaging Science Education: Engaging students in science for Australia's future. *Australian Education Review* No. 51. Australian Council of Education Research, ACER press.

Valentine, P. (1996). Difficulties for learning science for second language learners. Unpublished MA Thesis, University of York.

Values and Ethics: Guideline for Ethical Conduct in Aboriginal and Torres Strait Islander Health Research (2006). Retrieved 22/11/08 from: www.nhmrc.gov.au/publications/synopses/e52sym.htm

Van Driel, J. H.,Verloop, N. & de Vos, W. (1998). Developing Science Teachers' Pedagogical Content Knowledge. *Journal of Research in Science Teaching*, Vol 35, No 6, pp 673-695.

Verhoeven, L. (2000). Sociolinguistics and Education. In F. Coulmas (Ed), *The Handbook of sociolinguistics*. Oxford: Blackwell Publishers.

Vilsaint, F., & Heurtelou, M. (1996). *English Haitian – Creole Science Dictionary*. Temple Terrace, FL: Educa Vision Inc.

Vygotsky, L. S. (1978). *Mind and society: The development of higher psychological processes.* Cambridge: Harvard University Press.

Waiti, P., & Hipkins, R. (2002). Cultural issues that challenge traditional science teaching. Paper presented at the Third Annual New Zealand Science Education Symposium, Massey University, Wellington, 22-23 Nov. Retrieved 11/1/06 from http://www.nzcer.org.nz/pdfs/12619.pdf

Waldrip, B. G., & Taylor, P. C. S. (1994). Are students' world views permeable to their school views in a non-western developing country? A paper presented at the annual conference of the Australian Association for Research in Education. Retrieved 12/1/06 from http://www.aare.edu.au/94pap/waldb94324.txt

Walker, O. (2001). *100 Mini Science experiments, Book A*. NSW: User friendly resource enterprise Ltd.

Wandersee, J. H. (1990). Concept mapping and the cartography of cognition. *Journal of Research in Science Teaching*, Vol 27, No 10, pp 923-936.

Wareing, S. (2004). What is language and what does it do. In I. Singh & J. S. Peccei, (Eds). *Language, Society and Power* (pp. 2-15). London: Routledge.

Watkins, P. (1985). *Agency and structure: Dialectics in the Administrations of Education*. Victoria: Deakin University Press.

Watson, H. (1989). *Singing the land, signing the land: a portfolio of exhibits, Helen Watson with the Yolngu community at Yirrkala and David Wade Chambers*. Victoria: Deakin University Press.

Watt, J. (1995). Ethical issues for teacher researchers. The Scottish Council for Research in Education Centre. Retrieved 18/8/2006 from http://www.scre.ac.uk/spotlight/spotlight49.html

Webb, J., Schrato, T., & Danaher, G. (2002). *Understanding Bourdieu*. NSW: Allen & Unwin.

Wellington. J., & Osborne, J. (2001). *Language and literacy in school science education*. Buckingham: Open University Press.

Wellington, J., Henderson, J., Lally, V., Scaife, J., Knutton, S., & Nott, M. (1994). *Secondary Science: Contemporary Issues and Practical Approaches*. London: Routledge.

White, R., & Gunston, R. (1992). *Probing Understanding*. London: Falmer Press.

Whitehouse, H. (2007). *Science on the oval: A guide for doing primary science in school grounds Cairns*. Queensland: James Cook University, School of Education.

Williamson, J., & Dalal, P. (2007). Indigenising the curriculum or negotiating the tensions at the cultural interface? Embedding indigenous perspectives and pedagogies in a university curriculum. *Australian Journal of Indigenous Education*, Vol 36 Supplement, pp. 51-58.

Winford, D. (2003). Ideologies of language and socially realistic linguistics. In S. Makoni, G. Smitherman, A. Ball & A. Spears (Eds.), *Black linguistics: Language, society, and politics in Africa and the Americas* (pp. 21–39). New York: Routledge.

Winter, R. (1989). *Learning from experience: Principles and practice in action research.* London: Falmer.

Wolters, A. M. (1985). *Creation regained: A transforming view of the world*. Leicester: Intervarsity Press.

Worsley, P. (1997). *Knowledge: culture, counterculture, subculture*. London: Profile Books.

Yore, L. D. (2001). What is meant by constructivist science teaching and will the science education community stay the course for meaningful reform? *Electronic Journal of Science Education,* Vol 5(4). Online journal: Retrieved 10/8/08 from http://unr.edu/homepage/Crowther/ejse/yore.html.

Yore, L. D. (2008). Science literacy for all students: Language, culture and knowledge about nature and naturally occurring events. *L1 – Educational Studies in Language and Literature,* Vol 8 (1), pp 5-21.

Yore, L. (2009). Science Literacy for all – More than a logo or rally flag. Paper presented at the International Science Education Conference, Singapore, 24th – 26th November.

Yore, L. D., Hand, B. M., & Florence, M. L. (2004). Scientists' views of science, models of writing and science writing practice. *Journal of Research in Science Teaching,* Vol 41(4), pp 338-369.

Yore, L. D., & Treagust, D. (2006). Current realities and future possibilities: Language and science literacy – empowering research and informing instruction. *International Journal of Science Education*, Vol 28(2-3), pp 291-314.

Yosso, T. J. (2005). Whose culture has capital? A critical race theory discussion of community cultural wealth. *Race Ethnicity and Education*, Vol 8, No. 1, pp 69 – 91.

Yunkaporta, T., & McGinty, S. (2009). Reclaiming Aboriginal knowledge at the cultural interface. *The Australian Educational Researcher*, Vol. 36, No. 2, pp 55 -72.

Zeichner, K. (1997). Action research as a tool for educational and social reconstruction. Paper presented at the annual meeting of the Brazilian National Association of Postgraduate Education and Educational Research (ANPED), Caxambu, Brazil.

Zeichner, K. M., & Noffke, S. E. (2002). Practitioner Research. In R. Virginia (Ed), *Handbook of Research on Teaching, Fourth Edition.* Washington DC: American Educational Research Association.

Zen, E-AN. (1992).Scientific literacy: What it is, why it is important, and what can scientists do to improve the situation. *The Australian Science Teacher's Journal*, September, Vol 38, No 3, pp 18-23.

Zevenbergen, R., Sullivan, P., Lerman, S., Boaler, J., Grootenboer, P., & Niesche, R. (2008). Reforming pedagogy in remote Indigenous contexts. *Curriculum Leadership*, Vol 6, Issue 24.

Appendix A

INFORMED CONSENT FORM (parents and guardians)

PRINCIPAL INVESTIGATOR	Philemon Tatenda Chigeza
PROJECT TITLE:	A study on how middle school Torres Strait Islander students understand the topics of Energy and Force.
SCHOOL	School of Education, JCU
CONTACT DETAILS	**Philemon.chigeza@jcu.edu.au**

Taking part in this study is voluntary and your consent is requested. Your son/daughter has been invited in this study because they have boarded in the school for more than a year, ensuring regular attendance. Your son/daughter will complete learning activities on the topics of Energy and Force.
Your son/daughter will be observed and informally interviewed about the activities, to make clear their personal understanding, experience and conception of Energy and Force.
Each of the activity sessions will take approximately one hour and the interview sessions approximately thirty minutes. This data is the focus of analysis for my thesis.

I agree for my son/daughter to take part in the study.	☐ YES	☐ NO
I agree to audio taping of my son/daughter's interview.	☐ YES	☐ NO

The aims of this study have been clearly explained to me and I understand what is wanted of my son/daughter. I know that taking part in this study is voluntary and my son/daughter can stop taking part in it at any time and may refuse to answer any questions.

I understand that **that no names will be used to identify my son/daughter in the study or in any publications.**

Name: *(printed)*	
Signature:	**Date:**

Appendix B

<u>Information sheet for parents and guardians</u> (This will be read to you).

Title:

A study on how middle school Torres Straits Islander students understand the topics of Energy and Force.

Description of study:

Taking part in this study is voluntary and your son/daughter is invited. There is no penalty for not taking part. Your son/daughter will not be made public in the study results.

The study will involve Mr Chigeza and your son/daughter's class attending [redacted] college in [redacted]

The study has two main stages. The first stage involves Mr Chigeza observing groups of students in your son/daughter's science classroom. Your son/daughter will complete learning activities on the topics of Energy and Force. The second stage, Mr Chigeza will interview your son/daughter informally on the learning activities your son/daughter has completed to make clear his/her understanding of Energy and Force.

Each of the activity sessions will take approximately one hour and the interview sessions approximately thirty minutes.

This data is the focus of analysis for Mr Chigeza's thesis.

Permission to audio tape the interview sessions is requested from you.

If you require further details of the study or wishes to contact the research team:

Researcher: Philemon Chigeza, (07) 4043 3777, philemon.chigeza@jcu.edu.au

Supervisors: Dr. Hilary Whitehouse, (07) 4042 1421, Hilary.Whitehouse@jcu.edu.au

Dr. Leah Simons, (07) 4042 1543, Leah.Simons@jcu.edu.au

Human Ethics Sub Committee:

If you have any further questions regarding the ethical contact of the research project, please contact:

Tina Langford, Ethics Administrator, Research Office, James Cook University, Townsville, QLD 4811. phone (07) 4781 4342, fax (07) 4781 5521 Email: Tina.Langford@jcu.edu.au

Appendix C

Information sheet for students (This will be read to you the student).

Title:

A study on how middle school Torres Straits Islander students understand the topics of Energy and Force.

Description of study:

Taking part in this study is voluntary and you are invited. There is no penalty for not taking part. You will not be made public in the study results.

The study will involve Mr Chigeza and your class of students attending [redacted] college in [redacted]

The study has two main stages. The first stage involves Mr Chigeza observing groups of students in your science classroom. You will complete learning activities on the topics of Energy and Force. The second stage, Mr Chigeza will interview you individually on the learning activities you have completed to make clear your understanding of Energy and Force.

Each of the activity sessions will take approximately one hour and the interview sessions approximately thirty minutes.

This data is the focus of analysis for Mr Chigeza's Masters of Education thesis.

Permission to audio tape the interview sessions is requested from you.

If you require further details of the study or wishes to contact the research team:

Researcher: Philemon Chigeza, (07) 4043 3777, philemon.chigeza@jcu.edu.au

Supervisors: Dr. Hilary Whitehouse, (07) 4042 1421, Hilary.Whitehouse@jcu.edu.au

Dr. Leah Simons, (07) 4042 1543, Leah.Simons@jcu.edu.au

Human Ethics Sub Committee:

If you have any further questions regarding the ethical contact of the research project, please contact:

Tina Langford, Ethics Administrator, Research Office, James Cook University, Townsville, QLD 4811. phone (07) 4781 4342, fax (07) 4781 5521

Email: Tina.Langford@jcu.edu.au

Appendix D

INFORMED CONSENT FORM (students)

PRINCIPAL Philemon Tatenda Chigeza

INVESTIGATOR

PROJECT TITLE: A study on how middle school Torres Strait Islander students understand the topics of Energy and Force.

SCHOOL School of Education, JCU

CONTACT DETAILS **Philemon.chigeza@jcu.edu.au**

Taking part in this study is voluntary and your consent is requested. You have been invited in this study because you have boarded in the school for more than a year, ensuring regular attendance. You will complete learning activities on the topics of Energy and Force.
You will then be interviewed individually about the activities, to make clear your personal understanding, experience and conception of Energy and Force.
Each of the activity sessions will take approximately one hour and the interview sessions approximately thirty minutes. This data is the focus of analysis for Philemon's thesis.

I agree to take part in the study.	☐ YES	☐ NO
I agree to audio taping of my interview.	☐ YES	☐ NO

The aims of this study have been clearly explained to me and I understand what is wanted of me. I know that taking part in this study is voluntary and l can stop taking part in it at any time and may refuse to answer any questions.

I understand that **that no names will be used to identify me in the study or in any publications**

Name: *(printed)*	
Signature:	**Date:**

Appendix E

Information sheet for assistant teachers

Title:

A study on how Torres Strait Islander students can understand the concepts of Energy and Force.

Background Information:

Philemon Chigeza is a middle school science and maths teacher a[redacted] college and a part-time research student with JCU, School of Education. His research interest is on conceptual understanding of middle school Indigenous students in science education.

Description of study:

Taking part in this study is voluntary and you are invited. There is no penalty for not taking part. You will not be made public in the study results.

The initial part of the study has two main stages. The first stage involves Philemon observing groups of students in a science classroom. The students will complete learning activities on the topics of Energy and Force. The second stage, Philemon will interview students on the learning activities they have completed to make clear their understanding of Energy and Force.

Each of the activity sessions will take approximately one hour and the interview sessions approximately thirty minutes.

Where you come in:

You will be invited to attend some of the science lesson.

Philemon will interview you on what you think and feel about the micro-pedagogy.

The interview sessions will take approximately 30 minutes.

This data is the focus of analysis for Philemon's thesis.

Permission to audio tape the interview sessions is requested from you.

If you require further details of the study or wishes to contact the research team:

Researcher: Philemon Chigeza, (07) 4043 3777, philemon.chigeza@jcu.edu.au

Supervisors:

Dr. Hilary Whitehouse, (07) 4042 1421, Hilary.Whitehouse@jcu.edu.au

Dr. Leah Simons, (07) 4042 1543, Leah.Simons@jcu.edu.au

Human Ethics Sub Committee:

If you have any further questions regarding the ethical contact of the research project, please contact:

Tina Langford, Ethics Administrator, Research Office, James Cook University, Townsville, QLD 4811. phone (07) 4781 4342, fax (07) 4781 5521 Email: Tina.Langford@jcu.edu.au

Appendix F

INFORMED CONSENT FORM (assistant teacher)

PRINCIPAL INVESTIGATOR	Philemon Tatenda Chigeza
PROJECT TITLE:	Conceptual understanding in middle school Torres Strait Islander students: A study on the meta concepts of Energy and Force.
SCHOOL	School of Education, JCU
CONTACT DETAILS	**Philemon.chigeza@jcu.edu.au**

Taking part in this study is voluntary and your consent is requested. You have been invited in this study because you because you are a Torres Strait Islander. You will be consulted on teaching unit on Energy and Force. How Torres Strait Islander students can learn the concepts using their cultural resources. The unit will have activities aiming to elicit students' understanding, experience and conception of Energy and Force. You will be Interviewed informally on what you think and feel about this micro-pedagogy. This data is the focus of analysis for Philemon's thesis.

I agree to take part in the study.	☐ YES	☐ NO
I agree to audio taping of my interview.	☐ YES	☐ NO

The aims of this study have been clearly explained to me and I understand what is wanted of me. I know that taking part in this study is voluntary and l can stop taking part in it at any time and may refuse to answer any questions.

I understand that **that no names will be used to identify me in the study or in any publications**

Name: *(printed)*	
Signature:	**Date:**

Appendix G

[redacted] College
[redacted]

Dear Colleague,

I am inviting you to participate in this study, a part of a research project for my research with JCU, School of Education.

Please note that taking part in this study is voluntary, that your name will not be made public and you can stop taking part at any time.

I have enclosed the information sheet and an informed consent form which you can return to me using the enclosed envelope.

Thank you,

Philemon Chigeza.

Phone: (07) 4043 3777, philemon.chigeza@jcu.edu.au

Appendix H

JAMES COOK UNIVERSITY

Townsville Qld 4811 Australia Tina Langford, Ethics Officer, Research Office. Ph: 07 4781 4342; Fax: 07 4781 5521 \\Research-server\RS\Ethics_Templates\ApprovalFormHuman.doc

<table>
<tr><td colspan="7">ETHICS REVIEW COMMITTEE
Human Research Ethics Committee
APPROVAL FOR RESEARCH OR TEACHING INVOLVING HUMAN SUBJECTS</td></tr>
<tr><td colspan="5">PRINCIPAL INVESTIGATOR</td><td colspan="2">Mr Philemon Chigeza</td></tr>
<tr><td colspan="5">SUPERVISORS</td><td colspan="2">Dr Hilary Whitehouse & Ms Glenda Shopen (Education)</td></tr>
<tr><td colspan="5">SCHOOL</td><td colspan="2">Education</td></tr>
<tr><td colspan="5">PROJECT TITLE</td><td colspan="2">Conceptual understanding in middle school Torres Strait Islander students: a study on the meta concept of energy</td></tr>
<tr><td>APPROVAL DATE</td><td>29 Aug 2006</td><td>EXPIRY DATE</td><td>30 May 2008</td><td>CATEGORY</td><td colspan="2">1</td></tr>
<tr><td colspan="5">This project has been allocated Ethics Approval Number with the following conditions:</td><td>H</td><td>2417</td></tr>
<tr><td colspan="7">1. All subsequent records and correspondence relating to this project must refer to this number.
2. That there is NO departure from the approved protocols unless prior approval has been sought from the Human Research Ethics Committee.

3. The Principal Investigator must advise the responsible Ethics Monitor appointed by the Ethics Review Committee:

• periodically of the progress of the project;
• when the project is completed, suspended or prematurely terminated for any reason;
• if serious or adverse effects on participants occur; and if any
• unforeseen events occur that might affect continued ethical acceptability of the project.

4. In compliance with the National Health and Medical Research Council (NHMRC) “National Statement on Ethical Conduct in Research Involving Humans” (1999), it is MANDATORY that you provide an annual report on the progress and conduct of your project. This report must detail compliance with approvals granted and any unexpected events or serious adverse effects that may have occurred during the study.</td></tr>
<tr><td colspan="5">NAME OF RESPONSIBLE MONITOR</td><td colspan="2">Sorin, Reesa</td></tr>
<tr><td colspan="5">EMAIL ADDRESS:</td><td colspan="2">reesa.sorin@jcu.edu.au</td></tr>
<tr><td colspan="5">ASSESSED AT MEETING
14 Nov 07: Amendment approved for extension of time to 30 May 08
APPROVED Professor Peter Leggat
Chair, Human Research Ethics Committee</td><td colspan="2">Date: 26 Jul 2006

Date: 29 Aug 2006</td></tr>
<tr><td colspan="5">Tina Langford
Ethics Officer
Research Office
Tina.Langford@jcu.edu.au</td><td colspan="2">Date: 14 November 2007</td></tr>
</table>

Appendix I

JAMES COOK UNIVERSITY AUSTRALIA

Celebrating 40 YEARS 1970~2010

News and Media

Search

Didgeridoo joins sounds of science

A James Cook University PhD candidate has found a new purpose for the iconic Aboriginal instrument the didgeridoo: educational tool.

"A didgeridoo plus a barometer makes a science experiment, and the lessons learned include kinetic energy and sound transfer," Philemon Chigeza said.

The didgeridoo experiment is one lesson taught by Mr Chigeza at [redacted] College in [redacted] where he is a science teacher. Mr Chigeza's extraordinary classes form part of his thesis research which focuses on how the use of cultural resources can assist in the understanding of Queensland's science curriculum.

[redacted] College has a predominantly Aboriginal and Torres Straight Islander student base and is well known for its high student retention and impressive academic results. Mr Chigeza believes this is due to the school's unique teaching practices.

"Many classes at [redacted] are delivered in a way that better suits the Indigenous culture," Mr Chigeza said.

Mr Chigeza uses his students' local language, experiences and knowledge in applying science, and said the students more willingly engage in learning as a result.

"This experience facilitates these students to create and celebrate their ways of knowing and take ownership of that knowledge. It is more likely to make them knowledge creators and not recipients of other people's knowledge," Mr Chigeza said.

Mr Chigeza uses both old and new Indigenous cultural resources in his lessons. For example, students used the *Kup Mauri* (or *Kopa Maurii)* which is a traditional sand oven used to cook food for feasting. This cultural practice was explored and used to explain how heat transfers. This was also compared to modern substitutes for the sand oven.

Taking it to the playground, Mr Chigeza used a football game to teach about changing the angle of kicking a football and exploring the forces acting on that football including the gravitational pull and frictional drag.

“Indigenous students are disadvantaged by language and cultural barriers in mainstream Australian schools and I’m aiming to manipulate teaching techniques in a way that they can respond to,” Mr Chigeza said.

Mr Chigeza is hoping that his research will influence policy makers.

“I hope this framework will allow other teachers and policy makers to provide a more equitable and positive education experience for Indigenous students,” Mr Chigeza said.

“I want to raise the status of Indigenous students in the education system to bring them on par with their non-Indigenous counterparts.”

Issued: Wednesday, October 7, 2009

For more information, contact Jo Meehan, JCU Media on 4781 4586.

Appendix J

Rubric

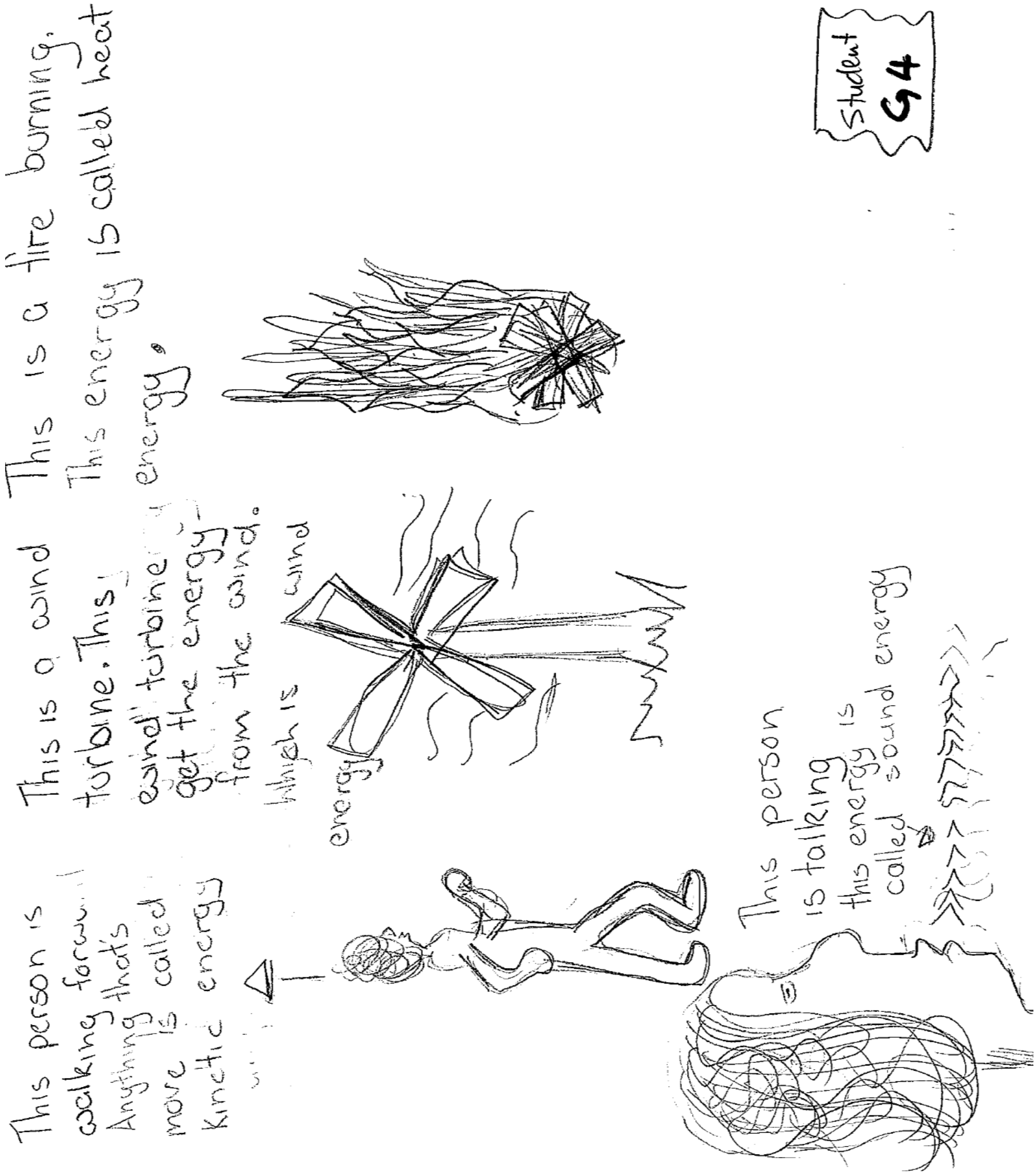
A well designed rubric enhances instruction, guides learning and is a powerful self-assessment tool that states the requirements, range of skills to be acquired and guides individual goal setting (Bean, 2005).

Criteria	Assessment Pointers
Pre-inquiry concept map	Are the major ideas outlined? Does it represent scientific ways of knowing? Is scientific terminology used? Does it represent everyday ways of knowing?
Brainstorming	Are the major ideas discussed? Are scientific ways of knowing discussed? Is scientific terminology used? Are everyday ways of knowing discussed?
Guided comprehensive inquiry	*Scientific Process* Aims of the inquiry, hypothesis and predictions stated. A fair test was done, and method and materials used given. Clearly labelled diagrams tabulate and graph results. Discuss if the results supports relevant scientific theory *Content* Was student able to interpret scientific facts from textbook? Does the work show evidence of scientific ways of knowing? Is scientific terminology used? Is there evidence of scientific process?
Venn-Diagram	Are the major ideas outlined? Does it represent scientific ways of knowing? Is scientific terminology used? Does it represent everyday ways of knowing?
Post-inquiry concept map	Are the major ideas outlined? Does it represent scientific ways of knowing? Is scientific terminology used? Does it represent everyday ways of knowing? Is there a change of understanding compared with the first text?
Individual student reflection on the whole process	Are the major ideas outlined? Does it represent scientific ways of knowing? Is scientific terminology used? Does it represent everyday ways of knowing? Is there a change of understanding compared with the first text?

Appendix K

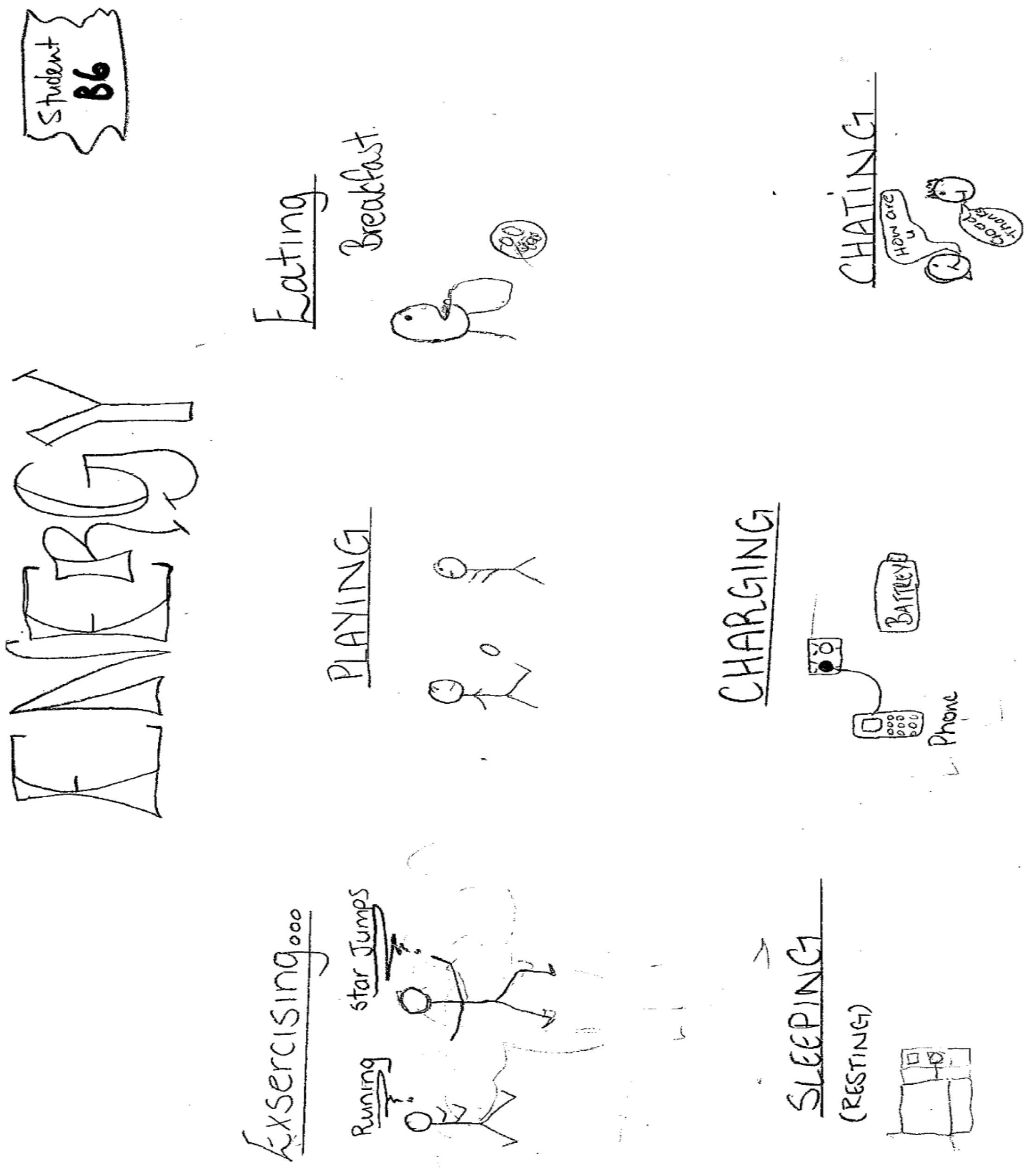
Sample of student's reflection task 1

Student G4 was put in Category A because she used English science words.



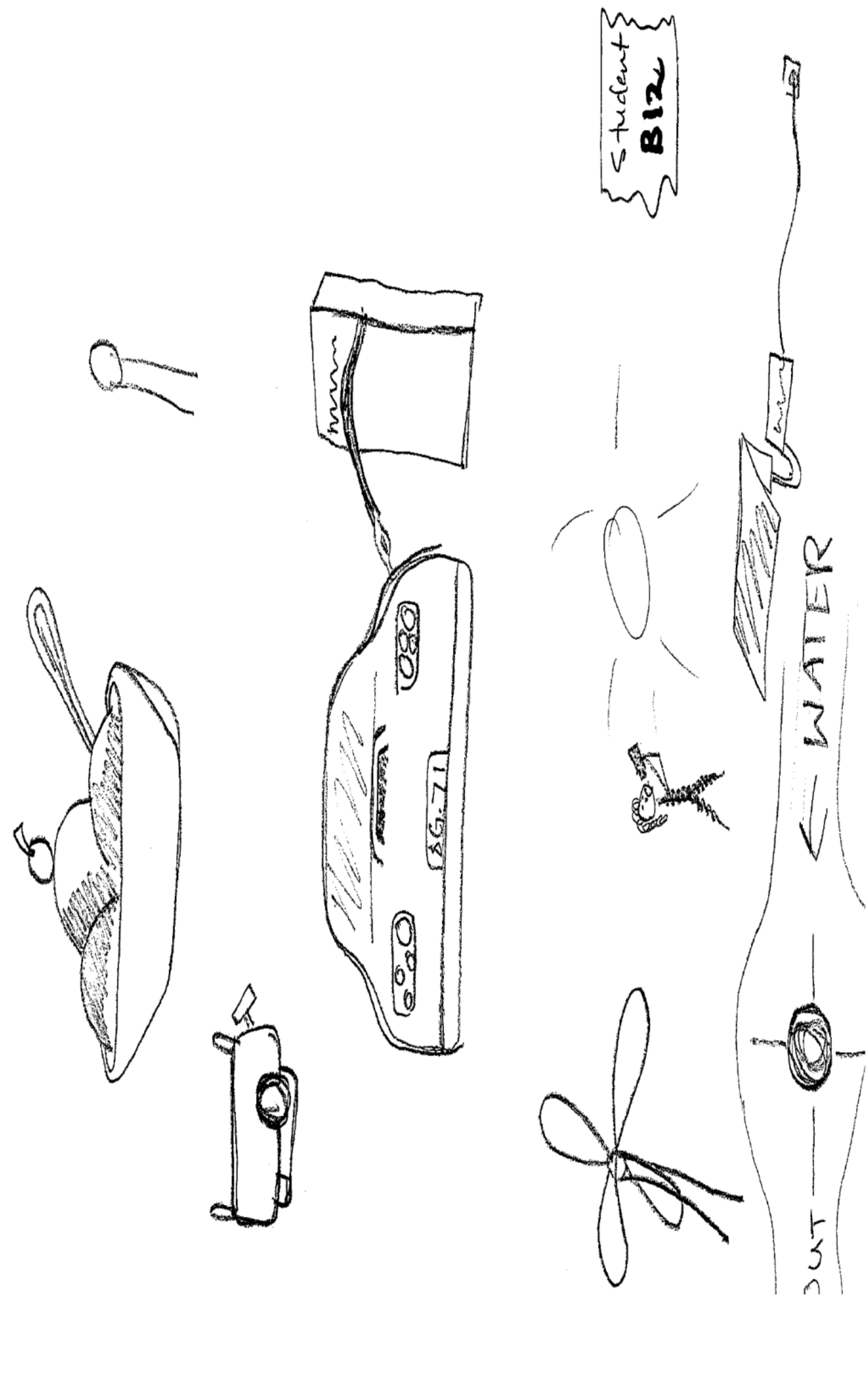
Sample of student's reflection task 2

Student B6 was put in Category B because he used limited English science words.



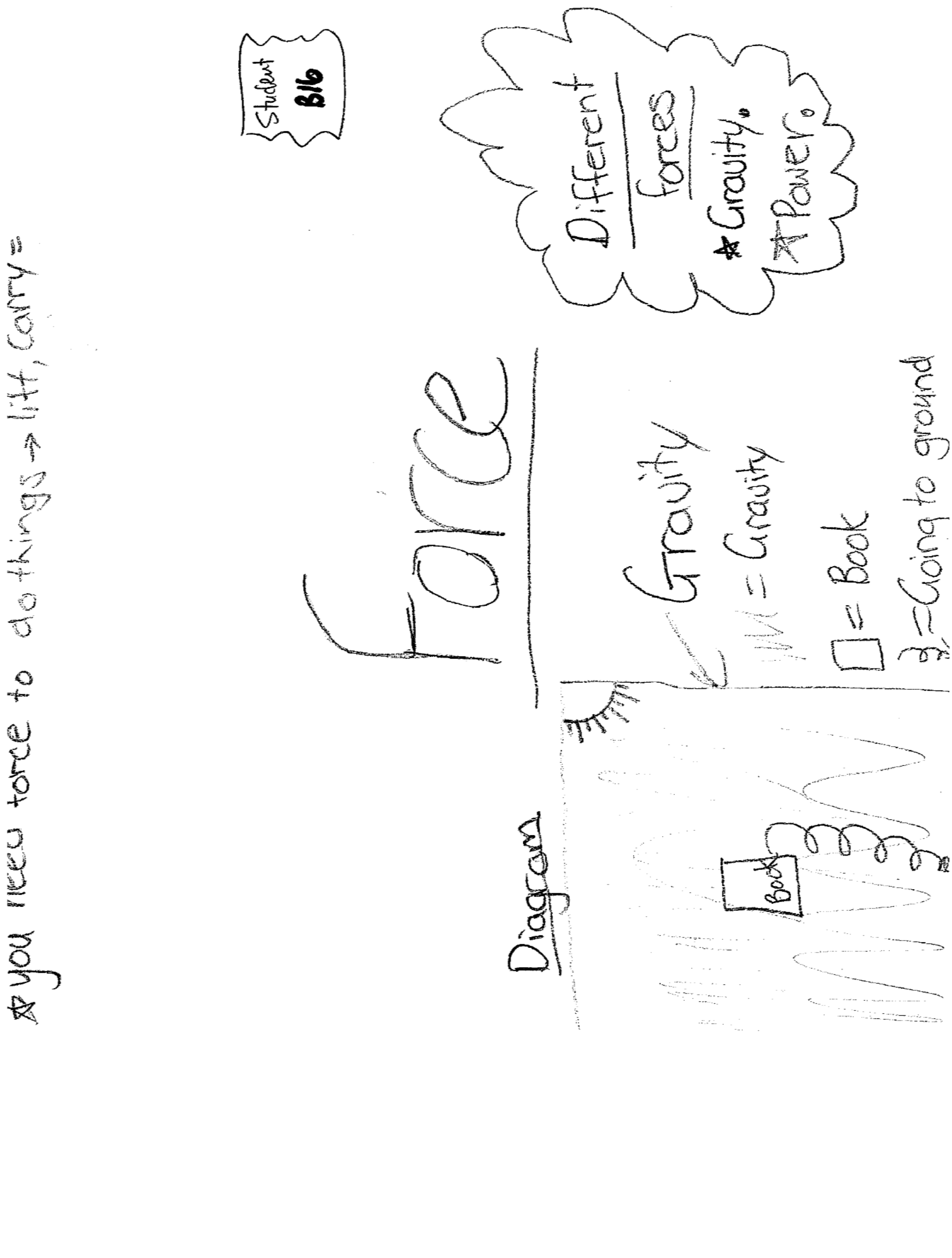
Sample of student's reflection task 3

Student B12 was put in Category C because he did not use English science words.



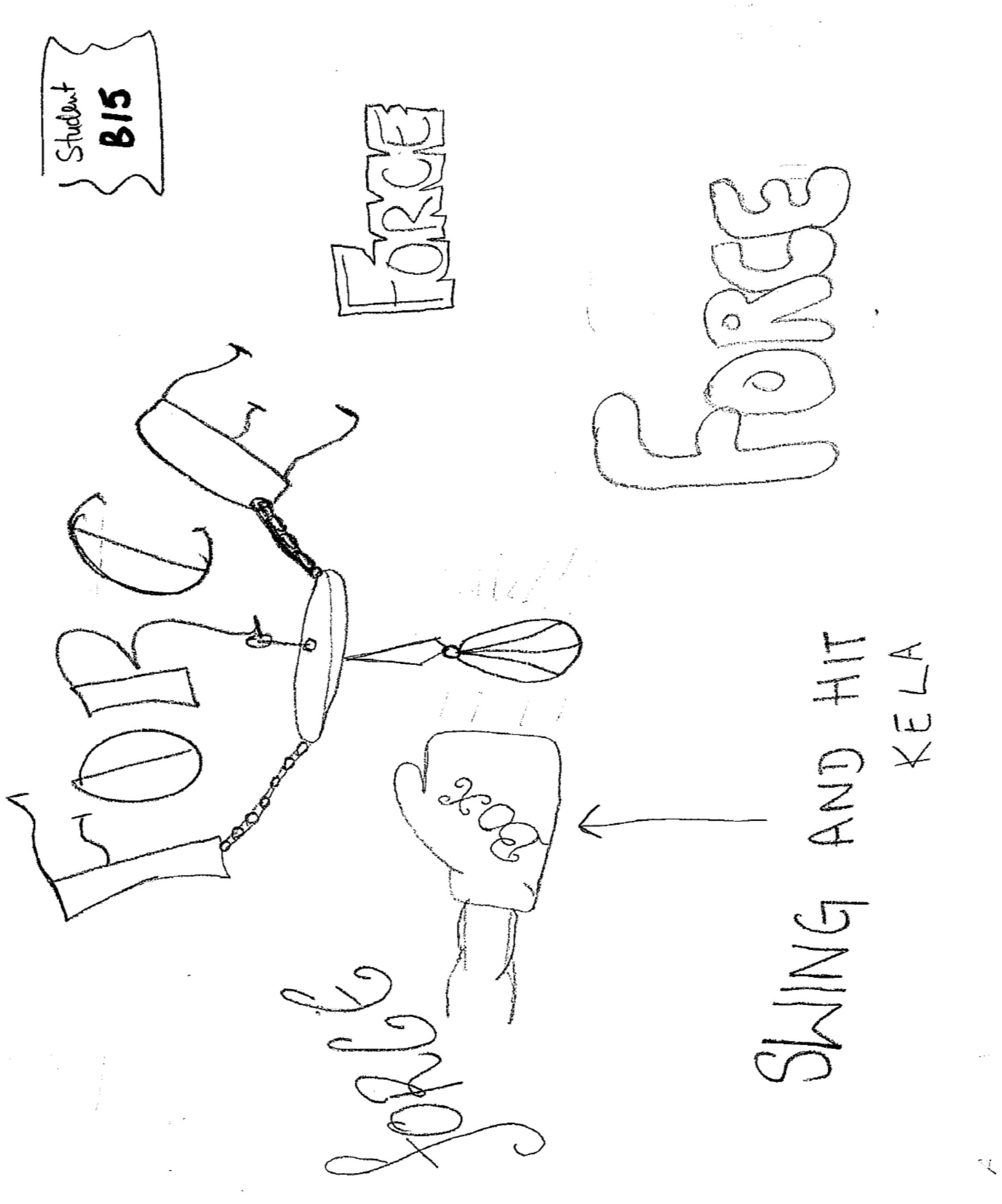
Sample of student's reflection task 4

Student B16 was put in Category A because he used science words.



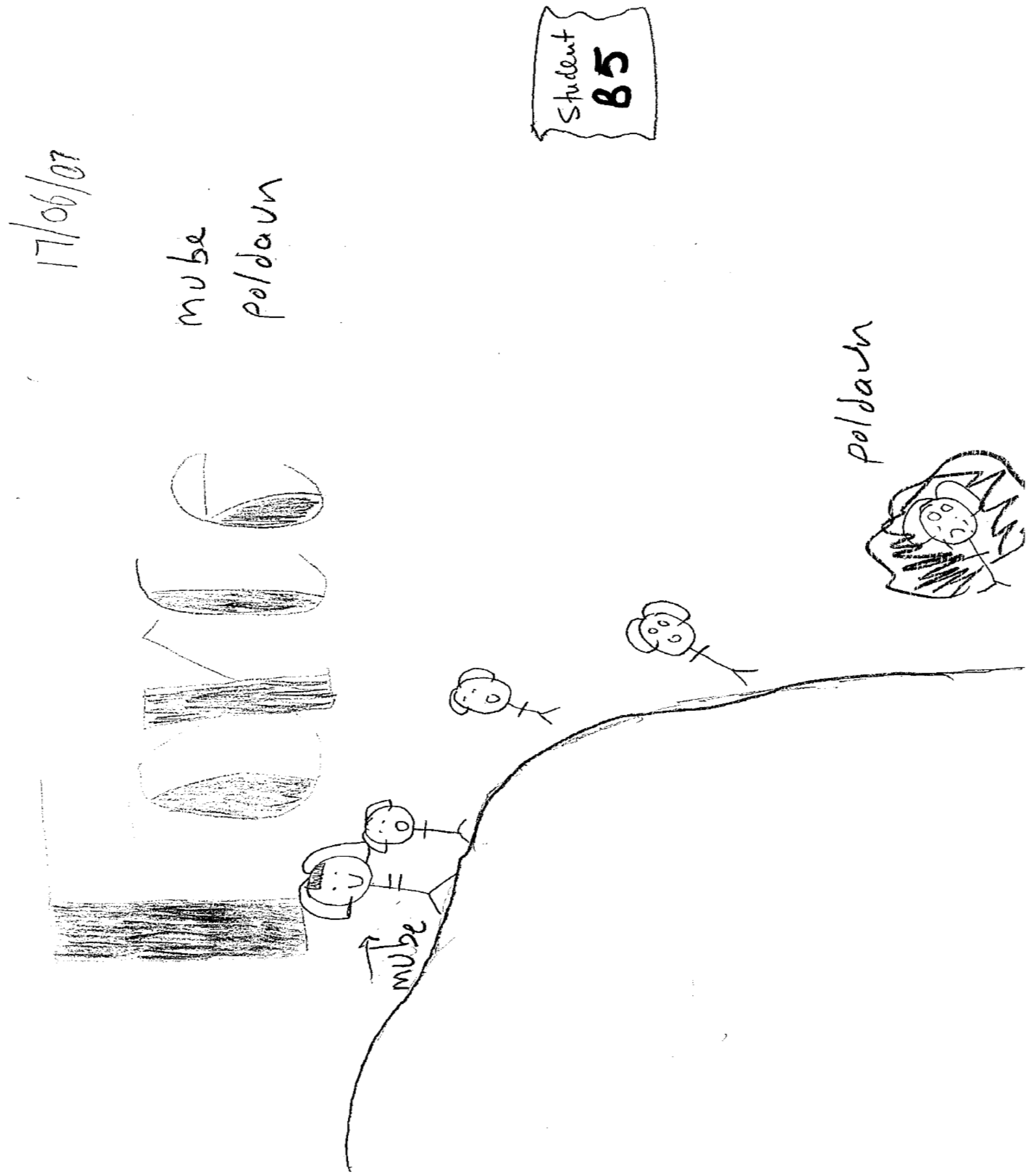
Sample of student's reflection task 5

Student B15 was put in Category C because he did not use English science words. Note that *kela* is a Creole word.



Sample of student's reflection task 6

Student B5 was put in Category C because he did not use English science words. Note that *mube* and *poldaun* are Creole words which can mean to move and fall over respectively.



Appendix L

A teaching unit on Energy

The sequence of the pedagogical strategies:

1. Individual 'pre-inquiry' concept mapping.

2. Group brainstorming on students' everyday ways of understanding.

3. Group guided comprehensive hands-on/minds-on inquiry on scientific ways of understanding.

4. Group construction of Venn Diagrams to compare and contrast the two ways of understanding.

5. Group 'post- inquiry' concept mapping.

6. Application to students' life world and individual student reflection on the whole process.

<u>Lesson Plan Format:</u>

1. Pedagogical focus:

2. Topic:

3. Starter:

Teacher introduces topic/concept and probes for students' thinking.
Encourage one or two students to explain their thinking.

4. Introducing and unpacking learning objectives:

Teacher unpacks what students can expect to achieve: learning objectives and the role of activities in relation to objectives and learning outcomes.
Teacher defines key vocabulary, and explains processes or ideas in the learning objectives.

5. Activities to support student learning:

These include demonstrations, hands-on/minds-on activities, making observations, identifying patterns, linking ideas or models, carrying out procedures, collecting data, etc.
Teacher moves around to assess through listening, observation and questioning what learning is taking place.
Evaluation is done in the context of learning.

6. Plenary (students reporting) stage:

Students are seated to enable class discussions.

Students state what they have learnt, what they found easy or difficult and how their thinking has been changed or confirmed.

Evaluation is done in the context of learning.

(e). Conclusion:

Class revisits learning objectives and activities, and state evidence to show learning has taken place.

Evaluation is done in the context of learning.

Teacher summarises and proposes what needs to be developed in the next lesson.

The unit on Energy

Week 1

Pedagogical focus:

1. Individual pre-inquiry concept mapping
2. Group brainstorming on the students' everyday ways of understanding.

Topic:

Pre-inquire and brainstorm on Energy.

(a). Starter:

Introduce the concept of Energy and ask one or two students to explain their thinking.

(b). Introducing and unpacking learning objectives:

Students should attempt or complete:

1. Individual pre-inquiry concept map on the concept of energy.
2. Group brainstorm on their everyday ways of understanding the concept of energy.

(c). Activities to support student learning:

1. Students attempt or complete the individual pre-inquiry concept map on the concept of energy.
2. Students brainstorm and record ideas on their everyday ways of understanding the concept of energy.

(d). Plenary (students reporting) stage:

Groups present to the class the results, ideas and knowledge they have generated or discussed.

(e). Conclusion:

Class revisits the learning objectives, learning activities and reflect on whether they were achieved.

Teacher summarises the lesson and proposes what needs to be developed in the next lesson.

Week 2

Pedagogical focus:

Group guided comprehensive hands-on/minds-on inquiry on scientific ways of understanding.

Topic:

Energy from food, fuels, wind and water.

(a). Starter:

Introduce the topic and students encouraged to explain how we get energy from food and fuels.

(b). Introducing and unpacking learning objectives:

Students should be able to realise that food, fuels, wind and water are sources of energy.

(c). Activities to support student learning:

1. Stored energy from food worksheets. (Todd, 1999, pp 5, 6&7)
2. Stored energy from fuels worksheets. (Happs, 1996, pp 9-13)
3. Wind and water as sources of energy. (Happs, 1996, p 14)

(d). Plenary (students reporting) stage:

Groups present to the class the results, ideas and knowledge they have generated or discussed.

(e). Conclusion:

Class revisits the learning objectives, learning activities and reflect on whether they were achieved.

Teacher summarises the lesson and proposes what needs to be developed in the next lesson

Week 3

Pedagogical focus:

Group guided comprehensive hands-on/minds-on inquiry on scientific ways of understanding.

Topic:

Different energy forms.

(a). Starter:

Introduce topic and probe for different forms of energy from students.

(b). Introducing and unpacking learning objectives:

Students should be able to:

1. Identify sources of Heat Energy, Light Energy and Sound Energy.
2. Describe characteristics of Heat Energy, Light Energy and Sound Energy.

(c). Activities to support student learning:

1. Activities on Heat energy: (Todd, 1999, pp 10-13); (Happs,1996, pp20 & 32)
2. Activities on Light Energy. (Todd, 1999, p 14); (Happs,1994, p40)
3. Activities on Sound Energy. (Todd, 1999, p 15); (Clutterbuck, 2000, pp 37, 54, 55)

(d). Plenary (students reporting) stage:

Groups present to the class the results, ideas and knowledge they have generated or discussed.

(e). Conclusion:

Class revisits the learning objectives, learning activities and reflect on whether they were achieved.

Teacher summarises the lesson and proposes what needs to be developed in the next lesson.

Week 4

Pedagogical focus:

Group guided comprehensive hands-on/minds-on inquiry on scientific ways of understanding.

Topic:

Different energy forms.

(a). Starter:

Probe more on different forms of energy from students.

(b). Introducing and unpacking learning objectives:

Students should be able to:

1. Describe characteristics of Electrical Energy and Mechanical Energies.

2. Identify sources of Electrical Energy and Mechanical energies.

(c). Activities to support student learning:

1. Electricity worksheet. (Clutterbuck, 2000, p 35)
2. Electrical energy activities. Switch on/off, BLM 1 & Serious circuitry, BML 2 Y (Dearborn, 2002, pp 18 & 19).
3. Mechanical energy worksheet. (Happs, 1996, p 19)
4. Extension on Mechanical energy. (Todd, 1999, p 19)

(d). Plenary (students reporting) stage:

Groups present to the class the results, ideas and knowledge they have generated or discussed.

(e). Conclusion:

Class revisits the learning objectives, learning activities and reflect on whether they were achieved.

Teacher summarises the lesson and proposes what needs to be developed in the next lesson.

Week 5

Pedagogical focus:

Group guided comprehensive hands-on/minds-on inquiry on scientific ways of understanding.

Topic:

Energy transfers.

(a). Starter:

Introduce the topic and probe students on energy transfers.

(b). Introducing and unpacking learning objectives:

Students should be able to:

1. Demonstrate that living and non living things can be energy receivers.

2. Demonstrate that living and non living things can be energy sources.

(c). Activities to support student learning:

1. Plants and energy. (Happs, 1994, p 44)
2. Animals and energy. (Happs, 1994, p46)
3. Non living things and energy. (Happs, 1994, pp 49&50)
4. Can you convert energy? (Walker 2001, p 24)

(d). Plenary (students reporting) stage:

Groups present to the class the results, ideas and knowledge they have generated or discussed.

(e). Conclusion:

Class revisits the learning objectives, learning activities and reflect on whether they were achieved.

Teacher summarises the lesson and proposes what needs to be developed in the next lesson.

Week 6

Pedagogical focus:

Group guided comprehensive hands-on/minds-on inquiry on scientific ways of understanding.

Topic:

Energy conversions.

(a). Starter:

Introduce topic and probe students on energy conversions or changes.

(b). Introducing and unpacking learning objectives:

Students should be able to:

Describe and identify energy conversions or changes that occur in events.

(c). Activities to support student learning:

1. Friction and heat energy (Happs, 1996, p 46)
2. Electromagnetism (Happs, 1996, p 47)
3. Energy transformations worksheet. (Happ2, 1996, p49)
4. Transfer of energy on belt drives. (Todd, 1999, p 20)

(d). Plenary (students reporting) stage:

Groups present to the class the results, ideas and knowledge they have generated or discussed.

(e). Conclusion:

Class revisits the learning objectives, learning activities and reflect on whether they were achieved.

Teacher summarises the lesson and proposes what needs to be developed in the next lesson.

Week 7

Pedagogical focus:

Group guided comprehensive hands-on/minds-on inquiry on scientific ways of understanding.

Topic:

Energy conservations.

(a). Starter:

Introduce topic and describe: conservation of energy, renewable and non renewable sources of energy.

(b). Introducing and unpacking learning objectives:

Students should be able to:

1. Realise that one cannot destroy energy, cannot create energy but can only change it from one form to another.
2. Identify renewable and non-renewable sources of energy.

(c). Activities to support student learning:

1. Can you make energy be made to disappear (Walker, 2001, p 26).
2. Activity on renewable and non renewable sources of energy: students list examples of renewable and non renewable sources of energy.

(d). Plenary (students reporting) stage:

Groups present to the class the results, ideas and knowledge they have generated or discussed.

(e). Conclusion:

Class revisits the learning objectives, learning activities and reflect on whether they were achieved.

Teacher summarises the lesson and proposes what needs to be developed in the next lesson.

Week 8

Pedagogical focus:

Group guided comprehensive hands-on/minds-on inquiry on scientific ways of understanding.

Topic:

Energy consumption.

(a). Starter:

Introduce topic and probe students on energy consumption in their community.

(b). Introducing and unpacking learning objectives:

Students should be able to:

1. Compare household energy consumption of different appliances at different times (peak and off peak times).
2. Realise that different sections of the community use different amounts and kinds of energy.

(c). Activities to support student learning:

Please note that surveys to be done prior to lesson times

1. Energy surveys in the house activities. (Happs, 1994, pp 8 & 9)
2. Community energy consumptions. (Happs, 1994, pp 12 & 13)
3. Cost of Electricity. (Happs, 1994, p14 & 15)

(d). Plenary (students reporting) stage:

Groups present to the class the results, ideas and knowledge they have generated or discussed.

(e). Conclusion:

Class revisits the learning objectives, learning activities and reflect on whether they were achieved.

Teacher summarises the lesson and proposes what needs to be developed in the next lesson.

Week 9

Pedagogical focus:

Conclude Group guided comprehensive hands-on/minds-on inquiry on scientific ways of understanding.

Topic:

School science ways of understanding the concept of energy.

(a). Starter:

Quick revisit on the school science ways of understanding the concept of energy.

(b). Introducing and unpacking learning objectives:

1. Encourage students to look at, talk about, share and predict: definitions, characteristics, the big ideas and details of the concept of energy.
2. Students to compile the comprehensive hands-on/minds-on inquiries on the scientific ways of understanding the concept of energy.

(c). Activities to support student learning:

Students in their groups attempt or complete the probing and record their ideas during talking about, sharing and predicting: definitions, characteristics, the big ideas and details of the concept of energy.

(d). Plenary (students reporting) stage:

Groups present to the class the results, ideas and knowledge they have generated or discussed.

(e). Conclusion:

Class revisits the learning objectives, learning activities and reflect on whether they were achieved.

Teacher summarises the lesson and proposes what needs to be developed in the next lesson.

Week 10

Pedagogical focus:

Venn diagram to compare and contrast the two ways of understanding.

Topic:

Comparing and contrasting the everyday ways of understanding the concept of energy and the school scientific ways of understanding the meta concept of energy.

(a). Starter:

Remind students on what a Venn diagram looks like and what it represents.

(b). Introducing and unpacking learning objectives:

Students should highlight the similarities and differences between the everyday ways and the school science ways of understanding the concept of energy.

(c). Activities to support student learning:

Students in their groups attempt or complete the Venn diagram to compare and contrast the two ways of understanding. Students need to highlight the similarities in the intersection of the Venn diagram.

(d). Plenary (students reporting) stage:

Groups present to the class the results, ideas and knowledge they have generated or discussed.

(e). Conclusion:

Class revisits the learning objectives, learning activities and reflect on whether they were achieved.

Teacher summarises the lesson and proposes what needs to be developed in the next lesson.

Week 11

Pedagogical focus:

Group post inquiry concept mapping

Topic:

Post inquiry understanding on the concept of energy.

(a). Starter:

Remind students of what a concept map is and what it represents.

(b). Introducing and unpacking learning objectives:

Students discuss and represent their post inquiry understanding of the concept of energy on a concept map.

(c). Activities to support student learning:

Students in their groups attempt or complete a post inquiry concept map on their new understanding of the concept of energy.

(d). Plenary (students reporting) stage:

Groups present to the class the results, ideas and knowledge they have generated or discussed on their post inquiry concept map.

(e). Conclusion:

Class revisits the learning objectives, learning activities and reflect on whether they were achieved.

Teacher summarises the lesson and proposes what needs to be developed in the next lesson.

Week 12

Pedagogical focus:

Application of scientific ways of understanding the concept of energy to the life experiences of students and individual student reflection.

Topic:

Application of scientific ways of understanding the concept of energy to students' life experiences.

(a). Starter:

Recap on the post inquiry concept mapping on the concept of energy.

(b). Introducing and unpacking learning objectives:

Students to articulate where scientific ways of understanding the meta concept of energy apply to their real life experiences and list examples or situations.

(c). Activities to support student learning:

Students in their groups articulate and tabulate real life experiences where the scientific ways of understanding the concept of energy apply to them and their environment.

(d). Individual student reflection:

Students reflect individually on the whole process and on what inquiring the concept of energy has meant to them. Students record their sentiments.

(e). Conclusion:

Class revisits the learning objectives, learning activities and reflect on whether they were achieved.

Teacher summarises the unit.

References

Clutterbuck, P. (2003*). Understanding Science, Upper Primary*. NSW: Blake Education.

Dearborn, T. (2002). *Science experiments, Upper Primary*. NSW: Blake Education.

Happs, J. C. (1996). *Science in Focus, Energy and Change, Level 4*. Victoria: Learning Solutions.

Todd, A. (1999). *Energy, A step by step guide*. Victoria: Learning Solutions.

Walker, O. (2001). *100 Mini Science experiments, Book A*. NSW: User friendly resource enterprise Ltd.

Appendix M

A teaching unit on Force

The sequence of the pedagogical strategies:

1. Individual 'pre-inquiry' concept mapping.

2. Group brainstorming on students' everyday ways of understanding.

3. Group guided comprehensive hands-on/minds-on inquiry on scientific ways of understanding.

4. Group construction of Venn Diagrams to compare and contrast the two ways of understanding.

5. Group 'post- inquiry' concept mapping.

6. Application to students' life world and individual student reflection on the whole process.

<u>Lesson Plan Format:</u>

1. Pedagogical focus:

2. Topic:

3. Starter:

Teacher introduces topic/concept and probes for students' thinking.

Encourage students to explain their thinking.

4. Introducing and unpacking learning objectives:

Teacher unpacks what students can expect to achieve: learning objectives and the role of activities in relation to objectives and learning outcomes.

Teacher defines key vocabulary, and explains processes or ideas in the learning objectives.

5. Activities to support student learning:

These include demonstrations, hands-on/minds-on activities, making observations, identifying patterns, linking ideas or models, carrying out procedures, collecting data, etc.

Teacher moves around to assess through listening, observation and questioning what learning is taking place.

Evaluation is done in the context of learning.

6. Plenary (students reporting) stage:

Students are seated to enable class discussions.

Students state what they have learnt, what they found easy or difficult and how their thinking has been changed or confirmed.

Evaluation is done in the context of learning.

(e). Conclusion:

Class revisits learning objectives and activities, and state evidence to show learning has taken place.

Evaluation is done in the context of learning.

Teacher summarises and proposes what needs to be developed in the next lesson.

The unit on Force:

Week 1

Pedagogical focus:

1. Individual pre-inquiry concept mapping
2. Group brainstorming on the students' everyday ways of understanding.

Topic:

Pre-inquire and brainstorm on the concept of Force.

(a). Starter:

Introduce the concept of Force and probe students to explain their thinking.

(b). Introducing and unpacking learning objectives:

Students should attempt or complete:

1. Individual pre-inquiry concept map on the concept of force.
2. Group brainstorm on their everyday ways of understanding the concept of force.

(c). Activities to support student learning:

3. Students attempt or complete the individual pre-inquiry concept map on the concept of force.
4. Students brainstorm and record ideas on their everyday ways of understanding the concept of force.

(d). Plenary (students reporting) stage:

Groups present to the class the results, ideas and knowledge they have generated or discussed.

(e). Conclusion:

Class revisits the learning objectives, learning activities and reflect on whether they were achieved.

Teacher summarises the lesson and proposes what needs to be developed in the next lesson.

Week 2

Pedagogical focus:

Group guided comprehensive hands-on/minds-on inquiry on scientific ways of understanding.

Topic:

Effects of a force.

(a). Starter (2 min):

Student demonstrate the push/pull effects of a force.

(b). Introducing and unpacking learning objectives:

1. Students should demonstrate and describe the effects of forces on shapes of objects.
2. Students calibrate a spring and measure forces.

(c). Activities to support student learning:

1. What forces do; compressing and stretching springs; force of gravity.
   (Quinn & Schaak, 2004, pp 2, 4 & 6)
2. Calibrating a spring so it can be used to measure the size of a force.
   (Quinn & Schaak, 2004, p 16)

(d). Plenary (students reporting) stage:

Groups present to the class the results, ideas and knowledge they have generated or discussed.

(e). Conclusion:

Class revisits the learning objectives, learning activities and reflect on whether they were achieved.

Teacher summarises the lesson and proposes what needs to be developed in the next lesson.

Week 3

Pedagogical focus:

Group guided comprehensive hands-on/minds-on inquiry on scientific ways of understanding.

Topic:

Representing forces on force diagrams.

(a). Starter:

Students demonstrate the push/pull effects of a force.

(b). Introducing and unpacking learning objectives:

Students should be able to:

1. Represent forces on force diagrams, identify balanced and unbalanced forces and resultant/net force.
2. Identify action and reaction forces and the rocket/jet motion.

(c). Activities to support student learning:

1. The push of water (Quinn & Schaak, 2004, pp 12 & 13).
2. Balanced and unbalanced forces, Pushing and pulling forces. (Downey, 2002, p 8.1)
3. Bottle rocket (teacher demonstrates): (Palmer, 1999, p 43).

(d). Plenary (students reporting) stage:

Groups present to the class the results, ideas and knowledge they have generated or discussed.

(e). Conclusion:

Class revisits the learning objectives, learning activities and reflect on whether they were achieved.

Teacher summarises the lesson and proposes what needs to be developed in the next lesson.

Week 4

Pedagogical focus:

Group guided comprehensive hands-on/minds-on inquiry on scientific ways of understanding.

Topic:

Friction opposes motion.

(a). Starter:

Introduce the topic, define and demonstrate friction force.

(b). Introducing and unpacking learning objectives:

Students should be able to:

1. Demonstrate that friction is a force that opposes motion.
2. Identify different types of friction forces.

(c). Activities to support student learning:

1. Friction between two surfaces is affected by
   Nature of the surfaces the materials are made, how hard the surfaces are pressed together and not by the amount of surface area in contact.
   (Todd, 1999, p 6)
2. Activities on friction.(Downey, 2002, p 8.3) and (Clutterbuck, 2000, p 51)

(d). Plenary (students reporting) stage:

Groups present to the class the results, ideas and knowledge they have generated or discussed.

(e). Conclusion:

Class revisits the learning objectives, learning activities and reflect on whether they were achieved.

Teacher summarises the lesson and proposes what needs to be developed in the next lesson.

Week 5

Pedagogical focus:

Group guided comprehensive hands-on/minds-on inquiry on scientific ways of understanding.

Topic:

Different types of forces: Gravitational force and Upthrust.

(a). Starter:

Introduce topic and probe on different types of forces from students.

(b). Introducing and unpacking learning objectives:

Students should be able to:

1. Describe gravitational force/attraction/weight

2. Describe the upthrust in water and air.

(c). Activities to support student learning:

1. Gravitational force: measuring weight (Quinn & Schaak, 2004, pp 8 & 9).
2. Activity on Gravity. (Todd, 1999, p 13)
3. Upthrust in water.
4. Dropping paper (Quinn & Schaak, 2004, p 17).

(d). Plenary (students reporting) stage:

Groups present to the class the results, ideas and knowledge they have generated or discussed.

(e). Conclusion:

Class revisits the learning objectives, learning activities and reflect on whether they were achieved.

Teacher summarises the lesson and proposes what needs to be developed in the next lesson.

Week 6

Pedagogical focus:

Group guided comprehensive hands-on/minds-on inquiry on scientific ways of understanding.

Topic:

Different types of forces: Magnetic forces, Electrical forces and other forces

(a). Starter:

Probe on different types of forces from students.

(b). Introducing and unpacking learning objectives:

Students should be able to identify magnetic and electric forces

(c). Activities to support student learning:

1. Magnetic force and magnetic field lines (Quinn & Schaak, 2004, p 3).
2. Electromagnetism.
3. Activity on other forces: students to identify other types of forces.

(d). Plenary (students reporting) stage:

Groups present to the class the results, ideas and knowledge they have generated or discussed.

(e). Conclusion:

Class revisits the learning objectives, learning activities and reflect on whether they were achieved.

Teacher summarises the lesson and proposes what needs to be developed in the next lesson.

Week 7

Pedagogical focus:

Conclude Group guided comprehensive hands-on/minds-on inquiry on scientific ways of understanding.

Topic:

School science ways of understanding the concept of force.

(a). Starter:

Quick revisit on the school science ways of understanding the concept of force.

(b). Introducing and unpacking learning objectives:

1. Encourage students to look at, talk about, share and predict: definitions, characteristics, the big ideas and details of the concept of force.
2. Students to compile the comprehensive hands-on/minds-on inquiries on the scientific ways of understanding the concept of force.

(c). Activities to support student learning:

Students in their groups attempt or complete the probing and record their ideas during talking about, sharing and predicting: definitions, characteristics, the big ideas and details of the concept of force.

(d). Plenary (students reporting) stage:

Groups present to the class the results, ideas and knowledge they have generated or discussed.

(e). Conclusion:

Class revisits the learning objectives, learning activities and reflect on whether they were achieved.

Teacher summarises the lesson and proposes what needs to be developed in the next lesson.

Week 8

Pedagogical focus:

Venn diagram to compare and contrast the two ways of understanding.

Topic:

Comparing and contrasting the everyday ways of understanding the concept of force and the school scientific ways of understanding the concept of force.

(a). Starter:

Remind students on what a Venn diagram looks like and what it represents.

(b). Introducing and unpacking learning objectives:

Students should highlight the similarities and differences between the everyday ways and the school science ways of understanding the concept of force.

(c). Activities to support student learning:

Students in their groups attempt or complete the Venn diagram to compare and contrast the two ways of understanding. Students need to highlight the similarities in the intersection of the Venn diagram.

(d). Plenary (students reporting) stage:

Groups present to the class the results, ideas and knowledge they have generated or discussed.

(e). Conclusion:

Class revisits the learning objectives, learning activities and reflect on whether they were achieved.

Teacher summarises the lesson and proposes what needs to be developed in the next lesson.

Week 9

Pedagogical focus:

Group post inquiry concept mapping

Topic:

Post inquiry understanding on the concept of force.

(a). Starter:

Remind students of what a concept map is and what it represents.

(b). Introducing and unpacking learning objectives:

Students discuss and represent their post inquiry understanding of the concept of force on a concept map.

(c). Activities to support student learning:

Students in their groups attempt or complete a post inquiry concept map on their new understanding of the concept of force.

(d). Plenary (students reporting) stage:

Groups present to the class the results, ideas and knowledge they have generated or discussed on their post inquiry concept map.

(e). Conclusion:

Class revisits the learning objectives, learning activities and reflect on whether they were achieved.

Teacher summarises the lesson and proposes what needs to be developed in the next lesson.

Week 10

Pedagogical focus:

Application of scientific ways of understanding the concept of force to the life experiences of students and student individual reflection.

Topic:

Application of scientific ways of understanding the concept of force to students' life experiences.

(a). Starter:

Recap on the post inquiry concept mapping on the concept of force.

(b). Introducing and unpacking learning objectives:

Students to articulate where scientific ways of understanding the meta concept of force apply to their real life experiences and list examples or situations.

(c). Activities to support student learning:

Students in their groups articulate and tabulate real life experiences where the scientific ways of understanding the concept of force apply to them and their environment.

(d). Individual student reflection:

Students reflect individually on the whole process and on what inquiring the concept of force has meant to them. Students record their sentiments.

(e). Conclusion:

Class revisits the learning objectives, learning activities and reflect on whether they were achieved.

Teacher summarises the unit.

References

Clutterbuck, P. (2003*). Understanding Science, Upper Primary*. NSW: Blake Education.

Downey, E. (2002). *Heinemann achieve science two. Alternative outcome based worksheets*, Victoria: Heinemann Education.

Palmer, D. (1999). *Attention grabbing science, Book 2*. NSW: Emerald City Books.

Quinn, M. & Schaak, M. (2004). *MYZONE Science. Forces in action*. Victoria: Heinemann Education.

Todd, A. (1999). *Concept Science*. Victoria: Learning Solutions.

Appendix N

Research Journal Entry 1

April 2007 (1st cycle)

Reconnaissance

The school opened its doors to students in 2001, with seventy one students enrolled, and has had a rapid growth over the last eight years. The school enrols five hundred and twenty students in the first semester of 2008, from Prep to grade 12, with about two hundred and fifty in the middle school. The number of students who have been enrolled in the school increased at a faster rate than the funding and acquisition of science equipment, resulting in shortages of facilities and equipment in science teaching.

The school has two groups of middle school students who have different literacy and numeracy skills. The first group are those who joined the school during their early primary school years as day students and progressed in the system to middle school. Most of the families of this group of students live in and around Cairns. Generally, this group has relatively higher literacy and numeracy skills. The group is about a third of the middle school student population. The second group is made up of students who joined the school at Grade 8 from community schools in the Cape York Region as boarding students. Most of the students in this group, which constitute two thirds of the middle school students, in general, have relatively lower literacy and numeracy skills. This group of students also has very limited school science experiences and relatively lower scientific literacy skills.

Mellor & Corrigan (2004) suggest a distinction exists between two types of Indigenous community population. The first group are those from traditional and remote communities, where the vernacular is the common daily language, and where English exists only in the schools. The second group are those communities where English is the community and school language, even given that Aboriginal English is part of the language mix.

The school implements an intensive literacy, numeracy and computer skills program to newly enrolled students during their first semester in the school to improve their skills. So, there is very little time for the students to do science. While students might improve their literacy and numeracy skills which are essential to learning science, their limited scientific experience in the class saves to further alienate students from science and perpetuate low levels of scientific literacy. The three focus areas: literacy, numeracy and computer skills also attract most of the limited funds in the school, and merger funding for science in particular.

The school is implementing a “fun science” program which was meant to interest students into science. This “fun science” program was a collection of science experiments meant to excite and induce student interest in science. Most of the experiments in this “fun science” program involved mixing specific chemicals and watching the reactions that occurred, which stretch from changes of colour to minor explosions. The teacher would then explain to the students the science involved in the reactions. The students’ view of science was reduced to mixing stuff, watching them change colour or pop and the teacher talk. If the mixture of the substances changes colour or pops, then the science is fun, and if it does not, then it’s boring. The nature and meaning of science is lost to the students. The teaching of science is reduced to what the teacher has prepared for the students and whether it changed colour or pop and was fun or not. The limited resources and equipment further relegates science teaching to teacher demonstrations. Science is seen as a teacher thing and not a student thing.

They are limited pedagogical strategies/pointers that are guiding the teachers. The main document the teachers are using is the Queensland Study Authority, Science Syllabus. The Queensland Study Authority, Science Syllabus mentions very briefly on appropriate pedagogical strategies to target and be inclusive of Indigenous students. It does not detail strategies teachers can use.

How science lessons are run

Teacher centred activities in the science room lead students to ask the teacher to show them what was happening, or tell them what is happening. Science was seen as something that is happening inside the beaker or coming from the teacher’s mouth, from the teacher’s actions or from the textbook. Science was seen as the mixing of things, which sometimes explode or change colour and other times do not. If they explode or change colour, then the science was seen as exiting, and if they do not, the science was boring.

Students ask to go to the science room to do science, or ask the teacher to show them some science.

But science is a way of understanding, thinking and doing which can be done anywhere and by anyone who uses a process of scientific inquiry (Graziano & Raulin, 2004).

Science is not only happening in the science room, in the beaker or coming from the teacher or textbook. Students should realize that they are the makers of science as they shape their everyday ways of understanding during their inquiries and investigations. This leads them to new understands, new ways of communicating their changing understanding, and as they compare their new understanding with the current scientific understanding.

Students participating in science activities

Most students come into the school with very limited experiences in primary school science, which translate to limited experience in handling science apparatus.

The teacher demonstrations of chemical reactions further perpetuated alienating the students from science. This scenario was also fuelled by the limited science resources and equipment.

The limited science equipment and the "fun science" program in the school reduced science teaching to teacher centred, further perpetuating the lack of experience in handling the science apparatus and doing science by the students. As a result of these demonstrations, the teacher will not have confidence in students handling the apparatus; the students will not have the confidence in handling the apparatus, students do not have trust in each other handling the apparatus. This scenario degenerated into lack of trust between the students and teachers.

The teacher is in control of the science activities and the doer of science. It reduces the students' role in their learning of science to marvelling at what the teacher has decided to do or the science happening inside the beaker, test tube or flask.

Action Plan

The State of Queensland, Queensland Studies Authority (2007), Science Essential Learning by the end of Year 9, Queensland Curriculum, Assessment and Reporting Framework taken as adequate guidelines and descriptors for the study. The guidelines and descriptors highlight knowledge and understanding, and scientific ways of working: which involves investigating, communicating and reflecting. They emphasise a learner-centred approach to learning and teaching, where the learning of science is considered as a construction of meaning, creation of opportunities for students to practice critical and creative thinking, problem solving and decision making capabilities.

This involves skills and processes such as recall, application, analysis, synthesis, prediction and evaluation of scientific knowledge, leading towards development of conceptual understanding of science. Students reflect on and monitor their thinking as they make decisions and take action.

Students should be encouraged to employ science language and realise that force and energy are identified and analysed to help understand and develop technologies, and to make predictions about events in the world.

Organisation

The organization of the learning should attempt to change ways the students are relating on the concepts of energy and force towards scientific understanding. The learning should specifically seek to:

1. Change the students' everyday ways of knowing to realising that in interaction and change, energy is transferred and transformed but is not created or destroyed.
2. Change the students' everyday ways of perceptions to make them analyse situations where various forces (including balanced and unbalanced forces) act on objects and deduce resultant outcomes (Queensland Study Authority, Science Syllabus Years 1 to 10).

Some pedagogical strategies that can help include: individual 'pre-inquiry' concept mapping, group brainstorming on students' everyday ways of understanding, group guided comprehensive hands-on/minds-on inquiry on scientific ways of understanding, group construction of Venn Diagrams to compare and contrast the two ways of understanding, group ‘post- inquiry’ concept mapping, application to real life experiences and individual student reflection on the whole process.

Activities

Each student attempts or completes a “Conceptual Understanding Tracking Record” (see Appendix A) with the pedagogical strategies:

1. Individual ‘pre-inquiry’ concept mapping,
2. Group brainstorming on students’ everyday ways of understanding,
3. Group guided comprehensive hands-on/minds-on inquiry on scientific ways of understanding,
4. Group construction of Venn Diagrams to compare and contrast the two ways of understanding,
5. Group ‘post- inquiry’ concept mapping,
6. Application to real life experiences and individual student reflection on the whole process.

Students are encouraged to draw diagrams, pictures, cartoons, etc to reflect on their feeling or ideas during and after the data collection sessions.

In the pedagogical strategies, students should attempt to:

1. Design and perform investigations into relationships between forces, motion and energy.
2. Analyse situations where various forces (including balanced and unbalanced forces) act on objects.
3. Collect and present information about the transfer and transformation of energy (including Heat Energy, Light Energy, Sound Energy, Electrical Energy, Kinetic Energy, Gravitational Potential Energy, and Chemical Energy)
4. Explain how energy is transferred and transformed (including Heat Energy, Light Energy, Sound Energy, Electrical Energy, Kinetic Energy, Gravitational Potential Energy, and Chemical Energy).
5. Present alternative ways of obtaining and using energy (including energy from the sun and from fossil fuels) for particular purposes.
6. Discuss the consequences of different ways of obtaining and using energy (including nuclear energy). (Queensland Study Authority, Science Syllabus Years 1 to 10).

Language

Students should be actively and explicitly coached about the nature of scientific texts, language and vocabulary and given time to practice and develop competency in genre commonly used in science contexts. They can then be encouraged to communicate scientific ideas, explanations, conclusions, decisions and data, using scientific argument and terminology, in appropriate formats.

Students should attempt to:

e. Define a force as a push or pull with magnitude and direction, measured in Newtons (N).
f. Recall that they are different forces, which affect the motion, shape, behaviour and energy of objects.
g. Explain balanced and unbalanced forces, action and reaction, contact and non conduct forces.
h. Explain Relationships between forces, motion and energy: Pushes and pulls, machines, floating, sinking, flight, space travel, gravity, electromagnetic, friction, and static situation.
i. Define energy as the capacity to do work, measured in Joules (J).
j. Describe forms of energy (including Heat Energy, Light Energy, Sound Energy, Electrical Energy, Kinetic Energy, Gravitational Potential Energy, and Chemical Energy) and the effects and characteristics of these different forms.
k. Explain energy transfer from one object to another: Reflection and refraction of light, absorption and transmission, conduction and convection,
l. Explain energy converters: Appliances in homes, in industry, in the biological world (plants and animals)
m. Explain alternative ways of obtaining or harnessing energy: Fossil fuels, hydro-electric, wind, geothermal, solar, nuclear
n. Explain alternative ways of using energy: Generating electrical energy, heating, cooling. (Queensland Study Authority, Science Syllabus Years 1 to 10).

Observation

In the pre-inquiry and brainstorming sessions students communicated in Creole and used very little science words.

During the hands-on/minds-on activities, students were quite actively engaged with the motor skills. Most of the students' communication was in Creole and also very little science words were used. Their presentations were mostly in diagrammatical form, with some science words used for labelling the diagrams.
In the Venn diagrams for comparing and contrasting the everyday ways of understanding and the scientific ways of understanding, a few more science words were used. Students were starting to claim scientific words as their everyday ways of knowing. In the post-inquiry concept mapping, evidence of scientific words, some students flooding the Venn Diagrams with science words. Most student communication is still in Creole with some science words.

But, most students could not articulate their prior knowledge and experience they brought into the science learning. Most of the difficulties had to do with communicating these positions in English language. This left the teacher with the choice of deducing what the student's position entails. In the inquiring and exploring phase of learning, students communicated with each other mostly in Creole with a bit of English words and science words.
It was difficult for the teacher to rate the majority of the students' achievement or position. The students were constructing new understandings and communicated in Creole with each other. The descriptors of learning are proposed in English, yet most TSI students communicated those descriptors in their Creole language. It was hard for the teacher to evaluate this knew understanding during formative assessment.

Conceptual change calls for exploring and challenging students' ideas. Exploring the students' ideas was hard to achieve effectively because the teacher could not speak the TSI students' diverse community and Creole languages. Challenging students' ideas was achieved by exposing them to science ideas in the hands-on activities. The monitoring and establishment of the scientific ideas, extension of these ideas and explicit evaluation was hard to achieve because most of the communication was done using community languages and or Creole language, but descriptors of learning are articulated in English. The interpretation of the student's achievement cannot be mapped with these descriptors and is left to the discretion of the teacher. Has conceptual change occurred?

Context based; integration of the science activities with other content was attempted. Interactive dialogue with students about local issues with the students in both the students' language and English was challenging, the teacher was not familiar with all the students' community languages, and most students did not dialogue in English. The teacher could not successfully ascertain whether the students were successfully applying and relating to the concepts?

Some TSI students did very little writing; most communication was done through direct action and demonstrations with a mixed language of Creole and science words. Is scientific language enabling or disabling students to apply and relate to the concepts.

Students preferred to do the hands-on activities, were very engaged in the hands-on activities and enjoyed them. They however did most communication in their community or Creole languages, except for a few occasional science words. Students attempted to explain to each other about the instructions and activities in their Creole languages. Students' presentations were done orally or using diagrams. Most students refused to do the explaining, presentation, discussing, the few who did used mostly illustrations, direct action with little bits of scientific words.

In the individual pre-inquiry concept mapping, most students did not write much, did not use science words. Only two students showed some scientific ways of knowing. During the group brainstorming sessions, most students engaged in the debates but most of the communication was in the students' Creole languages. They used very few science words.

During the group guided hands-on/minds-on activities, most students participated in the motor activities. Listening, reading, understanding and following instructions was challenging because most students were not familiar with the use of some of the language of instruction in science. The teacher had to repeat the instructions several times or illustrate using direct action. But most students to student explanations, students resorted back to their community languages or Creole.

Most students had difficulties with designing their investigation, did not want to write down steps of a fair test, and referring back to the teacher for the steps to follow. Once they familiarised themselves with the steps, they would get into their investigations, sometimes with so much enjoyment and fun doing the activities. Collection of data was done using limited scientific genre, but a lot of direct action, illustrations and diagrams. The reporting, presentation, analysis and explanations were very limited due to use of English science language terms. Also in the Venn diagrams and post-inquiry concept maps, students had the same difficulties.

But when two members of the group do not understand each other, they resort back to English. Is the scientific language enabling or disabling students to participate in the science activities.

Reflection

Is use of science words enabling or disabling students in their talking, writing, labelling of drawings and direct action?
Most verbal communication was done in the students' community languages or Creole. This was good initially BUT??

Most students have problems with spelling and pronouncing the science words. Pronouncing words, if you correct, are you not saying that their way of talking is inadequate, what of mine, l pronounce different.
How can one assess learning summatively, and justify it as a true reflection. Constructivism, context based , conceptual change require that we start from what the students know, which can imply the communal languages/Creole, but students continue to use the languages in science learning, at what point do you expect students to talk science in English?
If the students are talking about science in Creole, are they learning science in that language, what right have we as educator to challenge that?
Uses of English, the teacher spend too much time focusing on writing the words correctly and not learning science concepts.

How is this as a challenge to teachers who have a class of 24 students or more?

Appendix O

Research Journal Entry 2

August 2007 (2^{nd} cycle)

Action Plan

I need to shift from language challenges to communication challenges in science learning of Indigenous students. Ways of communicating: speaking, writing, drawing, direct action.

Try to make sense of the group, monitor each student's responses and try to put it into perspective (making meaning of the data).

1. How are students reproducing knowledge?
2. Implement improved micro pedagogy (divide language into categories, adjusting the language of science, representations)
3. Monitor for evidence of excelling or difficulties

TSI students bring a diverse of knowledge and languages, a unique learning style????, Teaching science has to be addressed in the context of teaching a language ???
Are students making sense of science, accepting the discourse of science????

(a) Divide science words into 2 categories:

1. Instructional language in science, teaching the expression of language from a scientific perspective. Talking science means: describe, ………. These instructional words should be specifically coached so students know what they are supposed to do / expected to do. You can not transport meaning, meaning is not portable, have to teach it from what the students already know. These words in science have to be taught using or aiding from a Creole language, to build solid understanding of students (evidence of students explaining to each other in Creole in 1^{st} and 2^{nd} cycles)
2. Science terminology (7 types of vocabulary challenges). Most of these words are unfamiliar to students, do not have Creole equivalents. Students are enthused to learn these knew words and use them. Students can cope with about 10 new science words….. (Wellington)

(b). Adjusting the language of science (oral / written). Grammatical challenges: logical connectives, qualifying words, part of 1 above, use Creole. Passive voice needs to be avoided, it confuses students.

Lexical density, must be avoided eg. Magnetic flux density. Scientific words, talk in specific science words.

Short sentences, paraphrasing, using repetition for emphasis. Assessment instruments should be adjusted accordingly, aim is not to dilute the science curriculum, but to use extra precautions and effort to clarify, guide and provide feedback.

(c). Representations: using objects, pictures, visuals, and hands-on experiments when creating a connection new word and concept, concrete to abstract. But putting anything into words is it not abstracting it?

Introduce key words in different contexts, guiding students into their use. Label objects and highlight key terms (talk, repetition and emphasis), text (bold or italics)

Activities to monitor

Is scientific terminology affecting the learning of science positively or negatively (but science is a discourse, its language, its thinking through language, its doing/acting, it's a way of understanding through language.

Are students using most of the time learning or trying to copy the science words and not focusing on other aspects of science learning.

First differentiate the new science words from the English words:

All new science words ……

Instructional science words ………

Other words ……

Give students one set of cuttings of these words.

Template scientific words, template fair test procedures, so students can fill the variables, aspects of hypothesising, more coaching, more scaffolding.

Introduce less scientific words per lesson, use concrete objects and representations.

Contestations: will the state/federal or international assessment instruments respect this level of scaffolding???????

QSA essential learning, respect this as science or just “dumping down” the science curriculum, but constructivism prescribes this approach, will QSA extend this to scaffolding assessment instruments???????

What is done this week?

All the new vocabulary provided as one set of cut outs per group.
Cut out to be used to introduce scientific terminology in a non threatening way
Non scientific words in black; scientific words in blue
Students don’t take time copying spelling of the new words during class / decreases the feeling of being wrong than cross out and rewrite the new words
One set per group increases the small groups to work together

Monitor

Difficulties with categories of the scientific words:
Problem with writing scientific reports (understanding the requirements of the steps in the science report format given)
Problem with spelling/pronouncing the words
Taking too much time focusing on writing the words correctly

Most verbal communication in Creole/community languages
Scientific language is “universal”, but Problem with pronouncing the words (mboma..is it not depriving their..???????)

Aha

Are students starting to realize that science is not a teacher thing, why, trying to explain to each other what is happening / teacher no longer the focal point of the lessons but the activities!!!!!!!!!

Language for the semester (third research cycle)

To monitor two groups of words used in talking and writing about science: science words and instructional words in science.
Science words include:

1. Force; magnitude and direction; Newtons (N).

2. Balanced and unbalanced forces, action and reaction forces, contact and non-conduct forces.
3. Machines, gravity, electromagnetic, friction, and static friction.
4. Energy as the capacity to do work, Joules (J).
5. Heat Energy, Light Energy, Sound Energy, Electrical Energy, Kinetic Energy, Gravitational Potential Energy, and Chemical Energy
6. Energy transfer; reflection and refraction of light, absorption and transmission, conduction and convection,
7. Energy converters: in homes, in industry, in the biological world (plants and animals)
8. Fossil fuels, hydro-electric, wind, geothermal, solar, nuclear
9. Generating electrical energy, heating, cooling. (Queensland Study Authority, Science Syllabus Years 1 to 10).

The instructional words in science learning include:

1. Design and perform investigations into relationships between forces, motion and energy.
2. Analyse situations where various forces (including balanced and unbalanced forces) act on objects.
3. Collect and present information about the transfer and transformation of energy (including Heat Energy, Light Energy, Sound Energy, Electrical Energy, Kinetic Energy, Gravitational Potential Energy, and Chemical Energy)
4. Explain how energy is transferred and transformed (including Heat Energy, Light Energy, Sound Energy, Electrical Energy, Kinetic Energy, Gravitational Potential Energy, and Chemical Energy).
5. Present alternative ways of obtaining and using energy (including energy from the sun and from fossil fuels) for particular purposes.
6. Discuss the consequences of different ways of obtaining and using energy.

Observation from

Introducing few science words per lesson, using concrete materials and representations proved helpful to Indigenous students

Language

Introducing few science words per lesson, using concrete materials and representations proved helpful to Indigenous students. Instructional words in science learning include: observe, describe, compare, classify, analyse, discuss, hypothesise, theorise, question, challenge, argue, design experiments, follow procedures, judge, evaluate, decide, conclude, generalise and report (Lemke, 1990).

The meaning of these words is not a packaged product ready to be delivered to Indigenous students. The meanings and implications of these words are negotiated. Indigenous students construct meanings and understandings of these words from their everyday languages and experiences. The study shows evidence of students in all the three categories talking about science in their Creole languages. Creole language equivalents can be used to aid instructional words in science, not only to construct new meaning and understanding for Indigenous students, but to assess them.

Reflection

(see The reflection process)