Science and Mathematics Education Centre

An Interpretive Study of a Teacher's Development of a Constructivist Mathematics Pedagogy in his Primary Classroom.

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DECLARATION

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgement has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

Signature: 

Date: 13 May, 2017

DEDICATION

To my Jo-Ann,

Words cannot express my admiration and love for you. This research project has been a long journey for me, but these 8 years must have seemed an eternity to you.

How many hours were 'lost' to analysis, reading and writing? These were not my hours but our hours.

You made many, many sacrifices to allow me to pursue my dream and goal with never a word of complaint. I did, at times, consider the challenge too great, but for your encouragement and support it would have been abandoned.

However, your role in this achievement was so much more. You remain the most dedicated and professional teacher I have ever witnessed. The theory that I studied, I witnessed in your practice. You represent all that is noble in teaching. It is easy to talk about the ideals of teaching; it is so much more difficult to see these ideals manifest in your classroom. You do it daily.

All I have to give you is my appreciation, admiration and love for your never-ending support and encouragement.

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Peter shone a torch through the world of learning theory and research paradigm, illuminating them for me and sharing his extensive knowledge to my betterment. As I stopped and gazed at these exotic notions, Peter was always available to assist me to develop an increasing understanding of them.

Peter watched patiently as I attempted to present an interpretivist view through the lens of a positivist. His advice and guidance calmly reoriented me towards my proposed research goal. He modelled a truly constructivist perspective in his interactions with me as he sought to develop in me an understanding of concepts.

What a journey this was! Thank you Peter, for getting me to the destination safely and in a state greatly improved from when I started.

To all the students and staff at the school where my research was conducted - thank you for your cooperation, assistance and patience.

ABSTRACT

The complex phenomenon of a mathematics classroom undergoing constructivist pedagogical transformation is the focus of this research. During this research I sought to understand my experience of developing and implementing a constructivist perspective on teaching and learning. My constructivist perspective had three key foci that were derived from research literature on learning theory and constructivist pedagogy.

I designed a 'critical interpretive' research methodology to understand deeply my unfolding pedagogical transformation and, through thick description, to represent the everyday reality of my classroom, especially the impact on my students' learning experiences. Data were generated from student and teacher reflective journals, classroom participant observation and work samples, audiotape recordings, student and teacher interviews, and the CLES questionnaire.

As a teacher-researcher I experienced a parallel evolution of my practical understanding of both an interpretive research epistemology and a constructivist teaching perspective. During the research, it became apparent that my initial epistemic beliefs were largely positivist-behaviourist in nature and had unduly impacted my initial data collection/analysis and the constructivist perspective framing my teaching strategies. It was through prolonged critical self-reflection, narrative writing as inquiry, and peer mentoring that I was able to identify unwanted positivist and behaviourist tendencies and to subsequently take action to represent my research and learning experiences in a way that maintained fidelity with my newfound interpretive-constructivist perspective.

As a result of this research, my initial notion of constructivist teaching strategies has been replaced by an emphasis on a constructivist teaching perspective. Furthermore, I have come to understand that a constructivist teaching perspective is one perspective amongst others within a teacher's pedagogical 'toolkit'.

I have now arrived at a position whereby I understand that how I choose to enact my pedagogical practice – whether from a constructivist or behaviourist perspective - is a decision that needs to be made with careful consideration for the quality of my students' learning experiences.

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INTRODUCTION

> Positivist man is a curious creature who dwells in the tiny island of light composed of what he finds scientifically "meaningful," while the whole surrounding area in which ordinary men live from day to day and have their dealings with other men is consigned to the outer darkness of the "meaningless" (Barrett, 1958, p.21).

In this doctoral research I sought to transform my professional practice – my classroom pedagogy - and the following chapters document my journey towards teaching with a constructivist perspective. I designed a critical interpretive research methodology with an emphasis on understanding phenomena, as opposed to explaining them scientifically. A great deal of my understanding occurred in retrospect, during the process of my thesis writing, and involved a sustained period of critical self-reflection as I engaged in a process of 'writing as inquiry' (Richardson & Adams St. Pierre, 2005). It was through this process that I developed deep insight into both my unfolding constructivist perspective and my interpretivist epistemology of research practice. I came to evaluate and restructure myself as a teacher and a researcher.

Beliefs about what constitutes quality research and quality teaching had been developing in me over time. Given that I had spent in excess of 15,000 hours as a student in formal learning environments - classrooms, lecture theatres - it is likely that these experiences played a significant role in my early development as a teacher and researcher (Rutter, 1979).

During this research I came to realise that my background beliefs and values were affecting my journey of pedagogical transformation. Some of the main impediments can be attributed to these beliefs and values. Prior to commencing doctoral coursework I was not familiar with the term ‘epistemology’; however, my epistemic beliefs had certainly been forming well before my research commenced.

As I came to realise, these epistemic beliefs influenced my research methodology. As discussed in later chapters, a positivist epistemology posed difficulties for my implementation of an interpretivist research methodology.

Although as a professional educator I was familiar with ‘learning theory’, I had not considered it deeply in my professional practice, yet it too had been forming before this teaching innovation commenced. As I reflect on my history as a teacher, I am aghast that these two crucial concepts had not played a conscious role in my professional practice because, as I was to learn, they were playing a significant subconscious role in framing my professional practice.

Genesis Of My Behaviourist Beliefs

From 1974 to 1979, I attended a rural, all boys, Christian Brothers secondary school. Class sizes were between 30 and 50 students. In class, students sat at single desks in silence while a Brother or lay teacher presented a lecture from the front of the classroom.

A graded (basic to advanced) mathematics workbook was distributed to all students. Lecture and chalkboard were used frequently and silence was 'encouraged' through the use of a leather strap for students who spoke.

The teacher, who assumed the classical role at the front of the room, dispensed mathematical knowledge to us. Typically, the teacher provided an introduction to the concept being covered in the textbook and students worked in silence through the relevant pages of exercises. The teacher was in 'hard control' of the classroom and our learning experiences (Taylor, 1996). Our role as students was to passively receive knowledge. The teachers informed us that questions were only asked by 'fools' who did not listen carefully or were not capable of understanding simple explanations and instructions.

The leather strap was not used solely for student indiscretions - speaking, insolence - it was often dispensed to students who offered incorrect answers or, worse still, no answers to questions asked of them by the teacher.

Learning by rote was rewarded with the absence of the strap, and sadly those who faulted in their rote recall suffered the inevitable consequences. McNaught (2006) reported a similar situation in his research on classroom teaching of mathematics in a Christian Brothers school.

As a capable student who showed potential, but never fully realised it, I was relegated to the lower mathematics classes and the basic mathematics workbooks. It was my assessment at the time that I did not possess an innate mathematical ability and that there was little I could do about it except to 'listen harder' and remember facts and formulae more accurately. The flow of facts and formulae never stopped coming and never stopped being assessed. I recall memorising 'sine, tan and cosine' rules and being able to apply these in a rudimentary way, but I had no concept of what it was that I had just calculated or how I had completed the task.

Those students with the supposed innate mathematical gift were moved to 'higher' mathematics classes and worked on more advanced workbooks. I think that meant they received even more complex formulae and problems to solve. I recall walking past one of these classes and observed students talking to each other and discussing their work.

I was in no doubt that mathematical ability was innate and a gift. Capable students who did not fulfil their potential were told that they needed to 'lift their game' as they were not trying hard enough.

I was to see this negative self-perception in students throughout my teaching career; at the mention of mathematics many students automatically expressed their lack of ability. My experiences suggest that 'mathematics anxiety' (McNaught, 2006) is real and has considerable affect on the students in our classes who 'give up' because they believe that they do not have innate mathematics ability.

As a teacher, my development of strong behaviourist beliefs is likely to have stemmed from this earlier stage of my life. Put simply, behaviourism suggests that learning is the result of the principle of stimulus-response, where the passive learner responds to an environmental stimulus (see Chapter 3).

The ease with which I slipped into the role of transmitter of knowledge, despite my desire not to, quite possibly was a result of my early school mathematics learning experiences.

And thus, as a teacher, I developed a behaviourist theory of learning - a concept that was unknown to me at that time, but one that was certainly developing in an anonymous state. Its remnants resided throughout this research, always lurking in the shadows ready to pounce on my best-laid constructivist intentions.

In 1980, I gained an early entry acceptance offer from a Catholic teacher's college; instead, I accepted an administrative traineeship with a domestic airline. The traineeship led me to work in different areas of the airline for six-month periods over the course of three years. When I completed the traineeship I elected to work as an overseas travel consultant. Working for the airline provided me with the opportunity for travel, and I visited North America, Europe and the Middle East. After 12 years working for the airline I accepted a voluntary redundancy package. Next, I worked in a bar at a golf course for two years, and in 1993 I gained entry as a mature age student into an Australian Catholic University.

I completed a Bachelor of Teaching in 1995. The format of all lectures and tutorials was predominately the transmission process where lecturers lectured and students listened and took notes, thus confirming my experience of learning in high school. All questions were to be asked at the tutorial that was held a short time (1-2 days) after the lecture.

Most pen-and-paper assessments were in the form of multiple-choice questions, which sought to assess our ability to recall facts and details from lectures and textbooks. This served as further confirmation of the teaching and learning behaviours I had experienced at school. As a teacher, my classroom assessment tasks maintained this tradition. I came to realise, however, that it was in the assessment of my students that my strongest behaviourist tendencies lay. During this research I came to understand that assessment should be primarily for the betterment of my students, rather than simply serving an administrative function (see Chapters 5, 6 & 7).

When I reflect on my university teacher education experiences, I recall many words spoken about the benefits of student-centred pedagogy, but I do not recall ever witnessing it being put into practice. Lecturers generally practised knowledge transmission through lectures, including those advocating the need for a student-centred teaching approach. I cannot recall the term 'constructivist' ever being used; however, many teaching strategies that could be termed ‘constructivist’ were encouraged (e.g., group work, real-world contexts). Piaget was the focus of many courses. Generally, we were required to recall the stages of his theory of cognitive development and the ages of the children in each stage. I came to understand and appreciate Piaget's contribution to education through later scholarly development and my doctoral course on constructivism (see Chapter 3).

Genesis Of My Positivist Beliefs

On reflection, I believe that I was brought up in an education system and learning environment that believed there exists an objective reality that awaits discovery, and that knowledge of this reality can be passed on to others; one just needs to listen carefully to the person transmitting this truth. This view of the world reflects a positivist belief (see Chapter 3).

In 1996 I completed a Bachelor of Education. It was during this year that I first came to study 'Methods of Inquiry'. I learned about different methods of inquiry and their strengths and weaknesses. This subject was most feared by my fellow students because it was predominantly based on scientific methods of data collection, analysis and presentation. I recall an over-riding emphasis on numbers and statistics. We were required to recall - by rote - statistical terms and formulas. Through lectures and tutorials, I was led to believe that quantitative research had great advantages over qualitative research primarily, as we were told, because of the almost faultless reliability of quantitative data. At that time, it was hard for me to disagree, and so I developed a respect for positivist-based research and a somewhat dismissive attitude towards qualitative research.

I came to understand that my experiences in educational settings with respect to mathematics and research had promoted and supported the widely held belief, at that time, of the pre-eminence of positivism.

A Break In The Positivist-Behaviourist Fog

In 2005, I completed a Master of Education (Teacher Librarianship). It was at this time that I was introduced to the concept of 'post-modernism' in an educational context. This was an important development as it was contrary to my positivist beliefs. I was being asked to reconsider the manner in which I usually perceived children's books. In a post-modern picture book readers are confronted with text and structure that is unfamiliar to them. Multiple meanings provided an opportunity of critical analysis (Anstey, 2002). Further, I was asked to consider the notion of truth and perspective. I had always been a person who felt that poetry should rhyme, otherwise it's not poetry; and that fiction had certain 'rules' that governed its structure and format.

This was a valuable precursor to my doctoral studies. Could knowledge be viewed from different perspectives and could it be perceived differently depending on one's viewpoint? I didn't have the answer to this question, but I was beginning to ask some challenging questions of myself. My certainty about truth, knowledge and perspective was starting to be less set in concrete.

But mathematics seemed to be the exception to my newly developing constructivist perspective. It seemed to me that mathematics could not be looked at in a post-modern light; it was different to English and humanities subjects, and should be treated differently. Or so I believed. It was this initial belief about mathematics that formed the genesis of my doctoral research questions. The question of whether a constructivist teaching approach could be successfully implemented in a mathematics lesson piqued my interest as it was contrary to my positivist view that mathematics represented an objective reality and could be passed on to students through transmission.

The Master of Education course provided me with the skills, strategies and understandings to drastically improve my professional practice. It was my desire to further improve my teaching that led me to search for ways to develop, renew and improve my pedagogy. I saw in many of my students the younger version of me.

I wanted to provide students with learning experiences that developed understanding and skill; that made school an exciting place to be, and required of them more than the recitation of facts and figures. Easier said than done!

My Teaching Background

I commenced as a teacher in 1997, when I was appointed to teach at Father Chris Riley's Key College in Surry Hills in Sydney. This college catered for 'street kids' aged from 15 to 18 who were disconnected from mainstream education. The students had a range of needs and considerations, and this position proved to be both challenging and rewarding. Additionally I was required to develop a teaching and learning program for students placed in the care of Father Riley at his farm located in the southern tablelands of NSW.

For the ensuing two years I worked in a Catholic primary school in Sydney teaching a year 4 class. From 2000 until 2009 I worked as full-time primary school teacher. In that time I spent 2 years teaching stage 2 (year 3 and 4) and 8 years teaching stage 3 (year 5 and 6). In 2010 I worked in the school where this research was conducted for the entire school year as a part-time teacher.

My Doctoral Coursework Enlightenment

In 2009, I commenced doctoral coursework as a part-time student in the distance education mode. At that time I was a teacher in a regional primary school, and I continue to be one today.

When I was accepted into the Doctor of Science Education degree my initial plans were to pursue an interest in the use of concept maps in the primary school classroom. As a graphic organiser, concept maps appeared to provide students and teachers with many benefits (Novak & Canas, 2007). Learning more about the theory and application of concept maps in the classroom seemed an appropriate research objective, and my application to Curtin University's doctoral research degree reflected as much.

As a research degree, approximately two-thirds of the course was undertaken by research and the remainder by coursework. It was the unit on 'Constructivism' (Special Topics A - SMEC710), presented by Professor Peter Taylor, that changed me profoundly. The course deepened my understanding of research paradigms, professional practice, criticalism, reflexivity, epistemology and learning theory. It offered me the opportunity to improve my teaching practice, and thus the learning experiences of the students in my class.

The unit challenged me to reflect critically on my beliefs and values regarding my professional practice. It did not require me to recite definitions of key terms and concepts.

On hearing of my proposed research topic of concept maps, Professor Taylor pointed out that concept maps are often described as a constructivist teaching strategy. Together we decided that a broader research project, moving from concept maps to constructivism, was more appropriate.

During this unit, I came to realise that considerable research advocated the benefits of using a constructivist perspective for teaching, arguing that student academic achievement and development of deeper understanding within content areas could be enhanced. Further, research supported the claim that student motivation and self-confidence can be improved through the use of a constructivist perspective in the classroom. These educational benefits gave cause for me to consider carefully the possibility of using constructivism to inform my professional practice.

However, research also suggested that impediments exist to the successful implementation of constructivist classroom perspectives (see Chapter 3). Because constructivism is a theory of learning rather than a theory of teaching (Richardson, 2003), the gap between theory and practice can be difficult to bridge.

At this early stage of the doctoral coursework my understanding of a constructivist teaching approach was mostly theoretical and certainly still developing. The theory-practice gap was large.

Hijacking My Best Laid Plans

After my completion of the constructivism unit, I would not be in contact with Professor Taylor for four years. In that time I completed two more coursework units and commenced planning my classroom constructivist perspective. During these units, I became increasingly focused on the use of the Constructivist Learning Environment Survey (CLES) in my inquiry (Fraser, Taylor & White, 1994). The CLES is an instrument used to monitor teacher and student perceptions of key aspects of a constructivist learning environment.

My interpretive data collection methods - journals, student-teacher interviews, collaborative learning groups, audiotaped classroom episodes - became support acts to the CLES. My desire to use the CLES as the foremost data collection method in my research later identified me as a 'closet' positivist. Positivism in itself is not a bad thing, but it hijacked the epistemology of my inquiry (see Chapters 4, 5 & 6). This became increasingly apparent when I later reflected on the design of my research questions.

In 2009 I developed four initial research questions. In retrospect, I realised that these questions provide compelling evidence of my positivist beliefs and their hijacking of my intention to use an interpretivist research methodology. The CLES was given pre-eminence in these initial research questions, implying that this instrument could provide the best understanding of constructivist pedagogical change. All sense of an interpretivist research perspective was lost.

1. What were the measurable effects on student perceptions of the learning environment during the implementation of constructivism as a referent for teaching mathematics as measured using the Constructivist Learning Environment Survey (CLES)?

2. What were the measurable effects on the teacher's perceptions of the learning environment after the constructivist referent was implemented as measured using the Constructivist Learning Environment Survey (CLES)?

3. What significant issues and insights arise from my development and implementation of a constructivist teaching referent in a Year 4/5/6 composite mathematics class, from the perspectives of the teacher and students?

4. What is the impact on the learning environment during the implementation of a constructivist perspective for teaching mathematics?

My classroom-based research commenced in the final week of term 2 and concluded at the completion of term 4, 2010, in a composite year 4/5/6 primary classroom. I commenced the analysis of my research data in 2011, and it was at this time that I started to elevate the status of data acquired through the use of the CLES over that obtained from my qualitative methods (see Chapter 2). Whereas my original intention was to use the CLES to supplement my qualitative data the opposite occurred in practice.

From 2009 until 2013 I did not question my use of a positivist approach to my supposedly interpretivist research. However, a change to my thesis committee changed the direction of my research.

In 2013 Professor Taylor was appointed my research supervisor to replace my former supervisor. Professor Taylor noted the positivist tone of my initial research questions and the undue emphasis that I was giving to the CLES data and to my subsequent statistical inferences from the data (tables, graphs, trends) in my research writing.

However, it was not simply a matter of me removing the positivist perspective of my writing. My deep-seated positivist leanings continued to search for a way to assert dominance over my interpretive methods.

Although I had encountered theories of epistemology during my doctoral coursework, I had not made the link between this powerful concept and my professional practice and research methodology. This connection was to come later during my research and was enhanced as my understanding deepened through my pedagogical practice.

From 2013, through critical reflective inquiry and supervisory mentoring, I began to counter the influence of positivism as I engaged in critical interpretive research (see Chapter 2). This resulted in a de-emphasis of the CLES data - placed in the appendix of this thesis - and the removal of substantial statistical analyses. My qualitative research data - interviews, vignettes, journal entries - were reasserted and served as primary sources of episodic understanding of my pedagogic change. Slowly, I came to the realisation that I needed to present rich narrative portrayals of the teaching and learning episodes in my classroom.

In 2015 I redesigned my research questions (emergent questions), to reflect an interpretive research methodology.

1. How important to the successful implementation of constructivist teaching and learning strategies are my epistemological beliefs?

2. How could I more effectively implement a constructivist teaching perspective in the future?

This change guided the re-direction of my research writing, enabling me to create a realistic portrayal of my classroom and key teaching and learning episodes that occurred there everyday.

My emergent research questions reflect an evolving teacher-researcher. A teacher-researcher who was becoming familiar with contemporary teaching and research theory and practice.

Thesis Structure

Chapter 1 presents an introduction of the research and the researcher. The evolution of both occurred throughout the course of my research. Preliminary coursework presented the development and contemporary understanding of learning theory, epistemology and constructivism. These theoretical concepts and their interaction with my professional practice provided the stimulus for critical reflection on my understanding of educational theory and practice. My initial and emergent research questions are viewed in the light of my ongoing development as a researcher and teacher. This dual development is evident throughout my thesis.

In Chapter 2 I identify major educational paradigms – positivism, post-positivism, interpretivism and critical theory. My reasons for choosing critical interpretive methodology are presented. This is significant as it marks the first of my research obstacles. My desired methodology is confronted by a previously invisible threat, and the emergence of my deeply sedimented positivist influences is identified. The context of this study - my classroom - and my research design are described.

In Chapter 3, the concept of epistemology is introduced, and its importance to my study is considered. My understanding of epistemology and of my epistemic beliefs becomes central to the transformation of my professional practice.

The relationship between epistemology and learning theory - behaviourism and constructivism - is identified, and the influences epistemology may have on my planned constructivist teaching strategies are identified. The experiences of other teachers who have attempted similar pedagogical change are considered. It is noted that these teachers' success and failures were of significant and on-going importance to my planned teaching initiatives. From the experiences of other teachers and educational research, the key foci of my constructivist teaching experiment are identified and an explanation of each is provided.

My established classroom is presented in Chapter 4. A typical mathematics lesson is described to provide the reader with a glimpse of the existing social reality of the classroom. I discuss with my peers the concept of constructivism as presented in the CLES questionnaire. I begin to doubt my understanding of constructivism as a theory and as a teaching strategy as a result of these peer discussions. My proposed constructivist pedagogy is discussed with the Principal. I attempt to answer the question of what constructivism will 'look' like in the classroom. Chapter 4 marks the end of a theoretical look at pedagogical change. It is time for implementation.

Chapter 5 presents the term 3 episode of my teaching experiment, which is reported through the lens of my three constructivist foci, and discusses the changes that I made to my classroom practice. Successes and failures of my pedagogic transformation are analysed. The effects of my subconscious behaviourist learning theory on my constructivist teaching strategies are reviewed, and critical reflection begins to occur. Strategic changes are planned for the ensuing term.

Chapter 6 reports the term 4 episode of my teaching experiment. This involved implementing refinements to my term 3 teaching foci. My critical reflection on these teaching changes is presented. Student voice becomes a significant aspect of the changes within each foci, and the value of developing meaningful class communication is discussed.

Chapter 7 considers all that has gone before and attempts to answer the question of what it means to be a constructivist teacher. The notion of constructivism as an ideology is dispensed with. The key aspects from my teaching experiment, as identified in my construction of social reality, are presented. Notions of personal epistemic beliefs and the significant pedagogical aspects associated with my constructivist foci are identified. The relationship between epistemology and enacted teaching strategies becomes a significant issue for successful pedagogical change. The signs of positivism and behaviourism within a constructivist research paradigm and pedagogy, in my role as teacher and researcher, are used as a tool of critical reflection.

CHAPTER 2
RESEARCH METHODOLOGY

Overview

In section one of this chapter the concept of educational research paradigms and the implications for research methodology are discussed. The predominant educational research paradigms of positivism, post-positivism, interpretivism and critical theory are outlined. The role of the Constructivist Learning Environment Survey in measuring the perceptions of my classroom learning environment, prior to the commencement of my teaching experiment, is presented.

In the second section, my research methodology - critical interpretivist case study - is explained. The evolving nature of my research design is outlined; especially my conflation of the positivist and constructivist epistemologies of research and pedagogy, and the impact of this confusion on ‘my story’ is noted.

In the third section, my role as a teacher-researcher is presented, and the possible affects this role may have on my research is considered. Advantages and disadvantages of my role as teacher-researcher are discussed and my reasons for acting as teacher-researcher are identified.

In the fourth section, quality standards for interpretive-constructivist research are identified for optimising the trustworthiness of my study. These 'fourth generation' standards were applied to my research to support the methodology of critical interpretive case study. Ethical issues are identified, providing a background to these important research factors as they relate to my research.

The fifth section introduces the classroom in which I conducted my study and a brief description is given of the school’s educational profile. The layout of the school and my composite Year 4/5/6 class are described to develop further the setting for my research.

The sixth section presents a discussion of my methods of data production; the typical data collection methods of case study – participant observation, interview, survey, audiotape recordings and reflective journals. My break from the hegemony of positivism, permitting me to remain true to the interpretivist educational paradigm is presented. Through guidance, Professor Taylor assisted me in developing the skills of reflexivity, which proved beneficial to my educational research and my professional pedagogy. The section concludes with an overview of the process of data analysis.

Applying themes to my qualitative data allowed me to sort and classify the data effectively. I began to see themes within different data - interviews, reflections, and classroom contributions - as I developed my approach to data analysis. It was in comparing raw statistical numbers with a series of anecdotal notes and reflections that I began to see the richness and complexity of the information provided within qualitative data.

Educational Paradigms

Understanding social reality and subsequent interpretation of this reality are guided by the assumptions we make about our world. This worldview or belief system is referred to as a paradigm and it influences a researcher's choice of methodology (Cohen, Manion & Morrison, 2007). It is important that a researcher's worldview be analysed so that underlying assumptions made about social reality, knowledge and interpretations can be identified, considered and hopefully better understood. My research questions and methodology reflect an aspect of my worldview, and provide salient information about the direction and focus of my research and the methodology I used to conduct the study. Methodology should explain what I did in the course of my research and should identify the design, methods of data production and analysis, as well as the setting of the research (Willis, 2007).

There are a number of paradigms associated with educational research, and each of these represents a different position on the nature of reality and our ability to know and understand it.

There are four significant paradigms that frequently appear in educational research literature: positivism, post-positivism, interpretivism and critical theory (Cohen et al., 2007; Merriam, 2009; Willis, 2007).

It is appropriate to identify and discuss these influential paradigms so that the theoretical underpinnings for my chosen methodology may be explained and justified.

Positivism and post-positivism

Positivism and post-positivism have been the predominant paradigms used in educational research and are members of the objectivist family. Willis (2007) tells us that these paradigms are more alike than they are different. Both are concerned with the use of the scientific method and eschew researcher subjectivity so that knowledge produced is objective.

Positivism presents a worldview that originated in studies of the natural sciences and is characterised by the view that knowledge is real if it can be confirmed via the senses. Positivism views knowledge as being independent of the knower, and that this knowledge reflects an absolute truth or reality that exists 'out there' waiting to be discovered (Hinchey, 2010). This view of the world identifies observation and verification as the methods by which knowledge may be derived. Reality can be measured accurately and analysed thoroughly using statistical processes. These newly discovered objective truths are added to our established body of knowledge (Bryman, 2001; Cohen et al., 2007).

Positivist research was championed by French philosopher August Comte, who advocated its use in social environments because of the great success of the positivist scientific method in natural science environments (Cohen et al., 2007; Willis, 2007).

While there is a common belief that reality is objective, post-positivism represents a move away from the absolute notion of reality to a belief in the relative notion of reality, which reflects a critical realist position.

Like positivism, post-positivism is concerned with the discovery of truth; however, this truth can not be completely comprehended, only approximated from research using multiple methods to move closer and closer to assertions that are more probable than others (Denzin & Lincoln, 2005; Merriam, 2009).

Positivists advocate testing of hypotheses, created from a priori theory, in the pursuit of determining natural laws. Willis (2007) suggests that this represents a significant difference between positivism and post-positivism.

The formulation of theory in a positivist paradigm draws from collected data. It is through direct observation, in a research setting, that a researcher may develop a theory. Through scientific research, the correspondence theory of truth purports the reality of the universe can be accurately described by scientific knowledge (Taylor, 2014). When research continually supports a theory a positivist becomes increasingly assured that theory reflects the reality of the world.

The correspondence theory espoused in the positivist approach is replaced by a falsification approach in post-positivism. This post-positivist approach, regarding the significance or meaning of data, holds that research that falsifies a particular theory requires modification or the replacement of the theory. Karl Popper was credited with the movement from the positivist theory to the post-positivist theory of testing through research (Willis, 2007). Hypotheses that are not falsified are held to lead us ever closer to reality, or an approximation of reality.

In positivist research the role of the disinterested researcher reflects the need for unbiased, value-free research. Positivism contends that the research must be conducted from the outside, and the researcher must cease being a practitioner. Positivist research must strive to avoid bias and subjectivity, which may taint the research findings and theory development (Willis, 2007). However, post-positivism permits the researcher to interact more naturally with participants. This change in the role of the researcher sees the inclusion of qualitative methods such as semi-structured interviews and participant observation (Taylor & Medina, 2013). My role as teacher-researcher made me an active participant in my research. My desire was to present, from first-hand experience, the reality of a teacher (me) in his classroom.

Positivism and post-positivism are concerned with prediction and control. Reliability and validity are cornerstones of these approaches to research, and ultimately lead to the creation of 'building blocks' of knowledge, that can be added to the canon of knowledge in any particular field (Denzin & Lincoln, 2005).

It is argued that the objectivist approach of the natural sciences can work effectively in the study of social reality. However, critical questions have been raised about the effectiveness of positivism and post-positivism for researching human behaviour, especially its ability to adequately investigate the dynamics of teaching, learning and multi-level social interaction (Cohen et al., 2007; Denzin & Lincoln, 2005).

Positivism and the scientific method have been very successful in the natural sciences; however, they fail to take into account the presence of individuality, choice, freedom and moral decision-making (Cohen et al., 2007). Due to the value-free nature of positivism, the researcher aims to be remote from their subject preferring inferential methods of data collection and analysis. Questions have been raised about positivism's ability to get close enough to the participant to fully appreciate their perspective. Further, Ryan (2006) warns of the inability of positivism and post-positivism to adequately understand the way an individual views the world, how they manage their interactions with it, and how they amend their environment and the world. There is, as Denzin and Lincoln (2005) suggest, many different ways to tell the stories that emanate from the social world, and positivism and post-positivism represent their own particular, but partial, interpretation of our world.

Interpretivism

The world of human action and interaction requires a research methodology that can adequately understand the complex and changing environments of our social worlds. This complexity is readily apparent in the learning environments of our schools and classrooms.

Positivist approaches cannot account for the subjective realities of individuals being studied, whereas interpretivism contends that knowledge is built up by and builds on our conceptual constructions, and continues to adapt to the experiential world we encounter (Cohen et al., 2007).

Interpretive approaches have their roots in anthropology and sociology where researchers investigate phenomena *in situ* using observations, interviews, photographs, surveys and documents to inform their findings. The interpretivist paradigm of educational research represents a significant shift from the epistemological, ontological and methodological understandings of the positivist and post-positivist paradigms. Interpretivism does not attempt to discover an ultimate truth nor does it attempt to approximate objective truth, as is the goal in positivist and post-positivist approaches. Interpretivism claims that reality is individually and socially constructed, resulting in multiple realities.

Merriam (2009) claims that interpretive research views reality and knowledge as being socially constructed. This approach is in keeping with the axiom that social reality is constructed not discovered. There does not exist a single 'out there' reality rather there are many experiential realities comprising the lived experiences of humans. Knowledge is not something awaiting discovery. It is co-constructed by individuals and represents an intersubjective understanding of experiential reality (Taylor & Medina, 2013).

Qualitative interpretive research focuses on understanding behaviour and generating hypotheses, whereas positivist research focuses on explaining behaviour and hypotheses testing (Merriam, 2009; Taylor & Medina, 2013). My research did not aim to represent a single reality of pedagogic change, but instead sought to understand this change through a range of subjective lenses.

Erickson (1986) tells us that interpretive research in the field of social sciences has been conducted for almost 100 years. Denzin and Lincoln (2005) and Cresswell (2007) suggest that the term 'interpretivism' is interchangeable with 'constructivism'.

Phenomenology, ethnography, grounded theory and narrative analysis are examples of research methods that can be described as interpretive.

The move from explaining behaviour to better understanding behaviour is the significant difference between interpretivist and positivist approaches. Taylor (2014) claims that the interpretative researcher seeks insightful understandings of phenomena.

My research aimed to provide insightful understandings of my journey of implementing a constructivist perspective in my classroom. The shift in emphasis to an understanding of human behaviour draws on the notions of *Verteshen*, hermeneutics and phenomenology. The researcher needs to be aware of human thoughts and their subsequent actions within their social world (Bryman, 2001; Taylor & Medina, 2013).

Interpretivism requires the researcher to become a passionate participant in the research, and not to act as a remote and disinterested observer. It is essential that the researcher act within the frame of reference of the dynamic, subjective world being researched (Cohen et al., 2007). The intense involvement of the researcher in subjective research allows the researcher to move closer to the actors' viewpoints through the use of interviews, observations, journal logs and diaries.

In this research, I investigated my own changing subjective reality, an insider's interpretation of the events surrounding pedagogical change. It was the manifestation of constructivist learning theory inside my classroom that I sought to better understand (Taylor & Medina, 2013).

My subjectivity, values and biases were all important in better understanding my experiences in attempting pedagogical change. I wanted my research to 'ring true' to other practitioners. This quality of verisimilitude, where others recognise the learning and teaching environment I presented through my research, became an important aspect of my study.

Critical theory

The proponents of the critical theory paradigm claim there is more complexity to social behaviour than that illuminated by the positivist and interpretive paradigms. They point to a lack of emphasis on the political and ideological perspectives with respect to social behaviour. The purpose of critical theory research is to enact change and to transform social settings to be more socially just and egalitarian (Merriam, 2009; Willis, 2007; Cohen et al., 2007).

During this research I uncovered my deep-seated propensity to maintain a positivist perspective towards my research methodology and a behaviourist perspective in my classroom teaching. Brookfield (1999) identified self-reflection, understanding student experiences, peer review and scholarly literature as key elements for an 'excellent teacher'. I learned a great deal about my professional practice and epistemological beliefs through the process of critical reflexivity. The elements of criticalism evolved in me as my research evolved.

As I sought to better understand my teaching and the effects of my teaching, I found Brookfield's key elements assisted me to further understand what constructivism meant to my teaching rather than what it meant as a term isolated in a definition. It was through the 'lens' of critical theory that I was able to evaluate myself as a teacher and identify and emancipate myself from positivism.

Where the interpretivist researcher strives to interpret and better understand the world, the critical theorist wishes to transform society (Cohen et al., 2007; Taylor & Medina, 2013). Liberate, emancipate, empower, change, critique, equality, activism, freedom and inclusion are critical theory terms (Cohen et al., 2007; Merriam, 2009; Willis, 2007). These terms provide a sense of the desired social outcomes of critical theory research. Positivist-informed behaviourist pedagogy provides for a marked power imbalance in the classroom where the teacher is the central figure dispensing knowledge to students. It was the transformation from a positivist teaching perspective to a more constructivist perspective that was central to my research.

Critical theory has rich traditions and has been influenced in the early 20th century by Marxism and the concerns of class structures. Taylor (2014) explains that it was Jurgen Habermas who provided further development of critical theory with his notion of an emancipatory interest that informs our concept of knowledge. This interest serves to identify power imbalances and bring about change to socially unjust policies and practices.

Critical theorists share with positivists and post-positivists a view that there exists an external reality that is knowable to the observer. Critical theory research in education is aimed at uncovering detrimental power relationships and enacting change to the identified power relationship imbalance (Cohen et al., 2007; Willis, 2007). The research process involves a period of initial research to establish the current situation at the centre of the research problem. The critical theorist considers research findings in an attempt to uncover the previously distorted view of reality held by the participants. It is then that action can be taken to emancipate those concerned.

Critical theory holds that the knowledge gained from the research is superior to the knowledge of the situation held by the participants, as they have viewed a reality through the 'lens' of social and political system bias (Cohen et al., 2007; Willis, 2007).

Willis (2007) informs us that while many research projects using critical theory have critiqued existing structural imbalances little has been achieved by way of emancipation. Rather there is an imbalance in the research criticising existing structures and evidence of these structures changing through the emancipation of the participants. There is further criticism of critical theory's predetermined political position of looking for social injustice situations.

This predetermined agenda is by nature a critical view of the existing social order and requires the researcher to become an advocate and activist before the research has commenced. This represents the other extreme of the disinterested researcher proposed by the positivists.

A successful transformation of my pedagogy required a critical perspective within the classroom. Critical reflection on 'normal' assumed structures, roles and responsibilities of me, as a teacher, and the students was required.

Constructivist Learning Environment Survey

Critical theory also impacted my research through the use of the Constructivist Learning Environment Survey (CLES) (Taylor, Fraser & Fisher, 1997). I used this survey to provide a measure of the perceptions of my classroom learning environment prior to the commencement of my teaching experiment.

The CLES is based on the concept of critical constructivism, which was derived from the concepts of criticalism, personal constructivism, and social constructivism (Taylor, Fraser & Fisher, 1997).

The CLES assesses student and teacher perceptions of the occurrence of aspects of critical constructivism in the learning environment. These dimensions - Personal Relevance, Student Negotiation, Shared Control and Critical Voice - address aspects of the learning environment that are reflected in a classroom operating from a critical constructivist perspective. A classroom operating from a critical constructivist perspective attempts to encourage and nurture critical and open discourse where equity of participation is valued. Further, students are actively involved in negotiation with other students and teachers, and encounter and appreciate cultural aspects of curriculum and ways of knowing. Students learn in situations that are relevant to their out-of-school experiences (Taylor, Fraser & Fisher, 1997).

The use of the CLES in a classroom was cross-validated with a sample of 1081 students (Aldridge, Fraser, Taylor & Chen, 2000). Strong support for reliability and factorial validity was reported in research by Sebela, Fraser and Aldridge (2003). The CLES has been integral to many studies where the constructivist learning environment has been used to analyse student perceptions of the classroom (Johnson & McClure, 2004). The CLES has been validated in many countries, displaying factorial validity and internal consistency and reliability (Aldridge, Fraser, Taylor & Chen, 2000).

My Interpretive Case Study Research Methodology

A view of social reality that embodies an understanding of how individuals construct, modify and interpret the world favours the use of an interpretivist case study methodology (Cohen et al., 2007).

Further, Cohen et al. (2007) point out that this methodology is best suited to researching the complexities of human nature and social phenomena particularly that experienced in classrooms and schools. Additionally, modification and change to the existing classroom structures indicates the existence of criticalism in methodology.

Erickson (1986) described interpretive fieldwork research as an environment where detailed recordings (field notes, student work samples, audiotapes, memos, journals) are taken to describe the events of the focus of the research. These recordings are subjected to analysis and reported through generalised description, vignettes, table, charts and quotes from interviews.

Further, Orlikowski and Baroudi (1991) state that interpretive studies

> assume that people create and associate their own subjective and intersubjective meanings as they interact with the world around them. Interpretive researchers thus attempt to understand phenomena through accessing the meanings participants assign to them. (p. 5)

The purpose of my research was to investigate, understand and represent the students' and my experiences of our interactions during the implementation of a constructivist mathematics teaching approach in a composite year 4/5/6 class. Further, my efforts of transformative pedagogical change resulted in attempts to emancipate myself from behaviourism and positivism. The research was conducted as a critical interpretivist case study, and reflects characteristics of the critical and interpretive paradigms whereby individuals construct reality as they interact with the social world (Merriam, 2009) and where attempts to change or modify my own thinking by means of critical reflexivity (Brookfield, 1999) are evident.

Self- Study

Self-study is one of the more recent advances in educational research and focuses on the role of teacher as researcher (McNiff & Whitehead, 2006). Self-study research involves the teacher as researcher inquiring into their professional role within educational practices (Lunenberg & Samaras, 2009). The main goal of self-study research is to establish deeper understanding of educational practices and to provide others with experiences and insights that may be useful to them in their teaching endeavours (Bullough & Pinnegar, 2001). It is clear from my intention to analyse my professional practice, my desire for transformative change supported by my scholarly development (see Chapter 3), and my on-going critical reflexive practices that my research constitutes a form of self-study research. Further, this type of study often relies on the use of qualitative methods similar to those employed in this thesis research (Labosky, 2004).

Case Study

Case study research is well suited for use with classrooms that are implementing changes in pedagogy (Anderson, 1998; Cohen et al., 2007; Merriam, 2009).

Case studies investigate contemporary phenomena within a real-life context, and case study research allows the researcher to conduct an in-depth investigation into a bounded system where the researcher is the principle instrument for the production and analysis of data (Yin, 2003). In my research the case study was conducted in the bounded system of a composite year 4/5/6 classroom of a small rural primary school where a transformative pedagogy in the teaching of mathematics was implemented.

The researcher presents their understandings and findings through 'thick and rich' description. Merriam (2009) suggests that if you wish to shine a light on a phenomenon case study is appropriate. Interpretive case studies attempt to understand phenomena from an individual's point of view, and they ask questions about how the individual interprets the world.

Guba and Lincoln (2005) noted the transactional characteristics and the dialectical nature of dialogue inherent in using this method.

My initial understandings of constructivist theory and its classroom implementation, as well as my evolving understanding of pedagogical constructivism in my practice, were a key focus of my research. The construction of mathematical reality by my students as they interacted with my evolving constructivist pedagogy and their construction of knowledge and understandings was another focus of my research. Bryman (2001) points out that this requires an interpretation by the researcher of the interpretations of the participants.

An interpretive case study allowed me to engage in these complex hermeneutic processes and to evaluate and improve my pedagogy through personal transformation.

Evolving Research Design

Throughout this research two parallel stories unfolded. The first story involved the development of my initial epistemology of research practice, which was closer to positivistic. This thesis documents an important transformation of my epistemology, illustrating how a constructivist epistemology of research practice emerged over time.

The second story reflects my transformation from a behaviourist classroom standpoint informed by positivist pedagogical beliefs to a pedagogical perspective informed by constructivist epistemology. These transformations were important, as researchers had identified epistemic impediments to successful pedagogic change (Richardson, 2003; Windschitl, 2002).

CLES - Beware the lure of the siren's song

The Constructivist Learning Environment Survey (CLES) came to be an indicator of my pedagogical struggle. I had the students complete pre- and post-study CLES questionnaires.

Enamoured by this quantitative research method, I slowly shifted my planned interpretive study to a post-positivist study as I became consumed by the power that a spreadsheet seemed to provide.

At the outset of this research I planned to use the CLES to provide me with an assessment of classroom learning environment, as perceived by the students and me, both before and after my pedagogical changes. Because my research draws strongly on the interpretive research paradigm (see Chapter 2), I had intended to use the quantitative results of the CLES to supplement my qualitative research approach.

My previously unidentified positivist beliefs found 'the melody' of the CLES' quantitative results irresistible. Graphs, tables and class mean scores starved me of interpretive classroom episodes, and I used the qualitative data - vignettes, interviews, and observations - simply to support the quantitative analyses. The qualitative data had been subsumed by quantitative analysis and my research became situated firmly in the post-positivist paradigm.

Later, I came to realise that my rich, thick descriptions were serving the 'cold reason' (Taylor, 1996) of spreadsheets. In this way my research became situated firmly in the post-positivist paradigm. Later, I learned that Taylor (2014) has alerted interpretive researchers to this danger (see Chapters 4, 5 & 6).

Having realised my folly, I subsequently waged a long and drawn out battle to block my ears to the 'siren song' of the CLES. Professor Peter Taylor was my Odysseus, applying wax to my ears so that the song could not be heard. I came to realise that the CLES had stealthily assumed the most significant part of my research, laughing in the face of my interpretive plans. While it was eventually restrained this experience helped to reveal my underlying positivist epistemological beliefs. Beliefs that were very strongly sedimented (see Chapters 4, 5 & 6).

This outcome was not the original intention of my research. I wanted, above all else, for the quality of verisimilitude to reside in my research. I wanted the representation of my constructivist pedagogical reform efforts and of the interactions of the students with the developing classroom environment to 'ring true' to other teachers.

The CLES's real value to me lay in the questionnaire's five scales that describe important aspects of a constructivist classroom environment (Taylor, Fraser & White, 1994). It was in these scale descriptions that valuable pedagogical insights were provided.

For example, previously I found the social constructivist notion of 'student negotiation' in the classroom difficult to comprehend. However, the description of this scale, 'the extent to which opportunities exist for students to explain and justify to other students their newly developing ideas, to understand other students' ideas and reflect on their viability', was enlightening and provided direction and clarity when I needed to locate teaching strategies that could assist me.

The CLES comprises 5 items for each of the five learning environment scales. These items provided me with important new perspectives on the constructivist characteristics of my classroom. Thus, the CLES was an important influence on the development of my constructivist pedagogy.

The CLES provided an impetus for my discussion with my students (Chapters 5 & 6) and peers (see Chapter 4) about the changes I was attempting to make in my classroom. As noted in the discussion with my peers, I realised that I was unable to clearly explain my constructivist perspective and some of the strategies that I believed were important. Thus, at that particular time, the CLES was a useful tool that supported my growing understanding of the concept of constructivism and it enabled me to engage in valuable discussions and to discover my previously unidentified beliefs.

Although I intended to use the CLES in my research as an heuristic tool to explore my development of constructivist pedagogy, it became a touchstone for acquiring objective truth. Through its use as a pre and post-test, I came to believe that an accurate and true measurement of my pedagogical transition could be achieved.

After considerable critical reflection, I decided not to use the quantitative data gained from the CLES as a post-test of my pedagogical change because it added little of value to my interpretive research.

On the other hand, the CLES pre-test results provided a useful perspective of the overall learning environment of my classroom prior to my attempts to implement constructivist pedagogic change, and are included for this reason (see Chapter 4).

Teacher As Researcher

My role in this research was a teacher-researcher-participant. A teacher acting as both participant and researcher is not new a phenomenon and has its roots in the mid 1900s, drawing on the early work of John Dewey (Hammersley, 1993; Rust, 2009).

Interpretive case study research, of the type undertaken in this study, is a strand of teacher oriented research that aims to add to the knowledge base of educational practice by offering unique insights from the teacher's perspective (Craig, 2009; Nair, 2007). However, I did not initially appreciate the ramifications of my dual role as teacher-researcher.

The possibility that, almost Jekyll and Hyde like, I could apply dual epistemic constructs presented the irony of a constructivist teacher and a positivist researcher.

'My story' had me enacting a number of conflicting roles - positivist researcher and constructivist researcher, behaviourist teacher and constructivist teacher. Unpacking the conflation of these roles was a significant development in my transition to a more constructivist classroom teacher and yielded important insights into my struggle to achieve a pedagogical transformation.

The benefits of teacher-researchers can be considerable. It is claimed that teacher-researcher studies have initiated changes to classroom practices and to the thinking and policy development of administrators (Babkie & Provost, 2004; Craig, 2009; Nair 2007; Rust, 2009).

Additionally, this type of research methodology has resulted in improved student performance, implementation of 'best practice', development of teacher skills and improved research abilities (Babkie & Provost, 2004; Craig, 2009; Nair 2007; Rust, 2009).

Teachers conducting research on their professional practice brings advantages to the researcher that 'outsider' researchers cannot. Teachers have an intimate knowledge of their intentions and behaviour, and analysis is a much easier proposition. An independent observer is not in a position to appreciate the deeper feelings and emotions that arise in teachers within their classrooms (Hammersley, 1993).

Teacher-researchers usually provide a more detailed understanding of the learning environment being studied and of the participants in the study. Independent observers may never develop the type of relationships that enable participants to disclose their true feelings, especially during interviews (Petschler, 2012). Further, Rust (2009) points out that teacher research represents an insider's viewpoint that renders the findings of the research practical, whereby they ultimately inform pedagogy at the individual level, if not in a more generalisable setting.

Teacher as researcher presents teachers with research that is realistic as it represents authentic classrooms in authentic settings, and acts as a bridge between academic research and the subsequent understandings that are often developed from the research (Rust, 2009). During this research I found the experiences of my other teachers (see Chapter 3), both successful and unsuccessful, provided me with insight, encouragement and direction.

However, it must be noted that there has also been criticism of the role of the teacher-researcher. Questions regarding the rigor of the research methodology, the researcher's bias, and the value of the knowledge gained from the research have been questioned. Anderson and Herr (1999) suggest that teacher-researcher methodology presents critical questions about the collection of data, rendering findings of practitioner research very different from the accepted academic knowledge gained through more objective studies. Participants can deceive themselves or not fully appreciate the full scope of their motives and intentions.

Further, independent observers can develop and access more widespread groups of people within the research location. Participant trust can also prove to be a problematic element of data collection.

There is also the prospect of difficulties in obtaining data from colleagues who may find it easier to divulge information to an outsider than to a person from within the workplace (Petschler, 2012).

Aware of these criticisms, I have ensured that my representations of classroom vignettes, discussions with colleagues and quotes from my journal provide enough detail for the reader to become aware of the full scope of my underlying motives and intentions. Additionally, it is the benefits that arise from probing my construction of reality that adds weight to the interpretive methodology and the epistemology of this research.

It was the intention of my research to closely investigate the fluid social reality constructed by both the students and me while pedagogical change was underway. This research was designed to add to an evolving understanding of constructivist pedagogical transformation of mathematics lessons.

Standards For Quality Research

Whereas the quality of research in the positivist paradigm is judged on internal and external validity, reliability and objectivity, Guba and Lincoln (2005) claim that as quantitative and qualitative research approaches exhibit vastly different outlooks on ontology, epistemology and methodology; equally, the quality of these approaches requires vastly different criteria on which to be judged.

The trustworthiness of interpretive research is critical to establishing the worth of the study, and can be achieved through focused attention on the standards of credibility, transferability, dependability and confirmability (Guba & Lincoln, 2005).

Credibility

Credibility is a key aspect of the trustworthiness of my research. Using research methods that are recognised in educational research and appropriate for the particular phenomena are important in the establishment of credibility.

An important method of my critical interpretivist research was critical reflexivity or progressive subjectivity (Brookfield, 2009; Guba & Lincoln, 2005). My journal entries document the development and ongoing modification of my understanding of a range of concepts - positivism, pedagogy, constructivism - as my theoretical and practical understanding of transformative pedagogy was constructed.

I sought to provide details of my reflexive journey throughout my teaching experiment. Details of what I did are interspersed with my thoughts on how I attempted change, what I thought about the change and how I could improve my pedagogical changes. Interestingly, Mezirow (1990) claimed that the forerunner to transformative pedagogy is critical reflexivity. It seems that this method of establishing credibility is also a key method of transformative pedagogy.

A second widely accepted method of improving the credibility of research is triangulation (Kyburz-Graber, 2004; Merriam, 2009). In research, triangulation applies to the use of two or more data sources, investigators and methodological and theoretical stances within the study. When the use of triangulation in two or more areas of the study occurs, it can be said that the research has taken a multiple triangulation approach, which serves to strengthen the credibility of the research (Golafshani, 2003). However, Taylor (2014) points out that triangulation is not necessarily considered to be a quality standard of significant importance to interpretive research.

My research used triangulation of data that were collected through the CLES, classroom observations, interviews and journals (teacher and student). These data were used to compare and contrast my emergent understandings.

The CLES provided quantitative data within a largely qualitative study on student and teacher perceptions with respect to the different dimensions of the constructivist learning environment. These data provided the stimulus for subsequent interviews that were crosschecked with classroom observations.

Guba and Lincoln (2005) suggest that a prolonged engagement in the field provides a study with enhanced credibility.

My research was conducted over two school terms for three days a week over 20 weeks. This constituted a prolonged study that enabled persistent observation of participants at different stages of the research. Further, the teacher-researcher, Principal and students observed the implementation of a constructivist teaching perspective.

Peer debriefing in informal settings with the Principal and other experienced teachers enabled me to think out-loud regarding my developing understanding of constructivism while listening to other interpretations of the concept.

Member checking was conducted in an on-going process. I reflected on my audio recordings, student journals and personal reflections, and I discussed these with students and teachers to reconfirm their meaning and to seek greater clarification of what I believed their utterances and actions meant.

On more than a dozen occasions I found that my interpretation of their reality did not 'fit' with their interpretation of reality. This ability to seek clarification and confirmation from participants added to my research's credibility. An interpretive approach relies heavily on hearing the voices of the participants and hearing them truly.

Transferability

Transferability replaces the positivist criterion of external validity or the generalisability of the study. The choice of case study with ' rich, thick' descriptive detail of the phenomena under investigation aims to provide transferability.

It was my intention that, if deemed relevant, my readers could transfer these experiences to their own world experiences. Hahn (2004) asks the researcher to treat their work as an allegorical fairy tale that, while not hidden within its words, allows the reader to decide if anything can be learned from, applied and adopted into their own experiences. The onus is on the researcher to provide the necessary information within the research for the reader to make an informed decision regarding its transferability to other contexts (Guba & Lincoln, 2005).

My experiences were portrayed through rich, descriptive language of a world that was familiar to many in the teaching profession, and should be sufficient to allow others to decide if the findings based on these experiences can be applied to other times, settings, situations and people (Guba & Lincoln, 2005).

By portraying my experiences in this way I hoped that others could invoke empathy and at times sympathy as they are presented with insights of the day-to-day life in my classroom (Loh, 2013). Detailed and rich descriptions could establish the quality of verisimilitude and enhance the trustworthiness of my study. If my study is presented in a plausible and believable manner that resonates with the reader then trustworthiness and transferability are increased.

Dependability

Dependability addresses the reliability concerns of the positivist approach to research, and whether under similar circumstance, the same results will be recorded. However, in an interpretive study dependability looks at addressing whether all changes to the context have been addressed.

Guba and Lincoln (2005) highlight the strong connection between dependability and credibility. A detailed audit trail (written field notes, documents, summaries) was established and maintained, allowing both process and product to be scrutinised (Golafshani, 2003).

An interpretivist view of dependability suggests that as reality is constructed and reflects different interpretations it is not possible for the study to necessarily return the same findings and results.

Stenbacka (2001) suggests that matters pertaining to reliability have no place in qualitative research as they address the concept of measurement. Sufficient information should be provided to allow my research to be repeated. Furthermore the triangulation of methods, as discussed previously, further evidences the dependability of my study (Loh, 2013).

Confirmability

Confirmability is parallel to the positivist notion of objectivity, which is concerned with the concept of researcher bias. Understanding my motivations and interests with respect to this study was important in providing some confirmability to the research. To assist with drawing findings from the data and not from preconceived ideas, reflexivity was undertaken by my use of a journal throughout the research. This journal recorded my reflections on the process of developing and implementing constructivism in the mathematics class (Guba & Lincoln, 2005).

Based on my analysis of the CLES results a series of ongoing interviews was organised to probe further the students' thoughts and ideas regarding the application of constructivist strategies as perceived by them in their construction of the classroom reality. Guba and Lincoln (2005) argue that an audit trail (discussed earlier) enhances the confirmability of interpretive research.

Providing a detailed description of my research design, my method of data collection and analysis are central to the confirmability of my research. Rich and thick descriptions, obtained from the students and my reflective journals, support my research reporting throughout.

I have acted as Guba and Lincoln's (2005) passionate participant in my role of teacher-researcher. Far from being a disinterested researcher, it was my intention to present research that recognises the value-laden nature of my intrinsic involvement, as it is instrumental in the development of a real-life interpretation of the implementation of a constructivist teaching perspective.

Ethical Issues

Permission

It was necessary to obtain university ethics approval from the NSW Department of Education and Training (DET) to conduct research in NSW government schools.

Following State Education Research Application Approval (see Appendix A), details of the research proposal were forwarded to the Principal of the selected school for permission to conduct research at the school. Details regarding the research methodology, intended types of data, data collection and the intended use of the data were clearly identified for the Principal in order to obtain informed consent.

A parent consent form outlining the research aims and the involvement of the students was sent to each parent-guardian of the students within the class (see Appendix B). All participants were advised of their right to withdraw from the research at their discretion or to not participate in selected aspects if they so wished.

Privacy and confidentiality

The anonymity of the students, school and teachers was guaranteed through the use of pseudonyms and the use of alphanumeric coding. Access to all gathered data was only made available to the researcher and the doctoral supervisor.

Consideration

Consideration of interruptions to the children's educational time was important. I held discussions with the school's Principal regarding how this could be effectively managed. We discussed and planned how to include the research in the normal scope of professional teaching practice.

Acting as teacher-researcher assisted in reducing any undue interruptions to the children's educational experiences and the development of teaching and learning programs over the course of terms 3 and 4. The Principal agreed that the chosen research methodology afforded little if any undue intrusions into the normal school day, and she identified this as a significant benefit of the study (Interview, 27/7/10).

Data storage

All data records (transcripts, audio recordings, journals, CLES data) were stored in the school's safe and have subsequently been moved for storage at my residence in a fireproof and password-protected safe.

Copies of written materials were scanned and maintained on my password protected laptop computer and backed up on a removable storage device held in the school's safe and now stored at my residence in a fireproof safe.

Context Of The Research

My study was conducted over a six-month period, from the last week of term 2, 2010 through to the conclusion of school in term 4, 2010 at a small rural primary school in N.S.W. Terms 3 and 4 were both of 10-week duration.

The school's index of community socio-economic advantage (ICSEA) was 884. This index is a scale of a school community's educational advantage or disadvantage, and is calculated by taking into account parental occupation, educational achievement and occupation, the number of indigenous students, the geographic location of the school and the language backgrounds of the students. The median of the scale is 1000.

The Commonwealth Government identified the school as serving an area of low socio-economic status (SES) communities. The government reviewed the variables of housing, income, employment, occupation education and skills among other variables for the area 2.5 kilometres around the school to calculate the SES (Australian Curriculum, Assessment and Reporting Authority, 2010).

At the time of my case study the school had a Principal, four full-time classroom teachers, one Support Teacher Learning Assistant, one Teacher Librarian, one Counsellor 2 six school administrative and support staff. The school's student population of 78 was spread throughout four composite classrooms. A composite classroom is one that contains two or more grades or years of students (Cornish, 2006). There were 45 boys and 33 girls in the school. The class breakdowns were: Kindergarten/Year 1 class of 16 students; Year 1/2 class of 21 students; Year 3/4 class of 21 students and the Year 4/5/6 cross stage class of 25 students.

The school is a single storey, multi-building facility. The administration building, library and Year 3/4 classroom are separate buildings.

The administration building houses the school administration area, Principal's office, staffroom, sick bay and stationery room. The largest of the buildings houses the remaining three classrooms, computer laboratory and a resources and teacher reference area. The Year 4/5/6 classroom (where this study was conducted) interconnects with the computer laboratory, which in turn interconnects with the Year 1/2 classroom. Adjoining the Year 4/5/6 classroom is where the Kindergarten class is located and adjoining the Kindergarten room is the resource and teacher reference room. The resources room is well equipped with mathematics resources and reference materials.

I shared the classroom teaching with the school Principal (Susan). I worked each week on Tuesdays, Thursdays and Fridays. Susan took the class on Mondays and Wednesdays. Our daily teaching timetable consisted of a morning teaching block (9.15am – 11.00am), a middle block (11.30am - 1.15pm) and an afternoon block (2.00pm - 3.15pm). The morning session was predominantly English teaching time; however, morning assembly, library borrowing and scripture were also held in this session. The middle session was predominately dedicated to Mathematics. The afternoon session was timetabled for Creative and Practical Arts and Personal Development, and Health, which was taught by Susan. I taught Science, HSIE, and Physical Education in the afternoon block. Apart from English, Susan and I took responsibility for the planning of learning experiences in our dedicated subjects and the sub-strands of mathematics. In English, Susan and I jointly constructed teaching and learning experiences and assessment tasks. This arrangement allowed for an easy transition when the change of principal occurred (see Chapter 4) as English was the only key learning area that was jointly taught. At times, my teaching days were altered; however, these changes were infrequent. I worked additional days as a replacement for the Principal when she was required to attend meetings or educational in-services.

My mathematics lessons were scheduled for each of my teaching days and were conducted in the period leading up to the lunch break (12.00 pm to 1.15 pm). These lessons were programmed to cover the syllabus requirements with respect to the mathematics sub-strands of patterns and algebra, measurement and data.

Susan‘s mathematics lessons focused on drill and basic fact development for a one-hour period on Mondays and Wednesdays. Susan’s lesson, typically, used textbook mathematics questions and times-tables practice with a specific focus on the number, and space and geometry strands of the mathematics syllabus.

Merriam (2009) advises the researcher to select the sample that is likely to provide the most information on the phenomena being studied. While it was possible to conduct this research using another teacher in their classroom I chose to conduct the research using the students in the class that I was teaching. I believed the overall coordination of my research was more easily managed by conducting the research in my own classroom. The Principal shared this view. This choice allowed me greater flexibility in the delivery of constructivist lessons. The dynamic nature of modern education requires an approach and timetable that can accommodate change and disruption. Where clarification arising from data collection or extended questioning from interviews, journals, and anecdotal records was required I was able to accommodate these needs. When my anecdotal notes, audio recordings or journal entries were unclear I sought clarification at a time of convenience to my class and the individuals and groups concerned.

The composition of the Year 4/5/6 class is shown in Table 1 below. Of the 25 students in the class seven students (28%) identified themselves as being Aboriginal. This was an important consideration given that results from The National Assessment Program - Literacy and Numeracy (NAPLAN), TIMSS and PISA standardised assessments - indicate a significantly reduced level of achievement from indigenous students. Pedagogical change was identified as a significant component of improving the academic achievement of these at-risk students (Sullivan, 2011). At the commencement of the research the students' ages ranged from 9 years to 12 years.

Table 1. *Breakdown Of Students In The Year 4/5/6 Composite Class*

Year	Girls	Boys	Total
4	4	1	5
5	5	3	8
6	7	5	12
TOTAL	16	9	25

Data Sources And Collection Methods

A variety of qualitative and quantitative data sources were used in my research. My case study used surveys, classroom observations, detailed descriptions of classroom events, interactions, journals (personal and student) and multiple semi-structured interviews with students and informal teacher/Principal interviews. Anderson (1998) tells us that the process of gathering data from multiple sources, data collection methods and theories is an important component of qualitative research. It is appropriate that an interpretivist approach to research seeks to use methods that include the multiple realities that participants construct. No attempt to provide a universal truth was proposed; however, describing and understanding my experiences and those of the students as we made the transition to a more constructivist classroom was one of the aims of this research.

Willis (2007) explains that qualitative methods of gathering information allow researchers to get to the core of human interpretation of their world. This is a trait of the epistemology of an interpretive framework where analysis of personal experience aims to shed light on our understandings in a localised setting. An interpretive approach identifies personal interpretations as the only real knowledge that we can have about social behaviour. Cohen et al. (2007) noted how some people found post-positivist findings banal and trivial. They point out that statistically treated data can produce findings far removed from the dynamic world that exists in reality. As is common to case study research, the predominate source of data collection and analysis was the researcher (Merriam, 2009).

In my case study I implemented constructivist pedagogical change in my mathematics lessons and recorded observations from the perspective of researcher and participant.

Observations

Observations provided many benefits to my case study research. Merriam (2009) claims that observation is the best strategy to use when phenomena are being observed first hand, as in my interpretive case study. My significant involvement in the research, with the students' knowledge of my full role in it, saw me act as a participant observer (Merriam, 2009).

Further, observations offered a reference point for subsequent questioning through semi-structured interviews. Events observed in the classroom were raised and more deeply analysed through semi-structured interviews that provided a 'thick rich' description in my case study. Observation also enabled triangulation of data, allowing for increased credibility within the case study analysis and findings (Guba & Lincoln, 2005).

I recorded observations of the students in their learning environment. Field notes were written as observations were occurring or as soon as possible after the observation. Additionally, all lessons where a constructivist perspective was implemented were audiotaped.
These audiotapes were used to supplement my observational notes and served to refresh my memory when the observations were written at the conclusion of each lesson. At times, observational notes were spoken and audiotaped.

Field notes of conversations pertaining to the case study and providing insight or aiding in the understanding of the phenomena were also recorded. These field notes constituted conversations held between staff and parents in an informal setting and were not planned interactions/interviews with respect to the research.

Merriam (2009) and Anderson (1998) warn of the affect of the researcher's presence on the participants involved in the study.

Certainly, the presence of an audio recorder caused discussion within the class when the students were first informed of the audio recorder's presence. However, I believe that the students became familiar with the audio recorder's presence within days of the commencement of the study.

Over the first two weeks of the research I was asked on seven occasions whether the audio recorder was 'on'. After this two-week period I was asked about the audio recorder twice over the remaining 18 weeks of the research.

I recorded all field notes and reflections in an individual journal as near as possible to the event and always on the day of the occurrences.

Interviews

Merriam (2009) tells us that interviews are a commonly used method of data collection that has existed for centuries. Anderson (1998) informs us that interviews can be the source of rich data; however, he points out that this method of data collection can also be a problem for novice researchers. Further, Anderson (1998) suggests that interviews in educational settings are the most commonly used method for data collection. Interviews allowed me to further probe student in-class comments and journal entries in an effort to gain greater insights to the pedagogical changes experienced by them. It is the interview that provides us with an understanding of what is in and on someone else's mind (Merriam, 2009).

Interviews were used in my study to gather information from students that further enlightened my understandings of their CLES responses. Interestingly, students seldom raised matters that did not pertain to mathematics (see Chapter 5). This may have been a result of me discussing and holding interviews with students only during mathematics lessons. I may have indirectly insinuated to the students that these interviews were only relevant to their mathematics experiences.

Through interviews I was provided with opportunities to question further a participant's actions, answers or motivations (Diaz-Andrade, 2009; Yin, 2003).

Interviews with all students were conducted on a weekly basis, and these were generally group interviews. Students were asked if they wished to be interviewed within their mathematics groups (4-6 students) or individually. Where students wished to complain about others in the group or where they felt matters needed privacy they asked for individual interviews. Students could initiate an interview with me by organising an appointment time for lunch or recess time. All interviews with students were conducted in the classroom.

Where students wished to speak to me individually, another student was in the classroom outside of hearing distance. Where the interviews were not audiotaped, notes of what was covered were taken during the interviews and more detailed notes were made as soon as possible after the event to ensure an accurate portrayal. Stake (1995) noted that the exact wording of a participant's responses is secondary to recording what was meant by the participant in their discourse. This advice alleviated my need to record word for word the interaction of the interview, but to record the meaning of the discussion. I asked students if my paraphrasing was an accurate reflection of our interview.

In semi-structured interviews I spoke with students about changes that could be adopted in the classroom to further create a constructivist environment. While not specifically using the term 'constructivist', I questioned students on how they perceived changes to the classroom and what additional changes to the classroom could be made. At times I asked students to comment on activities that were undertaken during the mathematics lessons. Students were also asked to provide further insight or clarification on their responses to the CLES or from their entries in their mathematics journals. It was from these student interviews that information regarding the impact of the pedagogical change on students was identified and discussed.

Interviews between the Principal or Acting Principal and myself were conducted weekly throughout each term. I met with the Principal in her office for formal meetings before the commencement of the third term and discussed the plans for the implementation of my constructivist teaching. We discussed how this impacted my teaching program and the classroom.

The Principal was interested in discussing the perceived benefits of these pedagogical changes and how this was to be assessed at the conclusion of the term and of the research period. I met with the Principal in week 5 of term 3 prior to her taking long service leave.

At the conclusion of term 4 I discussed with the Principal my pedagogic implementation and how I perceived its effectiveness.

More informal discussions were held throughout the term with teachers and the Principal/Acting Principal regarding the implementation of my constructivist teaching. These discussions were recorded in my personal journal. I asked the staff for permission to use their answers to my informal questioning within the research and reviewed my notes of these discussions with staff as a member checking activity.

Journals

The students and I maintained journals of our experiences of pedagogical change in the classroom. Students maintained a journal at the back of their mathematics workbooks and in a separate journal book. The students were asked to make an entry in their journal during or at the conclusion of mathematics lessons. Students dated their entry and ruled off after each entry (Merriam, 2009). For the first four weeks of the research, I suggested possible considerations the students may like to focus on in their journal entry; however, I stressed that they were free to comment on any aspect of the lesson or their understandings. The guided journal entries asked students to consider what the aim of the lesson was, whether they felt the aim was achieved, what they learned from the lesson, and their thoughts on how the lessons had been conducted. At times, constructivist organisation (seating, group work) was the focus of the journal entries.

The requirement for student journal entries was not prescriptive, but rather reflected matters the students considered had some relationship to the pedagogical change brought about in my mathematics lessons (seating, talking, cooperative learning, lesson objectives, deeper understandings, resources).

I recorded all aspects of my pedagogical change in an A4 binder book journal throughout the course of the research. The right hand side of the journal recorded details of observations, important points gained from listening to audiotapes of classwork, and notes recorded during interviews with students. These entries were recorded as the events took place or as close as possible to the event occurring (Merriam, 2009).

My personal journal was recorded on the left hand side of the binder book and comprised my reflections on the research process or on the observations recorded on the right hand side of the page. It was here that I wrote down any concerns, insights, doubts or areas that required further review.

I found these entries to be a wonderful source of information as I traced my journey through the research process. The journal identified issues and concepts that I needed to further research to better understand or improve my professional practice. My inner thoughts about my own involvement in the research were clearly identified. At times, field notes from observations and reflection intermingled; and how could they not when so many of my observations raised consideration about how I perceived and interpreted the information or where I thought the learning environment could change even further. Observations were the stimulus and catalyst for some deeply considered reflections. I found that, overall, my thoughts continued to question my epistemological beliefs and my understanding of the manifestation of constructivist strategies in the classroom.

Survey

The CLES used in my study was based on the 30-question survey developed by Taylor, Fraser and White (1994). The CLES was developed to assess the extent to which a classroom reflects constructivist epistemology and forms the basis for teacher reflection and subsequent change to teaching practices (Fraser, 2007). During the last week of term 2, 2010, I presented the CLES to the class for their completion.

Initially, I had concerns about students being able to understand the survey questions (Taylor 1994) and my ability to adequately and clearly explain each of the scales - Personal Relevance, Uncertainty, Critical Voice, Shared Control and Student Negotiation.

Further, I sought input of two teaching colleagues regarding the CLES and student understanding of the questions (see Chapter 4). In this session, where I was explaining the survey to two teachers (Ann and Gavin), I was alerted to my difficulty in explaining and describing the CLES scales. The teachers asked questions about the dimensions that I was not able to clearly enunciate.
Ann and Gavin were helpful in allowing me to verbalise my thoughts and as a result seek to more accurately explain each scale.

As a result of these discussions, I developed a revised list of the explanations and descriptors of the dimensions (see Appendix C) as presented by Taylor, Fraser and White (1994) and Taylor, Fraser and Fisher (1997). This list provided more detailed understanding of each scale, using different terms to define them and was a resource that I referred to in explaining each scale when required.

Research As Writing

A recurrent theme throughout my research (see Chapters 4, 5, & 6) lay hidden from me for a considerable time. I noted (see Chapter 3) the threat that a teacher's often hidden epistemological beliefs has on their pedagogy. As a teacher-researcher my hidden epistemological beliefs impacted my research and my pedagogy. It was through interactions with Professor Taylor, my academic supervisor, that I was able to identify, acknowledge and emancipate myself from the hegemony of positivism. My emancipation was assisted through my development of the skill of critical reflexivity. It was through this practice that I became increasingly aware of my attempts to place quantitative analysis over qualitative analysis.

Discussion with Professor Taylor often ended with a period of self-reflection on my research and my understanding of the characteristics and intent of critical interpretivism. I found that knowing what reflexivity is and being able to undertake reflexive practice in my research were vastly different propositions.

True to an educational constructivist perspective, Professor Taylor mentored me on how to implement reflexivity into my professional practice.

Data Analysis

The data were collected from a range of quantitative and qualitative sources. I felt unsure of how to manage the data I was collecting and how best to record what I was receiving. Data itself was not unusual for me. As a teacher I collected test scores and anecdotal notes throughout my teaching career.
It was the quantity of data and the need to retrieve specific elements at a later time that I found difficult to deal with. Initially, I had 25 student journals, my journal and reflective notes, and transcripts of audiotapes around me in a disorganised manner.

Throughout the research I reviewed student and teacher journals, field notes, transcripts (where available) and workbooks. From these sources I analysed issues that were being raised by students. These issues served to inform my subsequent lessons, any pedagogical refinements that I was bringing to the classroom, and to provide stimulus for further reflection on my professional practice (see Chapters 5 & 6).

It was not possible to read all journals, field notes and workbooks daily; however, I ensured that I attended to the participants' voices by the commencement of the following week. Weekends provided me with time to listen to tapes, check journals and review my own reflective notes. Audiotapes were listened to whenever time permitted, and often this could be completed in the car or while exercising. I recorded salient points from the audiotapes into my personal journal or I recorded the position of particular entries on the audiotape (for example - audio 06/08/2010, 23-minute 15-seconds) in the personal journal for further analysis at a later time.

As suggested by Bryman and Burgess (1994), I read over my reflections weekly and sought to identify themes and categories within the words.

Bryman and Burgess (1994) suggest that coding provides the researcher with the connect between data and an ever evolving conceptual understanding. These initial codings were sorted according to themes. The codings were applied to the field notes and student journals and workbooks, allowing me to further refine the focus of my pedagogical change and my pedagogical actions (Bryman & Burgess, 1994).

For example, classroom seating organisation became a theme in almost all students' journal entries, and that theme guided me to review this aspect of the classroom changes I had made.

In particular, I coded according to my initial pedagogical change focus areas (see Chapter 3) - meaningful communication, real-world experiences and assessment. Coding allowed for key word searches in transcripts of audiotapes and of word-processed student journals. Indexes were created to assign certain key words associated with different codes for categorising, ease of retrieval and further conceptual refinement. This evolved to a colour coding of the pedagogical change focus areas.

It is through the process of coding that the researcher generates concepts relevant to the data collected and the case study. It was the case with my research that patterns of concepts, key words and issues arose in a variety of data collection methods. It was only through the synthesis and analysis of the data via a coding sorting mechanism that sense started to be created and my picture of reality began to form.

Where To From Here?

A range of concepts has been raised in this chapter. Educational research paradigms provide for a rich and confusing array of interrelated concepts, techniques and strategies. Arguments and discussions about the definition and value of concepts, techniques and strategies abound in educational environments.

In order for me to implement or modify my professional teaching practice I needed to provide myself with a strong theoretical foundation.

In building this foundation through scholarly reading and discussions I found that I could easily build a wall of theoretical knowledge. Equally, I found that my wall of knowledge could have a sledgehammer put through it, crashing it to the ground in a confused mess of concepts. The sledgehammer often was a simple sentence in a journal or an utterance from an academic.

Nevertheless, the theoretical underpinnings and the experiences of others dealing with transformative pedagogical change was an exciting, challenging and rewarding experience -an experience that continues to this day. It is the journey of my scholarly development that I now turn to.

CHAPTER 3

SCHOLARLY DEVELOPMENT OF MY CONSTRUCTIVIST PEDAGOGY

Overview

My scholarly development of a constructivist pedagogy was a process that occurred throughout my research and continues to be an on-going practice. I continuously engaged with the literature during the 8 years of my doctoral studies, including the two terms of my teaching experiment (see Chapters 5 and 6). In the interest of clarity, I have chosen to represent my engagement with the literature in this chapter, rather than distribute it within the narratives of the remaining chapters. Although, throughout this chapter I endeavour to indicate how the literature influenced my developing ideas at key moments of this research.

My experiences in the classroom highlighted a gap between my developing theory of professional practice and my professional teaching practice (Hirschkorn & Geelan, 2008). My early understanding of educational learning theories and teaching strategies was shown, in the initial stages of my research, to be at times naïve and shallow. As I implemented my planned pedagogic changes the interconnectedness between epistemology, learning theory, pedagogy and constructivist strategies started to be unveiled. There was neither a concept nor a constructivist teaching strategy related to my study that did not evolve in my understanding as a result of my scholarly development. My scholarly development proved to be a bumpy journey, but a journey that assisted me to grow in knowledge and skill. It allowed me to recognise tensions and differences in educational learning theories, epistemic beliefs and teaching practices that arose as I implemented teaching strategies with an increasingly constructivist perspective.

In the first section I investigate the concept of *epistemology* and its effects on the development and practice of learning theories. My study proposed a pedagogical move from traditional behaviourist learning theory towards constructivist learning theory. My understanding of the development of behaviourist learning theory was informed through my identification of behaviourist teaching characteristics as they might appear in a classroom.

It was in identifying ‘known’ behaviourist classroom activities (Dangel, 2011; Windschitl, 2002) that I came to realise the impact behaviourism was having on my professional practice. It was important for me to understand the traits and characteristics of the learning theory I hoped to transform from, for it was these traits and characteristics that allowed me to identify and assess my, at times subconscious, use of positivist epistemological beliefs.

The second section focuses on constructivist learning theory. It is this learning theory that guided the planning and implementation of my constructivist strategies and perspectives in the classroom. Trivial, radical and social constructivist theories are discussed. The contribution to constructivist learning theory of Piaget, Von Glasersfeld and Vygotsky are presented. The important notion of conceptual change theory that developed from a constructivist view of learning and teaching is discussed, highlighting students’ alternative conceptual views.

The third section examines the experiences of other teachers who have attempted similar pedagogical change. These experiences provided examples of the varied effectiveness of transformative pedagogical change. These case studies offered me insights and ‘real-world’ accounts of their experiences, and provided possible sources of guidance for my own pedagogical journey.

In the fourth section, the use of educational constructivism as the basis for my teaching pedagogy is developed. The question of what constructivism can look like in the classroom is discussed. The principles and characteristics of educational constructivism from a variety of perspectives are presented to assist my goal of finding common ground on which to develop a workable teaching referent based on constructivist principles. I identify the constructivist pedagogical 'focus areas' used as the foundation for my pedagogical transformation and an explanation of each is presented.

In the concluding section, the local educational context of this research is discussed. NSW Government Departmental policies and documents that have direct impact on teachers and their pedagogical practice are reviewed.

It is important that my proposed pedagogical change remains in line with the principles of the desired teaching and learning environment outlined by relevant government agencies. It became apparent when reading the NSW Board of Studies policies that a constructivist teaching referent is advocated.

Educational Epistemology

Consideration of epistemology, learning theory and subsequent pedagogy were significant to my study. Questions of epistemology are integral to an understanding of classrooms and the practices implemented in them (Magrini, 2009). In my study pedagogical change had at its core a developing understanding of my epistemic beliefs. It is, as Magrini (2009) points out, our professional practice as teachers that emanates from our epistemological beliefs. Consequently, there cannot be effective implementation of transformative teaching strategies without consideration of the teacher's epistemology.

The pedagogy of a teacher can act as a servant to their understanding of the acquisition of knowledge - our epistemology - what we can know and how we can know it (Brownlee, Boulton-Lewis & Berthelsen, 2008). In seeking to improve or change my pedagogical practice I needed to become familiar with my epistemic belief and the epistemic basis of the learning theory I intended to incorporate in my professional practice (Windschitl, 2002).

Epistemology derives from the Greek word *episteme,* which means knowledge and is concerned with theories of knowledge and how we come to know the things that exist. Questions that address what can we know about reality and what can be accepted as knowledge within a discipline are issues of epistemology (Ernest, 1995; Willis, 2007). Alexander (2006), and Willison and Taylor (2006) suggest the existence of two predominant epistemologies, which can be described as objectivist-positivist and constructivist-anti-positivist. Put simply, positivist epistemological belief focuses on knowledge being independent of the knower, and this knowledge reflects an objective truth that exists 'out there' waiting to be discovered with no need for it to be constructed by the individual (Brownlee, Boulton-Lewis & Berthelsen, 2008).

The frequently observed teacher-centred classroom is characterised by an objectivist view of scientific and mathematical knowledge, and a view that the curriculum is a product to be delivered by the teacher (Taylor, Fraser & White, 1994).

My initial classroom pedagogical problems emanated from not understanding or appreciating the implications that a teacher-centred classroom could have on curriculum delivery (see Chapters 4 & 5).

I wish now that, in those early stages of my research, I had stopped and asked myself what it meant to have a teacher-centred classroom, and how it was different to a student-centred classroom. If curriculum was not a product to be delivered then what exactly was it? I viewed curriculum, constructivism, pedagogy and epistemology as separate and unrelated aspects of teaching. I have come to believe that my compartmentalising of these concepts stemmed from a deep-seated belief that there existed an objective truth that could be transmitted from one individual to the next, that is, a teacher could pass knowledge to a student. This view resulted in my attempts to seek out and memorise definitions of key terms and concepts. I valued rote learning over a coherent understanding of concepts and their impacts on one another. The hegemony of positivism was not visible to me at this stage because it is problematic to interpret different worldviews when the 'lens' you use to view concepts is from a particular worldview. It was the need to explain the purposes of my study to others and the questioning of colleagues about relevant concepts and terms that focused attention on my positivist views. It became clear to me that I was comfortable regurgitating rote-learned definitions, but my lack of understanding of these concepts became apparent under sustained questioning (see Chapter 4). In those early stages I felt lost as I searched for a deep understanding of key concepts that could not be provided by definitions alone.

Constructivists/anti-positivists assert that there is no reality 'out there' waiting to be discovered or that there is no unmediated way of accessing it. Rather, humans create knowledge and reality through experience and interaction with the environment (von Glasersfeld, 1995). Knowledge is constructed and built up by and builds on our conceptual constructions. Knowledge continues to adapt to the experiential world we encounter.

Constructivism/anti-positivism presents reality as being personal constructs that are congruent with the world that we experience (von Glasersfeld, 1995). It is from different epistemological stances that alternative views of learning have been developed and continue to influence the realm of education throughout the world.

Through the journey of my research I probed the myriad of ideas and concepts that reside within 'constructivism'. The notion that epistemology and the principles of constructivism are inextricably intertwined did not exist within me at the commencement of my research. This development evolved as theory and practice collaborated within my own experiences in my classroom.

Learning Theories

Discussions regarding how people learn have existed for over 2000 years. Socrates (469-399 B.C.E.), Plato (427 – 347 B.C.E.) and Aristotle (384 – 322 B.C.E.) all engaged in debates concerning the attainment of knowledge (Alexander, 2006; Boudourides, 2003; Magrini, 2009). Of significance to my research and professional practice were the various learning theories that have been developed throughout history.

Learning theories are developed in an attempt to explain and better understand the process by which people learn. They are directly related to our beliefs about knowledge and its acquisition (Magrini, 2009). Each learning theory emanates from an epistemological tradition, which reflects a particular belief about the origin and nature of knowledge (Hofer & Pintrich, 1997). There exists a strong bond between learning theory and teaching practice. A search of learning theories in a research database or Internet search engine provides a wide range of theories that attempt to explain how people learn.

These theories are important in education as they provide a foundation from which pedagogy is based. For the purposes of my study the learning theories of behaviourism and constructivism are reviewed and discussed. It is these learning theories, and my transformation from a predominately behaviourist leaning pedagogy that my research documents.

Behaviourism

The dominant learning theory in the United States, U.K. and Australia until the late 1960s was behaviourism (Duit & Treagust, 1998; Novak, 1978). This learning theory uses stimulus-response conditioning as the premise for a change in a person's behaviour and subsequent learning.

According to behaviourism, learning is concerned with an individual's correct response. Behaviourist learning theory has an epistemic belief that knowledge is separate from the learner. Teaching and learning is about the successful movement of knowledge from the teacher to the student. It is often associated with the role of the teacher acting as though it is possible to transmit knowledge to students who passively absorb knowledge. It is the role of the teacher to teach 'right answers' and 'right ways' (Prawat, 1992; Windschitl, 2002). Behaviourist learning theory claims that learning is the result of a change in our observable behaviour usually as the result of a stimulus. Annan, Bowler, Mentis and Somerville (2011) claim that behaviourist learning theory derives from the work of Pavlov, Watson and Skinner who studied the effects of stimuli on individuals and their subsequent responses. Operant responses, or responses that have been modified by consequences, were shown to be applicable in humans as well as animals. Through the use of rewards and punishments the desired outcome can be 'hard-wired' into a person's memory (Barnett, McPherson & Sandieson, 2013). This led a search to identify the consequences that achieve the optimal educational outcome or learning. Gredler (2005) and Semple (2000) suggest that behaviourism pays significant attention to observable behaviour and an individual's environment, discounting completely the internal machinations of the individual.

The effects of behaviourism on education were the development of educational outcomes that stressed observable behaviours. These outcomes best occur in a rote-learning environment accompanied by feedback with an emphasis on skill development through drill and practice (Edgar, 2012; Gredler, 2005).

Windschitl (2002) suggests that the effects of behaviourism are often observed in teachers who experienced this learning theory when they attended school and university, and subsequently employ it in their own professional practice. He points out that the recall of facts presented to us by a teacher is often learned through drill and practice. It is these experiences, which many of us encountered in our school education, that informs our understanding of teaching, and that has developed in us an epistemic belief that knowledge is something that can be passed on from one individual to another.

Windschitl (2002) describes the classroom of the behaviourist teacher as being orderly and quiet with individual seating of students who face the dispenser of knowledge (the teacher) who holds a privileged position within the classroom.

The idea that my classroom could be a window into my epistemological beliefs was not something I had considered before; however, my teaching practices provided information about my previously sub-conscious epistemology. I was happy to espouse the theory of constructivism through words. However, my own classroom reflected my epistemological view of the world and displayed characteristics that Windschitl (2002) views as indicative of a behaviourist classroom. Students were individually seated in rows (conference style). It was expected that silence be maintained for considerable periods of time during mathematics lessons where students were permitted to ask questions of me at a time deemed appropriate by me, and certainly not while I was explaining a concept. I encouraged and supported the use of collaborative practices in the classroom key learning areas (subjects) but not in mathematics, thus reflecting my previously unidentified belief regarding the nature of mathematical knowledge.

Perhaps this was, as Windschitl (2002) suggests, the enactment of my own educational history, formed through my experience of a silent classroom where drill and practice were valued over other forms of pedagogical practices. The pedagogy I experienced over many years may have had profound effects on the development of my educational epistemology and subsequent pedagogy.

The notion that the acquisition of knowledge, developed throughout our previous educational experiences, could be a greater indicator of my likely professional teaching pedagogy than the teaching theories exposed to me in teacher training courses and teacher in-services was a great surprise to me (see Chapter 1) (Taylor, 2014; Windschitl, 2002).

While I proposed to make changes to my professional practice I needed to be diligent in reflecting on these changes to ensure that they were constructivist practices and not simply a constructivist strategy delivered in a behaviourist manner. It is important to understand constructivism firstly as a learning theory.

Constructivism – A theory of learning

My successful transformation from a behaviourist leaning pedagogy to a more constructivist pedagogy required a broad and deep understanding of what was meant by the term constructivism. As my understanding of constructivist learning theory deepened, so too the positive effects of my pedagogical change became more evident. My understanding of constructivist pedagogy, as you will note in Chapters 4, 5 and 6, move quite noticeably from a 'dry' rote-learned definition to a 'real' application-based understanding of the concept.

Russian scientific enterprise observable in the launch of the Sputnik space program, as well as an increasing focus on the quality and adequacy of science education in American schools, resulted in review and reform of the curriculum in the 1960s (Edgar, 2012). The rise of educational constructivism and its effects on the theories of learning within the different branches of science research and education supported the need to review the curriculum (Duit & Treagust, 1998; Edgar, 2012). Research into science education started to reflect a questioning of the prevailing learning theory and epistemological perspective with an emphasis on moving from quantitative to qualitative methods of research. This resulted in research beginning to place greater focus on why effects in learning had taken place rather than the changes to teaching procedures or curriculum (Duit & Treagust, 1998).

Piaget's contribution

The review of curriculum in the 1960s witnessed the rediscovery of Jean Piaget's research into cognitive development and formed the basis on which the proposed curriculum review was justified (Edgar, 2012; Novak, 1978).

Piaget is considered by some to be the founder of the constructivist movement (Duit & Treagust, 1998; Gordon, 2009), with von Glasersfeld (1996, p. 6) describing him as "the most prolific constructivist of our century". Piaget's research was widespread; however, a particular aspect of his work delved into the ways children could be assisted in moving from concrete to formal thinking.

He identified four stages of cognitive development (sensory motor for ages birth to two years, preoperational for ages 2-7 years, concrete operational for ages 7-11 years, formal operations for ages 11 years and up) and the concepts of schema assimilation, accommodation and disequilibrium (Agbenyaga, 2009; Edgar, 2012; Sullivan, 2011). Schemas represent units of knowledge that assist people in understanding the world around them. Assimilation refers to a child's use of an existing schema or way of organising information whereby new learning is added to existing schemas. Schema is used when the child encounters new situations and environments. If the existing schema is not adequate to deal with the new information, a state of disequilibrium occurs and creates new learning.

Existing schemas might accommodate new information through adaptation or modification of existing schema and a state of equilibrium occurs. However, the child's ability to learn, or their 'readiness' for learning, is dependent on the child's cognitive stage of development. A child experiences the world around them, and constructs knowledge and conceptual understandings about how the world functions. When disequilibrium occurs adaptation causes learning to occur. For Piaget the way knowledge is constructed is of critical importance, and remains an active process.

My first experiences of Piaget occurred at university in the mid 1990s. It was at university that my understanding of his and others' learning theories were 'tested' - assessed - through the use of extensive multiple-choice questions.

I recall rote-learning Piaget's cognitive development stage characteristics and definitions in preparation for assessments. I confess to having experienced a feeling of angst whenever the name Piaget was mentioned. This need not have been the case and it is ironic that the 'father of constructivism' had his theories taught and 'understood' in this way.

Agbenyaga (2009), Askew (as sited in Sullivan, 2011) and Duit and Treagust (1998) raised concerns about Piaget's stages of cognitive development. They pointed to research that questioned the notion that logical thinking is independent of context. Different domains require different types of operational thinking, and it cannot be assumed that logical thinking is effectively transferred to other domains.

Agbenyaga (2009) considers Piaget's failure to appreciate the effect of culture on a child's development and the notion that children develop largely in the same way with only minor differences as weaknesses of his arguments. For Semple (2000), Piaget lacked an appreciation of the effects of the child's social interaction and cultural environment on their cognition. Von Glasersfeld (1982) points out that Piaget's theory is not a learning theory, but the application of his developmental psychology view to an educational setting.

Von Glasersfeld's contribution

It was von Glasersfeld (1982) who further developed the re-emerging cognitive constructivist theories of Piaget, where the focus on knowledge construction centred on the individual and their active role in the development of knowledge (Davis & Sumara, 2003).

Von Glasersfeld (1989) asserted that there exists two principles regarding the essence of what he termed a 'radical constructivist' theory of learning. Von Glasersfeld (1989) noted that these principles are extremely important to the pedagogy of teachers, for the epistemological belief of constructivist teachers is paramount to the successful implementation of constructivist pedagogy, and as such seemed critical to my research.

The first principle states that ‘knowledge is not passively received but actively built by the cognizing subject’ (von Glasersfeld, 1989, p. 114). I dutifully memorised this principle without fully understanding the significance it was to have on my pedagogy. For von Glasersfeld (1982) this principle could be derived from the writings of Baldwin and Piaget, and indeed had been around since the days of Socrates.

The second principle states that ‘the function of cognition is adaptive and serves the individual's organisation of the experiential world, not the discovery of ontological reality’ (von Glasersfeld, 1989, p. 114).

For von Glasersfeld, adherence to both principles constitutes a belief in what he termed ‘radical constructivism’, whereas those who adhered only to the first principle held a ‘trivial constructivist’ belief.

It is epistemic belief and understanding of the nature of knowledge that changed trivial constructivism into radical constructivism. It was von Glasersfeld’s (1992) belief that it is not possible for us to make any claim to an absolute knowledge of reality because, as humans, we have only our experiences of this reality. To support a claim of absolute knowledge of a reality we must triangulate the claim using something other than our own experience of it. Radical constructivism does not concern itself with solving this dilemma, but avoids the claim of knowledge of an absolute reality by suggesting that it is unattainable (Tobin, 2007). Von Glasersfeld (1995) claimed that, in radical constructivism, truth is superseded by the notion of viability, or fit. He explained viability as similar to Piaget’s concept of assimilation. In the cognitive domain viability refers to conceptual constructs that remain adequate within the settings or contexts from which they develop. There is no need to consider knowledge as ‘truth’; rather we can describe our knowledge as something that is viable or fits within our experiences of the world.

Initially, I could not appreciate how either of von Glasersfeld's principles could be significant to the success of my pedagogical change.

I could not see any link between epistemology and constructivist learning principles, yet by the conclusion of my research, and as a result of my experiences, I gained an appreciation of the impact of these principles on my understanding and implementation of constructivism as a pedagogical strategy.

For von Glasersfeld (1991) cognition and knowing relate to the physical and social environments we encounter. The focus on students' understanding rather than their performance is a crucial factor.

Radical constructivism holds that a teacher whose instruction is aimed solely at student performance is using a form of trivial constructivism (von Glasersfeld, 1991). Indeed, von Glasersfeld's view was that constructivism, used as a learning theory, was always bound to be trivial when not accompanied by a post-epistemological use of constructivism, as is required for the implementation of a radical form of constructivism.

It was von Glasersfeld's first principle that I returned to over and over again during my research. My field notes are littered with comments questioning what he meant by his first principle, and what it subsequently means to me in the classroom. I was pleased that, over time, I realised that the ability to recite the first principle was of little use to me in the classroom, and that a deeper understanding of the principle and its implications for my pedagogical transformation was required. Over time, I started to appreciate and understand the implications for my classroom of a student 'constructing knowledge'.

Ernest (1995) points out that constructivism is a marked movement away from objectivist behaviourism, proposing that it is the individual who is actively constructing new knowledge based on previously developed understandings. The significance here lies in my need, as a teacher, to critically view the students' current conceptual understandings. It was the emphasis on an individual's construction of knowledge that led to some criticism of the theory and the development of the theory of social constructivism, which attempts to explain the social aspects of learning.

Vygotsky's contribution

Duit and Treagust (1998) and Jones and Brader-Araje (2002) suggest the development of a strain of constructivism - social constructivism - evolved from the work of Lev Vygotsky. The influence of the environment on an individual is an important aspect of learning (Vygotsky, 1978). This social aspect of the environment was the focus of Vygotsky's research.

He proposed a learning environment that encourages social interaction, because learners are intertwined with their social and cultural environments. Vygotsky believed that while learning is a personal cognitive construction it is mediated in social settings through the interaction of individuals and other members of the learning community (Stears, 2009).

Vygotsky developed a form of social constructivism that suggests learning does not progress through clearly defined sets of stages as suggested by Piaget, but was dependent on environmental factors, including language and its use and cultural and social factors (Stears, 2009).

Vygotsky considered the notion of the 'zone of proximal development' a significant factor in a child's development (McLeod, 2007). The zone of proximal development represents the difference between what a child can do independently and what a child can do with skilled assistance and guidance. It is in the zone of proximal development that a child requires guidance in the development of skills and knowledge that they will eventually use independently. This interaction with others can be an effective method of skill and knowledge development for children (McLeod, 2007). Vygotsky claimed that the formal education of a child should target the individual child's zone of proximal development as experienced in their encounters with a particular culture. Ideally, it is the teacher's role to support students at that particular point to successfully construct new skills and knowledge (Ivic, 1994).

For Vygotsky, the social and cultural environment plays a significant role in the construction of knowledge. Consequently, there are important roles to be played by peers and teachers as they provide learning scaffolds within the individual's zone of proximal development.

Cooperative and collaborative learning and reciprocal teaching are examples of possible classroom applications of learning scaffolds suggested in Vygotsky's theory (McLeod, 2007).

Vygotsky believed that Piaget's cognitive constructivism was inherently dependent on the contexts of culture and society. Students construct knowledge that is mediated and consensually agreed upon in social settings.

This knowledge has been agreed and accepted by a community of scientists, and forms a canonical base of knowledge that individuals in social settings learn (Robottom, 2004).

Learning resides in a complex context of political, social and cultural factors that impact on any learning that takes place. How concepts are constructed is heavily impacted by these factors and is significant for a teacher to consider prior to the implementation of teaching and learning experiences (Robottom, 2004).

Bringing The Theories Together

Constructivist learning theory has a growing influence in educational and psychological research (Richardson, 2003). It is a multifarious concept that requires considered thought before it can be used to inform the selection of pedagogical strategies. Contributions from Plato, Dewey, Freud, Friere, James, Kant, Pierce, Vico, and von Glasersfeld had significant influence on different forms of educational constructivism (Davis & Sumara, 2003; Gordon, 2009). Richardson (2003) identified 18 varieties of educational constructivism. Tobin (2007) recorded 711, 000 hits when he entered the terms 'constructivism' or 'constructivist' into a Google search engine. On entering those terms into a Google search engine I was presented with 6, 380, 000 hits (5/4/2016).

The diversity of perspectives and theories related to constructivist learning theory presented an obvious problem for me in my quest to use a constructivist perspective in my classroom. Wheatley (1991) rightly contends that constructivism conjures different meanings to different people and that finding a common understanding is difficult to come by.

As Windschitl (2002) points out, the success or failure of constructivist pedagogy in the classroom rests heavily on the teacher's understanding of the notion of constructivism.

It was difficult for me to manage the variety of constructivist theories. Moving from constructivist theory to practice appeared as a significant hurdle. What was I going to do in my class that was different as a result of a constructivist teaching perspective? The realisation that it was more likely how I taught than what I taught was not clear to me in these early stages of my classroom lesson planning.

A result of my concern about understanding constructivism as a learning theory and how this manifested in my classroom was a desire to find well identified constructivist practice and strategies that could be implemented in my classroom.

However, research has warned that so-called constructivist teaching strategies are not fool proof for implementing a constructivist perspective in the classroom. It is common for teachers to apply behaviourist pedagogy to constructivist strategies rendering the proposed pedagogical change devoid of constructivist learning principles (Dangel, Guyton & McIntyre, 2004; Richardson, 2003; Windschitl, 2002). My reflective notes question my use of supposed non-constructivist teaching strategies - direct-instruction, lectures, non-interactive devices, rote-learning, pen and paper assessment. Sadly, in the initial stages of my teaching experiment, worksheets, textbooks and 'lecturing' were totally removed from my classroom because I thought they represented a regressive behaviourist approach to my professional practice. Their use or non-use caused me angst throughout my teaching experiment (see Chapters 5 and 6).

Gordon (2009) identifies the need for a practical understanding of constructivism that is supported through the identification, development and use of professional strategies and practices in the classroom. It is the role of the researcher to identify these practices for the practitioner through the development of a prescriptive theory of constructivism as a referent for teaching that provides both the theoretical and practical components of constructivism (Gordon, 2009).

Conceptual Change Theory

Within the overall development of constructivism the notion of conceptual knowledge, and importantly, conceptual change theory developed. It is from constructivist learning theory that conceptual change theory has emanated and become a significant factor in education and educational research (Duit & Treagust, 2003; Vosniadou, 2007).

Full conceptual understanding not only incorporates how mathematics tasks are performed, but includes an understanding of why each of the component parts operate the way they do. As such, there resides interrelatedness between elements of knowledge when deep understanding is achieved (Skemp as cited in Sullivan, 2011). Conceptual change can be related to the Piagetian notions of assimilation and accommodation whereby the learner's existing schema has changed as a result of their interaction with new situations or environments (Vosniadou, 2007). However, as I have experienced often in the classroom, students appear torn between what they previously believed to be true and what they have just encountered or been told.

Students do not appear before us *tabular rasa* waiting to acquire new ideas. The students who sit before us arrive with pre-existing ideas and notions about how the world works (Robottom, 2004). Pre-existing naïve and intuitive concepts require change and modification that cannot be achieved through rote learning (Vosniadou, 2007).

Classrooms must be places that support this type of cognitive conceptual change, which can broadly be classified as either weak or strong change (Duit & Treagust, 2003). The degree to which a student hangs on to an alternative pre-concept determines the strength or weakness of the conceptual change. An example of weak conceptual change applies to students who construct a hybrid or synthetic model of the Earth based on the teacher presented scientific model of Earth as a sphere, and the naive child developed theory of a flat Earth (Vosniadou, 2007).

Presenting learning experiences that provide students with the necessary experiences to identify the inconsistencies in their naïve concepts may allow them to adopt the scientifically accepted canonical view. Windschitl (2002) suggests that weak construction of knowledge is fragile and sustained only by the act of memorisation. This is compared to the act of strong knowledge construction, which represents a move towards coherence and meaningfulness that is built on previous understandings and will be used to assist the construction of further understandings.

Reflecting on my understanding of constructivist terms and concepts led me to believe that I initially held a weak conceptual understanding of constructivism and a constructivist classroom perspective based on my memorisation of key concepts and definitions. I experienced, first hand, the difficulty in developing strong conceptual change. It was this type of critical reflexivity (see Chapter 2) that marked my ongoing critical development as a teacher (Brookfield, 2009).

Other Teachers' Experience With Pedagogical Change

Interpretive research, case histories and the experiences of other teachers implementing a constructivist perspective provide valuable insights for prospective teachers wishing to make an effective pedagogical change (Gordon, 2009; Richardson, 2003; Rust, 2009).

Further, Gordon (2009) and Richardson (2003) place particular importance on the experiences of other teachers who have attempted pedagogical change similar to that attempted in my study. They suggest that it is from these examples of the use of a constructivist teaching referent that teachers can learn a great deal about what should and should not be enacted in the classroom. It is through these experiences that the bridge from theory to effective practice can be built. Cohen (1988, p. 255) points out,

> Teachers who take this path must work harder, concentrate more, and embrace larger pedagogical responsibilities than if they only assigned text chapters and seatwork.

Cohen (1988) believes that teachers are unlikely to complicate their lives in this way without undergoing a significant change in their thinking. I became intrigued about what this new thinking was and how I could embrace it and apply it to my professional practice. Initially, I searched for pre-prepared (lessons constructed by others and available in textbooks or on-line) constructivist lessons to replace assigned text chapters and activities. It was my search for pre-prepared constructivist lessons that led me from pedagogy towards content. This is a warning pointed out by Richardson (2003) and Windschitl (2002).

Teachers' experiences of constructivist lessons focus on how they teach rather than what they teach. A focus on what to teach, I believe, returned me to the delivery of curriculum as a product and again reflected my behaviourist teaching tendencies. Too often pre-prepared lessons only mention particular strategies - open with a brainstorm, work in small groups - and do not discuss the rationale or workings of the particular practice or strategy.

Sowder (2007) claims that teachers should use case studies as they provide valuable information on the effectiveness of pedagogical change. Sowder (2007) cites the study into Mrs. Oublier's second grade class and her attempts to teach mathematics using a constructivist teaching perspective (Cohen, 1990). Cohen presents a fascinating and relevant portrayal of a teacher misunderstanding the use of constructivism in her classroom. I found the study informative as it highlighted how teaching practices can become attached to the traditional forms of mathematics teaching. I re-read Cohen (1990) throughout my research with growing understanding and appreciation of the complexities of using a constructivist perspective in my classroom.

Cohen (1990) pointed out that Mrs. Oublier was able to blend a traditional classroom with her dispensing fixed mathematics knowledge in a silent room with some of the 'new' mathematics strategies. The classroom was set up for co-operative learning, yet students were not encouraged to speak to each other. Student exploration of concepts was not encouraged. Students were never asked to explain their findings, and results were accepted as either right or wrong. It seems that Mrs. Oublier wanted to play "Guess what's in the teacher's head".

Concrete materials were considered essential for learning, but more importantly sufficient for learning. Mrs. Oublier presented the reality of a teacher implementing a constructivist teaching perspective without an understanding of its theoretical underpinnings. Mrs. Oublier's classroom represented the traditional and the modern views of learning and teaching. Mrs. Oublier's classroom looked and sounded like my own!

Windschitl (2002) reports on a teacher whose attempts to use a greater constructivist perspective in teaching focused on the use of the 'inquiry approach'. This constructivist strategy was implemented using an initial brainstorming strategy; however, the students were not required to discuss the purpose, approach or results of their studies. It was as if the activity was in itself enough to qualify as a true constructivist inquiry approach because inquiry and brainstorming had been listed as constructivist strategies.

The teacher was not sure what the 'inquiry approach' was meant to engender or what potential, through discourse, was available from such an approach. In the initial stages of my teaching experiment I reflected on how I acted in ways similar to this teacher. I was capable of using so-called constructivist strategies with a behaviourist perspective (see Chapter 5 & 6).

Additionally, I was aware that I had initially ignored or discounted student classroom input because they did not provide the answer or suggestion I was after -the 'right' answer. In the initial stages of my teaching experiment (see Chapter 5), I could not appreciate the benefit or need for me to actively seek student suggestions about the classroom or their learning. How these student suggestions could develop my knowledge and appreciation of their conceptual understandings was not a consideration of mine at that time.

Dangel et al. (2004) assert that it is simply not enough to apply what are believed to be constructivist practices without a fundamental assessment of a teacher's beliefs about learning and teaching.

Constructivist labelled activities, organisation, manipulatives and designed learning experiences within a learning environment are not in themselves necessarily an indication of the effective use of constructivism as a referent for teaching (Dangel et al, 2004; Davis & Sumara, 2003; Richardson, 2003; Windschitl, 2002). Richardson (2003) tells us that a teacher who believes they are constructivist in their professional practice, but is not very effective, may be using supposedly constructivist practices in a transmission-based method.

Similarly, many teachers use manipulatives in mathematics lessons simply because they have been told that these resources are supportive of a student-centred constructivist approach. Why this is the case is often not clear to teachers and encourages the misuse of the strategy (Windschitl, 2002).

Similar to Mrs. Oublier we find Taylor's (1996) high school mathematics teacher, Ray. Ray espoused constructivist ideals but was found to maintain a centralist approach to his teaching. I reviewed Ray's 'story' after the initial weeks of my pedagogical change and found there was a little bit of Ray in me.

Ray remained the informer and controller of the students, providing little opportunity for students to gain a deep and deepening understanding of mathematical concepts, nor were students permitted any autonomy in determining their learning activities and investigations. Taylor (1996) introduces the reader to possible causes of Ray's inability to effectively use a constructivist perspective. He suggests that the metaphors of 'cold reason' and 'hard control' restrain the successful adoption of constructivist learning environments.

Without the awareness of the socio-cultural nature of knowledge constructions teachers revert to what Taylor (1996) describes as the myth of cold reason. This myth perpetuates the positivist belief that knowledge exists independent of the world, and is deduced logically by individuals in an objectivist and traditional view of teaching. The culture of the classroom evolves through this quasi-empiricist view of the world. Student motivation is presumably gained through their efforts to reproduce 'correct' answers with little consideration given to the effects gained from providing students with real-world, problem-forming and problem-solving contexts.

Further, Taylor (1996) points out that signs and symbols become synonymous with mathematics concepts at the expense of mathematics creativity. The predisposition to reproduce a prevailing culture is seemingly the desired outcome of curriculum in many school systems.

The myth of hard control raises the importance of teachers and students in negotiating the curriculum. The myth of hard control appears to be a companion of the myth of cold reason where students and teachers are not empowered to take an active and effective role in the implementation or creation of the curriculum.
A positivist view of knowledge reflects in the creation of a curriculum that values pre-determined learning objectives attained through prescribed learning activities.

It is clear that an epistemology that claims an independently existing reality views learning as an asocial and passively received transmission of objective knowledge from the teacher. There is nothing, therefore, that needs to be negotiated by the learner. Taylor (1996) suggests that students lose their voice in this learning environment where their learning is not based on their pre-existing constructions and cultural tools but a desire to cover the curriculum content.

Taylor's (1996) myths of cold reason and hard control diagnosed the problems I experienced in the classroom and the difficulties I had in moving from behaviourist to constructivist learning theory (see Chapters 5 & 6). Ray showed me that it was possible to believe in the theory of constructivism, yet maintain a strong behaviourist pedagogy. In identifying Ray's pedagogical weaknesses I was provided with valuable insights into how I might transform my pedagogy.

On a more positive note, Gordon (2009) presents two teachers who applied what was considered to be a successful constructivist perspective to their teaching. Bill was the fifth grade teacher of the American Revolution and Rosemary a ninth grade mathematics teacher. Bill made learning an active experience through a recreation of a mock convention with students researching different aspects of the American Revolution. Students used multiple sources of information and investigated the topic from a number of different viewpoints.

Rosemary came from the school of transmission teaching; however, she reflected on why her students struggled to understand concepts and why their interest and engagement in her lessons waned. She started to implement constructivist strategies that supported her evolving understanding of the constructivist learning theory. Rosemary used brainstorming and other student directed techniques to identify students' prior conceptions before planning her lessons. On reviewing her lessons through student surveys, Rosemary became aware of mixed student feelings about her pedagogical reforms and she more fully appreciated the growing need to attend to student questions with adequate explanations. She needed to play a more active role in the classroom, stepping in with her own knowledge and understanding as required, and not allow the students to feel a sense of isolation (Gordon, 2009).

Important points from these examples were the need for teachers not to sit back, but to play an active role in the students' construction of knowledge. Gordon (2009) argues that there are a number of points that can be learned from case studies of teachers using constructivism as a referent for teaching. Firstly, both teachers made learning an active experience for the students thereby allowing them to construct knowledge themselves. The temptation 'to tell' was avoided by these teachers as they guided them through learning experiences designed to create deep understanding and knowledge.

These teachers found the correct mix of teacher input and direction and student directed learning. This 'correct mix' allowed the teacher to guide students to understandings that are not at odds with canonical standards. Both Bill and Rosemary allowed individual and social construction of knowledge in their classrooms. Students should be allowed to learn in a variety of ways within these constructivist learning environments (Gordon, 2009).

Davis and Sumara (2003) present the insights of teachers in an elementary and middle school as they struggled to effectively implement constructivist pedagogy. Through their interactions with teachers, Davis and Sumara (2003) identified and addressed interpretations of constructivism by the teachers. Teachers at the school implemented what they believed to be constructivist pedagogical organisation and strategies.

This gave rise to the same problems discussed in the experiences of Mrs. Oublier and Ray. Davis and Sumara (2003) highlighted the necessity for me to evaluate my beliefs about teaching and learning. They posed the salient question 'What are we doing when we claim to be teaching?'

Davis and Sumara (2003) provided insights for me to consider when my changes to classroom seating were not well received by the students (see Chapter 5). I read their paper closely to more fully understand the relationship between collaborative and cooperative group work.

Davis and Sumara (2003) found that classrooms, within the studied school, all followed a 'pod-seating' arrangement whereby desks were arranged in pairs facing each other. These arrangements were maintained throughout the school day to support the social aspect of constructivist learning.

The use of a collaborative learning environment was used to assist the teacher to develop an understanding of students' conceptual creations; however, Davis and Sumara (2003) found such beliefs, in certain circumstances, to be unfounded. They noticed that the small student collaborative groups in the study predominantly discussed topics that had nothing to do with the mathematics concepts they were asked to discuss. They found students worked individually within a group and used the group for more social activities. They labelled this type of group work as 'socialising interrupted by class work requirements'.

Davis and Sumara (2003) suggest that group learning requires teachers to have a thorough understanding of the dynamics of the collective, so that the advantages of this type of grouping arrangement can be achieved.

Through the course of my teaching experiment I found students remained on task when operating in their collaborative groups. I believe the school, through the processes of reciprocal teaching, developed many of the skills necessary for effective collaborative and cooperative group learning (see Chapter 5 & 6).

These reciprocal teaching and learning strategies had been in use throughout the school for a number of years and proved beneficial to this aspect of the study. However, I translated this 'success' into a permanent group seating arrangement, which reflected more my belief that it was the arrangement of the desks and chairs rather than the skills and activities within the groups that was important (see Chapter 5 & 6). I often referred back to Davis and Sumara's research to better understand the dynamics of group learning and how better to eliminate the isolation of students from group discussion.

I found comfort and guidance in the teaching case studies presented. The classroom details and unsuccessful pedagogical changes provided their experiences with verisimilitude. Ray's experience of cold reason and hard control were evident in my classroom. The successful attempts of Bill and Rosemary to change their professional practice provided concrete examples of teaching that could be replicated in my classroom.

These classroom experiences became increasingly important as my own teaching experiment evolved. I constantly reviewed these teachers' experiences and kept copies of the research with me at all times in class and when preparing my lessons. During my research I reflected on those teachers who had not successfully implemented a constructivist perspective in their classrooms. All showed signs of 'hanging on' to behaviourist beliefs, and they all presented lessons that appeared to be a hybrid of constructivist and behaviourist perspectives. When I reread their experiences, I felt that at times, I was holding a mirror to my own professional practice.

It was in self-recognition of my professional practice of implementing unintentional learning theory perspectives that provided a step forward for me in my understanding of transformative pedagogical change. I felt grateful to all the teachers who shared their classroom experiences, as it was their experiences that led me to more successfully develop my own pedagogy.

At times, I heard Orwell's *'four legs good, two legs bad'* simplicity apply to my evaluation of certain teaching strategies and practices. However, I learned to seek out and understand constructivist principles that could guide my teaching experiences and pedagogical practice. But it took time.

The idea of 'finding' constructivist lessons abated somewhat as my focus turned to how teachers implemented successful strategies and practices as a vehicle for the outcomes and objectives of their lessons.

Constructivist Perspective For Teaching

Lorsbach and Tobin (2005) describe a 'referent' or teaching perspective as a way for us to comprehend what we see, think, and do. Tobin and Tippins (1993) indicate that constructivism when used as a referent provides teachers with the opportunities to maximise the learning potential of any context. I needed to ensure that decisions made about my actions as a teacher should be based on constructivist beliefs.

Constructivism as a teaching referent implies the application of discrete teaching practices based on sound constructivist beliefs. Tobin and Tippins (1993) identify the student's prior knowledge, the social nature of learning, the teacher's role in mediation and offering activities that foster clarification, elaboration, justification and evaluation of other viewpoints as key components of educational constructivism.

Further, they contend that a constructivist teaching perspective should consider learning to be fundamentally about improvement in student social processes, making sense, experiencing, and extant knowledge. This is far removed from the behaviourist notion of learning that rewards and values recollection of dates, rules and formulas.

If you believe, as I did, that mathematics was solely about rules and formulas then a period of re-education and reflection is required. It was back to the books for me so I could continue to develop my understanding of ontology, epistemology and the notion of viablility over truth.

This 're-education' continued throughout the course of my study and beyond as I grappled with these powerful concepts and how they influence my teaching.

It is through critical self-reflection that effective considerations regarding your teaching role using constructivism as a teaching referent is possible (Brookfield, 1995).

Taylor (Personal Communication, August 2008) and Taylor (2014) suggest that using constructivism as a referent for teaching is one approach within a teacher's pedagogical 'tool kit'. It does not necessarily prescribe teaching strategies such as small-group learning, conceptual change, personal relevance or co-operative learning, but guides our thinking regarding how to teach in relation to a range of curricular or pedagogic goals and contexts. In using multiple referents in an epistemic pluralist way it can be that teaching didactically is ok, other times interactively, sometimes teacher-centred, other times student-centred, sometimes for understanding and other times for abstract symbolic manipulation. The choice of referent (constructivism, behaviourism, information processing or any other) depends heavily on the teacher's professional judgement.

This was a challenge to my initial way of thinking. Strangely, the notion of considering the outcome for a lesson and selecting a strategy or strategies to achieve the outcome was not something I had considered in a professional practice sense. My focus had always been on content and how to transmit the content to the children. They regurgitated the content verbally or in writing and I assessed this as understanding the content. Taylor's 'toolkit' was suggesting that there were differences that needed to be understood and appreciated.

Perhaps learning the times tables was best achieved through rote learning. However, rote learning times tables may not be an effective strategy for understanding arrays. I was slowly (ever so slowly) beginning to develop a much deeper understanding of the construction of knowledge and meaning.

Taylor's suggestion is practical and perhaps served as a warning to me to be aware of and use critically all that is available to me in my professional practice. This is further supported in the National Numeracy Review Report (Commonwealth of Australia, 2008) where the idea of a teacher innovating in their selection of pedagogic tools from their 'toolkit' is advocated.

In my study I decided to report on the use of a constructivist teaching perspective for teaching in mathematics classes, and while there were examples of other perspectives being used in the classroom they are not the main focus of this study. However, of considerable importance to me was Taylor's view that certain teaching strategies are not so much prescribed by constructivism, but a constructivist perspective could guide the implementation of these strategies.

According to von Glasersfeld (1991), a constructivist referent has the student identify problems as their own and teachers build on the students' problem-solving skills. This echoes Ausubel (1968, p. vi) who claimed, 'the most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly'. Initially this was another of my 'throw-away' rote-learned quotes used when I spoke of constructivism in the staffroom. I became aware of Ausubel's quote during my university days and in keeping with my 'weak' understanding of concepts I never really considered the implications of this simple but profound statement.

With respect to the statements of leading researchers and educationalists I needed to ask myself the question- what does this mean to me as a professional and how was I teaching differently as a result of this understanding?

As I looked towards the planning of my classroom practice I felt an overwhelming sensation of being swamped by the variety of theories and views regarding constructivist learning theory (Richardson, 2003). Gordon (2009) forewarns the constructivist teacher that more is required of them as a result of this pedagogical change. However, understanding and developing sound and pragmatic teaching practices can alleviate this additional requirement. It is not simply a matter of identifying certain strategies and practices that could be described as being constructivist and applying them to the classroom.

Discrete teaching strategies like cooperative-learning, hands-on experiences and direct instruction are often a superficial view of what a teacher needs to be doing (Dangel et al. 2004; Davis & Sumara, 2003: and Richardson, 2003. This struck me as being at odds with constructivism. I felt that these practices were an integral part of transformative pedagogical change.

Certain strategies lend themselves to a constructivist learning environment; however, the practice in itself is not necessarily a guarantee of success.

My initial foray into transforming the classroom (see Chapter 5) clearly showed how I believed that a supposed constructivist teaching strategy -collaborative learning groups - simply being implemented transformed my pedagogy. Von Glasersfeld (1995) pointed out that constructivism tells us about human learning and is descriptive rather than prescriptive, providing more details about what not to do rather than what to do. What often occurs in teachers' classrooms can be labelled as popularised understandings of the idea of constructivism as a referent for teaching, which has little or no reference to what they consider are the seminal writings on constructivism as a theory of learning (Davis & Sumara, 2003).

However, for my planned pedagogical transformation and with concerns about what I should and should not use in the classroom, I sought guidance from educational researchers. I hoped they could provide a blueprint for my subsequent planning of teaching and learning experiences and the learning environment that I wished to create.

A constructivist leaning environment is evident in the development of other countries' understandings of teaching and learning. The OECD (2011) reported that many high performing countries' education systems have an emphasis placed on active construction of knowledge, real-life experiences and learning in groups. While the document does not commit itself to any particular form of constructivism it is self-evident that these reforms are in alignment with generally accepted principles of constructivist learning.

Many researchers have attempted to shape a constructivist perspective for teaching as the move from learning theory to pedagogy develops. Windschitl (2002) provided me with insights that build on the first principle of constructivism, that knowledge is not passively received either through the senses or by way of communication but actively built up by the individual (von Glasersfeld, 1995; Sridevi, 2008).

Windschitl (2002) identifies the use of scaffolding, modelling, coaching and guiding as facets of the teacher's professional practice and these are designed to assist students to move from their current conceptual understandings.

Further, he identifies problem-based learning, inquiry learning, sense making, collaboration with peers and teachers, use of multiple sources of information and the use of a variety of assessment practices as examples of constructivism being used as a referent for teaching. The views of Vygotsky and Piaget are evident in these facets of a constructivist teaching strategies. Windschitl (2002) does not rule in or out any particular practices but asks teachers to consider whether these practices complement student construction of knowledge or are an attempt to determine student knowledge.

However, he warns that these strategies can account for nothing if they are appended to the traditional school day. It is collaboration that Windschitl (2002) describes as a core value of constructivism. For my personal pedagogical journey I found the thoughts of Windschitl to be instructional and cogent, providing me with an overview of a perspective or referent for my teaching. According to Windschitl, a constructivist teaching perspective provides for a classroom where multiple realities are evident, varieties of assessment opportunities exist for student use, and meaning making is actively constructed in collaborative ways.

I was starting to build my transformative change, if only in a theoretical perspective, but this provided me with a starting point on which to build.

Richardson (2003) provided me with five characteristics of constructivist pedagogy - attention to the individual and respect for students' background, facilitation of group dialogue, planned and often unplanned introduction of formal domain knowledge, students to determine, challenge, change or add to existing beliefs, development of students' meta-awareness - and stressed that these are not practices, but essentials for the constructivist classroom.

Richardson (2003) believes that these essentials contribute to the constructivist goal of creating an environment where deep understanding and learning can occur while producing skills that will aid the student well into the future.

Richardson's five characteristics were a manageable number of principles that I felt were beneficial in a time-deprived teacher's life.

Dangel et al. (2004) identified a different perspective of classroom constructivism after they completed research on a study into the classrooms of six teachers that involved a series of classroom observations and interviews. The researchers sought to identify the commonalities of constructivist classrooms. Their research provided support for the claim that I needed to move beyond the identification of discrete teaching practices (Richardson, 2003; Windschitl, 2002). Their findings suggest more emphasis needed to be placed on my epistemological beliefs and subsequent practice, a better understanding of the notion of learning and classroom discourse, authority and decision making structures. They found that constructivist classrooms exhibited respectful relationships between students and teachers where discourse was both real and purposeful. It is this emphasis on the development of purposeful interaction between teacher and student in a collaborative relationship that cultivates a constructivist learning environment. My existing classroom supported a question and answer relationship between the students and myself indicative of a behaviourist perspective.

Dangel et al, (2004), Richardson (2003) and Windschitl (2002) created principles of a constructivist classroom after extensive research into classrooms and reviewing the findings of researchers who reported on constructivism in a variety of disciplines.

It was from these researchers that I deduced what they described as tenets, characteristics and imperatives of constructivism in the hope that they might assist me in moving towards a successful implementation of a constructivist perspective. My 10 collated principles of a constructivist pedagogy drawn from the findings of these researchers are:

1. Teachers elicit students' ideas and experiences in relation to key topics, then fashion learning situations that help students elaborate on or restructure their current knowledge.

2. Teachers provide frequent opportunities for students to engage in complex, meaningful, problem-based activities that determine, challenge, change or add to existing beliefs and understanding through engagement in tasks that are structured for this purpose.

3. Teachers provide students with a variety of information resources as well as the tools (technological and conceptual) necessary to mediate learning.

4. Students work collaboratively and are given support to engage in task-oriented dialogue with one another.

5. Teachers make their own thinking processes explicit to learners and encourage students to do the same through dialogue, writing, drawings, or other representations.

6. Teachers routinely asked students to apply knowledge in diverse and authentic contexts, to explain ideas, interpret texts, predict phenomena, and construct arguments based on evidence, rather than to focus exclusively on the acquisition of predetermined "right answers."

7. Teachers employ a variety of assessment strategies to understand how students' ideas are evolving and to give feedback on the processes as well as the products of their thinking.

8. Teachers assist students to develop meta-awareness of their own understandings and learning processes.

9. Teachers clearly define conceptual goals for the learners and an understanding of how learners might progress toward these.

10. Teachers use planned and often unplanned introduction of formal domain knowledge into the conversation through direct instruction, reference to text, exploration of a Web site, or some other means.

However, attempting to make pedagogical transformations of the quantity and scope of those listed in these principles can be problematic.

Taylor (1996) and the Southwest Consortium for the Improvement of mathematics and Science Teaching (SCIMAST, 1995), caution teachers who are planning transformative pedagogical change. They claim that the impact on the students and the classroom environment from attempting a number of pedagogical changes needs to be considered, and that it may be beneficial to reduce the number of component pedagogical transformations attempted. Taylor (1996) and SCIMAST (1995) suggest that attempting too much pedagogical change might negatively impact on the success of my proposed pedagogical change. It could be that in attempting too much change the overall affect of poorly implemented strategies can adversely impact on other pedagogical changes.

My scholarly development provided me with a range of views regarding the implementation of a constructivist perspective in my classroom. I felt that although detailed information was available regarding the use of constructivist perspective, the development of a path from theory to practice could become a complicated process where priorities needed to be created so that an effective implementation of pedagogical reform could be developed.

It was important that I synthesised the previously identified 10 principles of effective constructivist pedagogy that I planned to use in my pedagogical transformation.

My Pedagogical Focus Areas

After reviewing the literature I decided to focus on (1) building a collaborative classroom environment that encourages and develops meaningful discussions between myself and students, (2) presenting learning activities that are relevant to students' real-world experiences and (3) assessing students in a manner that respects the central beliefs of constructivism. These three principles are generally agreed key facets of a constructivist learning environment and were clearly not being successfully implementing in my existing classroom.

Creating a collaborative learning environment and developing meaningful communication

Collaborative learning refers to pairs or groups of students completing a common task or activity. Establishing a collaborative learning environment in my classroom was important in my evolving pedagogy, as it is central to many constructivist models of teaching (Gupta, 2008; Sullivan, 2011). Collaboration in the classroom has the potential to move students from purely procedural rules of mathematics to the constructivist goal of sense making (Walshaw & Anthony, 2005). Panitz (1997) makes a distinction between collaborative and cooperative learning. He positions both strategies within the constructivist paradigm, but points out that that cooperative learning is a more structured teaching strategy with greater teacher control and direction. Cooperative learning is often a strategy used in primary schools where students are developing their social interactions (Panitz, 1997). As their ability to independently and productively function in group-learning arrangements develop students move to the less teacher directed strategy of collaborative learning.

Potential benefits of collaborative learning

The report of the National Numeracy Review (Commonwealth of Australia, 2008) lists many studies that support collaborative classroom strategies and suggests that student achievement and motivation improves as a result of collaborative learning techniques. The report found that group members often develop accountability, social interaction skills and group interdependence appreciation.

Karagiorgi and Symeou (2005) reported that collaborative learning has the potential to create multiple perspectives of concepts where student views become a part of the class's teaching resources. Predications, justifications, comparisons and clarifications are all visible to the group members or class. The developing student conceptual understanding is open for review by their peers as they share in sense making (Karagiorgi & Symeou, 2005; Sullivan, 2011; Walshaw & Anthony, 2008). Curtin University of Technology (2013b) lists the following benefits for students of a collaborative learning environment:

- Engage in subject specific discussions with peers
- Learn how to work cooperatively and support each other
- Develop effective teamwork and communication (including interpersonal and cross cultural awareness) skills
- Assimilate multiple views to deepen knowledge and promote critical thinking
- Foster individual accountability to the team
- Develop independent learning strategies
- Structure out-of-class learning
- Mitigate learner isolation

Students who are actively involved in the co-construction of meaning for themselves and their peers find the experience beneficial and threatening (Windschitl, 2002), and this was the experience of some of the students in my classroom (see Chapter 5).

Sullivan (2011) points out that meaningful communication can provide teachers with insights about students' interests and backgrounds that may become useful when planning teaching and learning opportunities, or in understanding the thinking that students display when dealing with mathematics concepts. It can be a misplaced belief that students and I share the same or similar cultural and social backgrounds. Often teachers appeal to middle class backgrounds and values when planning teaching and learning experiences, and these are not necessarily values or backgrounds that are familiar to the students. It is through effective collaborative classroom practice that I could better understand students, and be able to situate experiences that are relevant to them (Sullivan, 2011).

Effective classroom discursive practices potentially allowed me to establish students' conceptual understanding and effectively plan conceptual development of students (see Chapter 5 & 6). Students' current conceptual understanding is linked to their cultural background and their everyday experiences of the world. It is through directed discursive practices that existing conceptual understanding can be built on in the classroom (Walshaw & Anthony, 2008). Additionally, the modelling of appropriate mathematics language by capable peers or myself could assist with the development of conceptual understanding (Windschitl, 2002).

Potential impediments to successful implementation

Walshaw and Anthony's (2008) review of research into classroom discursive practices found pedagogical practices that developed students' belief in their participatory rights and obligations, encouraged the articulation and fine tuning of mathematics thinking through language and the understanding of the nature of argumentation within the classroom were all important to the successful implementation of collaborative practices in the classroom. The success or otherwise of collaborative learning groups depends on providing students with necessary skills (Walshaw & Anthony, 2008).

Further, they point out that collaborative group learning does not, in itself, necessarily generate sense making. It is the social aspect of collaborative classroom activities that necessitates the need to develop the social skills of the students.

Windschitl (2002) claims it is important to develop in students the skills necessary to differentiate between defending one's ideas and defending one's self. Rather than attacking a person, students need to accept alternative perceptions as an opportunity to explore contrasting views. It is essential for teachers to socialise students in group-work activities as students can have considerable influence on each other's thinking. Windschitl (2002) sees whole-class discursive practices as an excellent opportunity for teachers to tell students how to do it, show them how to do it, and then, to do it with them.

Walshaw and Anthony (2008) suggest the need for teachers to develop collaborative skills amongst the students, a view supported by Lubienski (2002). This training needs to identify skills that students need to achieve the potential that collaborative learning permits. Windschitl (2002) warns that collaborative group learning can lead to students being exposed to ill-conceived notions as well as clearly thought through ideas of others. Group members fighting, isolating students within the group and the unwarranted dismissal of the thoughts of some within the group are often problems identified with collaborative group learning (Windschitl, 2002).

Further, students from non-English speaking backgrounds and low-achieving students often do not respond positively to group processes, and often feel excluded from mathematics experiences created by the teacher (Walshaw & Anthony, 2008). There were no students from non-English speaking backgrounds in my classroom; however, there were two students who could be considered low achieving. They did at times experience a sense of exclusion in group learning activities (see Chapter 5 & 6).

Real-world learning experiences

Using a constructivist classroom perspective required me to develop real-world teaching and learning experiences (Oblinger, 2007; OECD, 2009; Walshaw & Anthony, 2008).

It is through real-world learning encounters, experiences and applications that opportunities are provided for an effective move from the recall of rote learned facts to the integration of newly acquired skills and knowledge to real-life problems (OECD, 2009).

Sullivan (2011) suggests that providing students with real-world contexts consists of mathematics that is relevant and useful to them as well as assisting them in solving everyday problems. Sullivan (2011) claims it is necessary to consider social aspects of mathematical problems. Sullivan (2011) uses the case of two friends who paid different amounts for a shared lottery ticket who attempt to share their winnings.

This example may give rise to students suggesting that because the two were friends, they share the prize equally, and not based on the proportion that each spent on the ticket. I had not considered the social aspect of mathematics in my lessons and I can recall previous teaching experiences where I asked students, who had made what I now know as social solutions, to come back to the question being asked and to answer it ‘properly’.

To speak of rich and engaging authentic, real-world tasks initially overwhelmed me. I had little understanding of how to provide students with activities that were a movement away from rote learning. I had only provided students with educational experiences that prepared them for further schooling, not the environments outside of school. There has been some agreement among researchers regarding the principles of activities that can be described as real-world or authentic learning experiences (Herrington & Herrington, 2006; Mantei & Kervin, 2009; Oblinger, 2007). These principles or characteristics suggest learning activities contain:

- Real-world relevance
- Ill-defined problem
- Sustained investigation
- Multiple sources and perspectives
- Collaboration
- Reflection (metacognition)
- Interdisciplinary perspective
- Integrated assessment
- Polished products
- Multiple interpretations and outcomes

From a constructivist perspective, students' informal mathematical conceptual constructions are developed from experiences of their societal and cultural experiences. It is these experiences, situated within their physical world, that can provide educators with an insight into current conceptual constructions and an understanding of the language of mathematics used by the students (Walshaw & Anthony, 2008).

Real-world learning experiences ask students to draw on previous experiences as well as knowledge and skills in order to solve problems they have been set. It is essential in setting real-world learning activities that teachers move beyond the jargon associated with the pedagogical strategy and move to tasks that allow students to better understand the role of mathematics and concepts within the community (Walshaw & Anthony, 2008).

Constructivist assessment practices

Reporting to parents on student achievement in NSW schools from Kindergarten to Year 10 requires teachers to use a five point common grade scaling (A to E), as evident in the online document *Grading and reporting student achievement from 2006*, (NSW Board of Studies, 2006). While not compulsory, the commonly used grade scales (see Appendix D) provide information regarding how students' individual achievements align with expected grade or stage level outcomes

From a constructivist perspective, assessment activities should be embedded in the learning activities that have been designed for the students (Brooks & Brooks, 1999; Lombardi, 2007; Windschitl, 2002). As such the notion of using only summative assessment tasks is not sound constructivist practice.

Constructivist assessment strategies require a connectedness to the physical world of the students' experiences in the classroom and a fidelity to learning experiences that students engage with in class (Herrington, 2009).

Windschitl (2002) goes further in suggesting that teachers must be prepared for students who wish to present assessment tasks through an abstract mathematics perspective as well as students who wish to display their understandings in a more concrete and tactile fashion. By way of an example, Windschitl (2002) explains that an understanding of density may be expressed in formulae or through an analysis of the sinking of the *Titanic*.

Brooks and Brooks (1999) and Windschitl (2002) do not decry the usefulness of standardised pen and paper tests, and support the claim that these provide educators with useful information. However, they insist that pen and paper tests should not be the only assessments used to evaluate student achievement. They stress the value that embedded learning task assessments can provide students and teachers in developing learning and teaching experiences.

As a proficient user of a constructivist teaching perspective, I needed to redesign my classroom learning experiences where authentic learning experiences are presented for students to analyse, evaluate and create rather than remembering, understanding and applying. I therefore, needed assessment practices that did not seek one right answer in single-assessment scenarios. It is ill-conceived of me to develop collaborative based inquiry learning experiences if I maintained behaviourist assessment practice (Lombardi, 2007). Assessment data should not be an end in themselves, but provide impetus for drawing inferences and the making of judgements that allow for the creation of targeted teaching and learning experiences.

Changing from a summative behaviourist assessment to a formative constructivist assessment was not a change that I easily adopted to my professional practice (see Chapters 5 & 6). Initially, I did not feel comfortable dispensing with my student assessment spread sheet, which generated graphs and means of assessment data. I found many examples of assessment practices that were considered constructivist; however, I consistently attempted to use assessment data in a behaviourist manner, eager to reduce students' achievements to a simple percentage. I felt great comfort in aligning the A-E grade scales to the percentages students achieved on assessment tasks. If a student scored between 0 and 10 I equated that with an 'E' achievement scale. Likewise a score of 90 to 100 equated to an 'A' achievement grade.

Sullivan (2011) highlights the use of structured assessment diagnostic interviews developed by educational authorities in NSW and Victoria. He claims that these interviews can produce helpful information for teachers. These student-teacher interviews were designed for the early years of primary school education provided for professional support in interpreting the responses and devising strategies that address identified deficiencies.

Sullivan (2011) identifies the benefits interview assessments can offer teachers in identifying strengths and weaknesses in students, and hence the opportunity to facilitate student learning.

I was to implement a regular timetabled interview with students to discuss their mathematics learning throughout the previous fortnight (see Chapter 6). This type of directed interview assisted me in supporting the students in their learning through planned and focussed teaching and learning experiences.

Educational Context Of The Study

Examples of constructivist classroom characteristics and strategies can be located in a variety of publications issued by the NSW government departments, including the *NSW Mathematics K-6 Syllabus (*NSW Board of Studies, 2002*), NSW Model of Pedagogy* (NSW Department of Education and Training, 2003b) and the *NSW Professional Teaching Standards* (NSW Institute of Teachers, 2005). Perhaps the sheer quantity of literature made available to teachers represents an impediment to the successful implementation of a constructivist classroom pedagogy (Sullivan, 2011; Windschitl, 2002).

As my research was conducted in a NSW government Kindergarten to Year 6 (5 years to 12 years of age) primary school, the educational context with respect to the NSW Department of Education and Training policy regarding pedagogy needs to be explained. At the time of this study the teaching of mathematics in NSW was guided predominately by three significant documents. The first document is the *NSW Mathematics K-6 Syllabus* (2002) which provides for curriculum content.

The second document, *Quality teaching in NSW Public Schools Discussion Paper* (NSW Department of Education and Training (DET), 2003b) proposes a model for pedagogy known as the Quality Teaching Model. This model was proposed for use from Kindergarten through Year 12 and is applicable to all key learning areas (KLAs).

The third document, *Professional Teaching Standards* (NSW Institute of Teachers, 2005), provides a framework of professional standards that serve as benchmarks for effective teaching practices. These documents serve to provide guidance in teaching 'best practice' in NSW public schools.

The *NSW Mathematics K-6 Syllabus* (NSW Board of Studies, 2002) was the syllabus document used in my research and it explicitly identifies many aspects of a constructivist learning theory.

The syllabus identifies self-reflection, use of a variety of sources, ethical consideration and cultural and social appreciation and awareness as desirable outcomes for students. It mentions the need for students to apply their knowledge to real-world situations and to understand that mathematics has been developed in many cultures throughout the world. The syllabus suggests that the benefits of student collaborative learning can be seen in development of students' ability to cooperate, persevere and conjecture. An appreciation and awareness of students' existing knowledge is acknowledged through the acceptance of the students' own language when discussing mathematics concepts as well as their use of canonical language. The desire for students to be given relevant and meaningful problems that ultimately develop a positive attitude towards mathematics and create opportunities for critical reflection and creativity are emphasised in the syllabus.

In 2009, in order to shape the writing of a national curriculum, the Federal government released *The Shape of the Australian Curriculum* (National Curriculum Board, 2009). A constructivist perspective is apparent in this document.

The use of the terms 'active construction', 'student prior knowledge', 'contexts outside of school', 'cultural perspectives', 'meaningful learning', 'deep knowledge' and 'collaborative work' illustrate a constructivist perspective. In 2015, a new NSW mathematics syllabus was introduced.

This document continues the constructivist perspective of the previous syllabus and highlights the need for 'active' student participation, 'genuine mathematical activity', use of mathematical inquiry, and relevance to everyday lives of the students.

The *NSW Model of Pedagogy* (NSW Department of Education and Training (DET), 2003) proposes a model of pedagogy that guides and supports all primary syllabuses.

The model focuses on three dimensions of pedagogy (intellectual quality, quality learning environment and significance), which it believes improve student outcomes. The *NSW Model of Pedagogy* (see Appendix E) comprises three dimensions that possess traits in common with constructivism. Within the scale of 'intellectual quality' the pedagogy informs teachers that knowledge is actively constructed.

Intellectual quality is enhanced through pedagogy that is concerned with students acquiring deep understanding and knowledge, and that this knowledge and understanding are communicated and developed through substantive and various conversations. Within the scale of a 'quality learning environment' the *NSW Model of Pedagogy* (NSW Department of Education and Training (DET), 2003b) reflects a constructivist perspective requiring students to self-regulate and self-direct their learning and assessment. Collaboration between peers and teachers in the environment is encouraged and the necessary communication skills are developed and explained. What is required of the student is explicitly identified and discussed, further developing a positive relationship between student and teacher.

The third scale of 'Significance' considers the students' current knowledge and understanding taking into account school and personal experiences that may impact on the proposed teaching and learning activities. It recommends that real-world problems and settings be used in learning activities to bring relevance to learning and to create connectedness with the world outside of school.

In 2005 the NSW Institute of Teachers published the Professional Teaching Standards (Appendix F). The standards identify the domains of 'professional knowledge', 'professional practice' and 'professional commitment' that best describe the nature of teachers' roles and responsibilities. Further, the standards list many terms and concepts consistent with a constructivist learning theory. It speaks of - making knowledge relevant to students, the world outside of school, acquiring a deep knowledge of learners. The standards address the need to foster and value learning, acknowledge the diversity of cultural perspectives, provide authentic learning experiences and appreciate how students construct knowledge.

Taken together, the *NSW Mathematics K-6 Syllabus (*NSW Board of Studies, 2002*), NSW Model of Pedagogy* (NSW Department of Education and Training (DET), 2003b) and the *NSW Professional Teaching Standards* (NSW Institute of Teachers, 2005) are evidence of the significant influence that constructivism has and continues to apply to the direction of teaching in NSW public schools (Australian Government, 2014).

CHAPTER 4

NEGOTIATION OF MY CONSTRUCTIVIST PEDAGOGY

Introduction

This chapter reviews my established teaching practice and my struggle to plan a constructivist pedagogy as I engaged in discussion with my colleagues late in term 2, prior to the commencement of my constructivist teaching experiment in term 3.

The first section describes the physical layout of the classroom. In the second section, my established way of teaching mathematics is described. The structure and timing of a typical mathematics lesson is detailed. My expectations of student behaviour with respect to noise levels, seating arrangements and way of working are identified. I review my teacher-centred role and the manner in which I assessed and provided feedback to students. A largely behaviourist teaching approach is identified.

In section three, the ongoing development of my thinking about constructivist pedagogy is highlighted in my consultation with two colleagues as I sought their assistance with validating the Constructivist Learning Environment Survey (CLES) for use with my class. My attempts to identify possible problems that students might encounter when they respond to the CLES highlight my inadequate understanding of constructivist theory. New perspectives on the notion of constructivist teaching and classroom practices began to form as I continued to read the literature (see Chapter 3) and consult with colleagues.

In section four I present the pre teaching experiment CLES results. These results support my beliefs that my classroom is predominantly teacher centred.

In the fifth section my planned constructivist pedagogical strategies are addressed. As this was a shared classroom with my teaching colleague, Susan (the Principal), it was important to keep her advised of my plans. My interactions with Susan were based on two teachers sharing a class; and the Principal advising and consulting one of her teachers.

These different levels of interaction portray the developing nature of my constructivist pedagogy. I detail a scope and sequence for my planned teaching over terms 3 and 4.

In the sixth section I present an overview of the changes planned for the classroom under the headings of each of my constructivist pedagogical focus areas (see Chapter 3) and a brief description of what this will 'look' like in the classroom.

My personal reflections indicate that I was uncomfortable and uncertain about the implementation of the planned changes, and unsure of my understanding of the theory and practice of constructivist teaching.

My Established Classroom

My Year 4/5/6 classroom was equipped with an interactive whiteboard (IWB), which was located at the front of the classroom, adjacent to the standard whiteboard. Connected to the IWB was equipment that enabled operation of tele-conferencing facilities. The IWB was operated from the teacher's desk via a computer mouse and keyboard. At the back of the classroom sat five stand-alone computers for classroom use. The interconnecting computer laboratory (doorway located at the back left hand side of the room) contained 29 computers and a computer projector.

The classroom seating arrangement prior to the implementation of pedagogical change saw students sitting in pairs at rectangular tables in a horseshoe, conference style arrangement (Figure. 1). My desk was located adjacent to the interactive white board and formed part of the horseshoe seating arrangement. The student tables were arranged length ways around the room so that students on the outside generally had a student either side of them. Students sitting inside the horseshoe sat in pairs.

The students were given a plastic storage tub, which contained their text and exercise books, reading novel, pencil case and personal items. These storage tubs were placed in storage containers around the outside of the classroom along the wall behind my desk. Items required by the students for the day were removed from the tub and placed in their individual chair-bags.

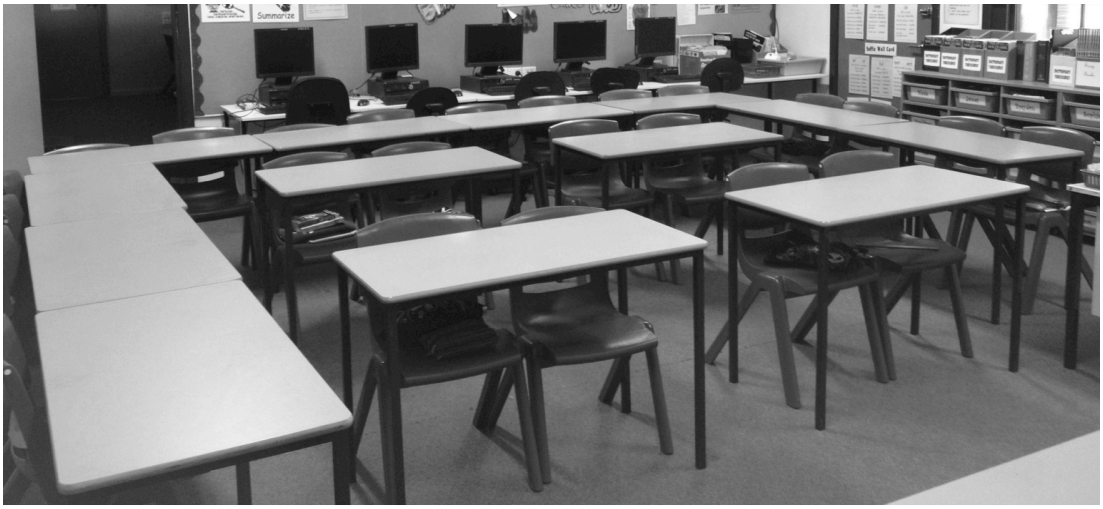

Figure 1. *My Year 4/5/6 Classroom Prior To Implementing My Constructivist Teaching Strategies*

The classroom had a variety of displays on the walls representing art and craft works completed by the students. There were no displays of student mathematical work or of any mathematical content around the room. The two opposite sides of the classroom were largely windows, which allowed natural light in. This reduced the amount of wall space available for displaying student work. As a result there was not enough wall space to showcase all key learning areas. The classroom was neatly presented and highly organised with all classroom resources labelled and housed in their appropriate places. Prior to my arrival in 2010, the Principal, Susan, shared the classroom with Ann, in the same work arrangement I now experienced. Ann now taught the Year 1/2 class. Ann and Susan were self-confessed highly organised teachers who shared a love of 'a place for everything and everything in its place'. Maintaining the classroom's physical organisation was to be one of my biggest challenges. Sharing a classroom with another teacher requires a great deal of respect for each other's work styles and work environments. I learned a lot from Susan about desk and room orderliness throughout my time in the classroom

A typical mathematics lesson

My scope and sequence for the teaching of mathematics was based on a commercial mathematics textbook. This textbook provided a term planner for the 4 terms of the school year, which satisfied all NSW syllabus requirements and outcomes.

Throughout terms 1 and 2, I delivered mathematics lessons using a traditional lecturing style. The lessons were consolidated with worksheets from the mathematics textbook that covered the concept being taught. At times a variety of mathematics textbooks were sourced to locate worksheets for classroom work and homework.

My mathematics lessons commenced with an initial input that was programed for approximately 10-15 minutes. After the introductory period the students were allocated work from their mathematics textbooks or I assigned other mathematics activities. In my Year 4/5/6 class, students operated from textbooks or worksheets that were aligned to Year 4, 5 and 6 outcomes. Prior to delivering my lessons, I reviewed the syllabus focus for students in stage 2 (Year 4) and stage 3 (Year 5 and 6). I reviewed the student textbooks and ascertained the focus in skills and knowledge that was being covered in each book. In my initial 10-15 minute introductory input, I presented the mathematical concept from a basic level (stage 2) and completed one or two examples on either the interactive whiteboard or the whiteboard. I instructed the Year 4 students to complete the set textbook pages or worksheets. No questions were accepted at this time as I wished to direct the students in Year 5 and 6 towards their work. I completed a few examples regarding the skills and concepts of the stage 3 (Year 5 and 6) level and allowed them to start their textbook or worksheet pages. Students were asked if they had any questions about the concept or activity they were required to do. Students continued their designated activities or tasks for approximately 30 minutes.

On occasions I directed students to computer-based activities. The web sites or software focused on the concept being taught and required students to watch a video explanation of the concept and/or asked them to solve questions that targeted the concept being taught.

Students were allowed to raise their hands if they did not understand something and needed my assistance. Students who experienced difficulties were provided with small-group or one-to-one assistance by me at the front of the room. I used manipulatives and concrete materials to assist the students to develop a better understanding of the concepts being covered.

I had a firm belief that manipulatives are an excellent resource for students to use in consolidating or developing their skills and understandings. In my later investigations about the nature of constructivist lessons I found that my established idea that concept development was aided by use of manipulatives, while considered conventional wisdom by many, may cause cognitive misunderstanding among students (Commonwealth of Australia, 2008). This report asks teachers to consider more critically the use of manipulatives, and presents extensive research that challenges teachers to reconsider their objectives for using manipulatives. However, this was not something I considered prior to this research. I had never critically considered the use of many resources. I came to ponder deeply many aspects of conventional teaching wisdom during this research.

The resources I made available in the room during mathematics lessons were multi-base arithmetic blocks, place-value mats, three-dimensional geometric shapes, one-centimetre grid paper, compasses (directional), dice and protractors. Most students brought their own calculators to class.

I encouraged students to work alone and insisted that most of each mathematics lesson be completed in silence. Computer work, related to mathematical games and problem solving, was rostered among the children, and I kept a record of who had been on the computer to ensure equity. Sadly, I didn't consider or research the value of these so-called mathematical games. Critically evaluating resources and strategies was not something I routinely completed as part of my professional practice. I seemed to outsource this and accepted rather blindly the conventional wisdom of other practitioners or marketing blurbs. Pleasingly, as my research unfolded, I was to change that position and seek understanding for myself about many practices that impacted my teaching and the learning environment. By the end of my teaching experiment I started to ask myself how a planned activity or teaching resource assisted students to construct meaning and understanding?

Throughout the lesson I circulated through the room, checking that students were completing their work and that they were not copying, talking or distracting each other. As I circulated I viewed, dated and initialled completed students' work.

A red X was used to indicate an incorrect answer and I asked students to rework the question.

A red tick complimented correct answers along with a verbal 'well done' or 'good work' comment to the student. Extension work was in the form of additional worksheets or harder questions were written on the whiteboard.

For the final 10 minutes of the lesson I conducted a whole-class review of the answers to all questions. I answered the mathematics textbook questions from each year group in turn. Students raised their hands if they wished to answer a question. I met each answer with a 'yes' or 'no' reply, or I asked the students to raise their hands if they also had the same answer. I then announced if this was the correct or incorrect answer. If it was an incorrect answer I asked for more student suggestions as to the correct answer to the question. I did not ask students to elaborate on how they arrived at an answer, nor did I have a whole-class collaborative discussion about possible answers to questions. I noted areas that required revision (many wrong answers) and attempted to address these with all students at a later time or recorded more generalised concept difficulties in my programme for when the concept was to be next addressed.

Each Friday I set a pen-and-paper mathematics assessment. This assessment involved students completing a times-tables quiz and solving a series of questions that focused on the concepts covered that week. I wrote these questions on the interactive whiteboard and students completed the questions in silence at their desks. I provided 3 sets of questions designed for each of Year 4, Year 5 and Year 6, as per the outcome requirements from the syllabus. Year 4 completed what I believed to be late stage 2 outcomes. Year 5 students answered questions from what I considered to be early stage 3 outcomes, and Year 6 completed what I believed were late stage 3 outcomes. Questions were generally an abstract view of the concept and did not relate to the students' out-of-school experiences. The mathematics textbooks also provided examples of questions that were appropriate for each year of schooling. Students were required to complete questions applicable to their year level but they could also answer 'harder' questions if they wished.

I corrected these assessments on the weekend and the students' score (usually out of 5 or 10) was recorded in an assessment book for tallying and referral at report writing time. I maintained a record of the students who did not perform well in the assessment (less than 50% correct) so that I could target them for specific assistance when next we visited the concept.

Taking My Developing Understandings To Peers

Prior to administering the Constructivist Learning Environment Survey (CLES) to the class, I had arranged a meeting (22/6/10) with two teachers at the school (Ann and Gavin). I asked them to look over the CLES survey and to question me about the dimensions and any other issues raised by the survey. I did this in an attempt to articulate my understanding of the dimensions so that I was well prepared to answer the students' questions should they arise. The following account of our discussion is based on my personal journal.

> The three of us meet in the Year 4/5/6 classroom where I show them the CLES that I am going to give the students. Both teachers look over the CLES and immediately identify three students that they feel might need further assistance in reading the items, but agree that if I read the questions out loud to the group there shouldn't be any problems with the students answering them.
>
> Gavin asks me about the CLES items which refer to students having a say in what they are doing, and where they are involved in planning lessons and being able to ask questions of the teacher.
>
> Ann adds her observation that theories of learning and teaching have been around for quite a while but they seem to be more fads than theory. "Fads come and go", she tells me, adding that she has seen many teaching innovations in her experience, but none ever seem to last more than a year.

“Good teaching is just that”, she adds. “You do what needs to be done in different circumstances. If they learn their times-tables by rote, then that’s a good thing. It is important to use sight words and have children recite them until they know them. But not everything is learned that way”.

I feel my ‘epistemic dualism’ rising. Yes, I too believe in rote learning some things. But isn’t that banned in constructivism? I am sure it is. I am not sure how constructivism stands with rote learning and now I am not sure where I stand with rote learning. Am I for it or against it? Where does it fit with my pedagogical change? I suddenly start to feel underprepared.

“We did all this at uni”, Gavin explains to me. He goes on to detail how university students sat in large halls and listened to lecturers speaking for an hour about how the preferred lecture style of instruction was not the best way for people to learn. Gavin is concerned about the ‘critical voice’ questions in the survey. He asks me if I can truly give students a say in what to learn? “We don’t get a say ourselves, so how can we give them a say. It’s all there in syllabus documents, and I’m not sure you can tell people exactly how they should teach in their room”.

I talk about the syllabus providing some direction for teachers, but that we have a say in how our class operates, and besides that, research tells us that kids learn better if we involve them more in the learning process. Gavin queries whether I am happy for a child to question me about my teaching, asking me why they have to learn or do things in the classroom. We discuss politeness and the way in which a student might say that to a teacher, but Gavin points to CLES items 3 and 8 (Critical Voice scale) and says that he is not sure if it is appropriate for children to ask this in the classroom setting. Come to think of it, neither am I.

“We have parents telling us what to do and they have no formal training in teaching”, offers Ann, eager to point out that the teacher is stuck in the middle of so many forces, that teaching often can be the last thing going on if we don’t take full control of the room and what goes on in it.

Ann and Gavin ask me for some concrete examples of exactly how I am planning to change my classroom in order to implement these constructivist practices.

I fumble around trying to put constructivist theory in a simple nutshell but am unable to coherently do that. I offer group work activities as an example of a change I am planning to make along with getting the students to write in learning journals. However, I feel that I am letting von Glasersfeld down with my shallow offering to Ann and Gavin of what constructivism could mean to the students. I seem more certain about what I intend to do but not about the rationale for doing it. Yeah, I have the students in groups Gavin informs me, and Ann confirms that arrangement in her class as well. A sinking feeling wells inside of me.

Gavin asks me if I am going to go home on the weekend with the students to help plan classroom learning activities with them. When I light-heartedly tell Gavin that he was taking it too far, he asks me when I am going to plan the teaching units with the kids in each subject. He reminds me that teaching programs are usually planned in advance and then viewed by the Principal. Both teachers remind me of the existing extensive workload of teaching. They point to how hard it is to get through what we are already planning without then meeting with students to see what they want to do. I raise the point of the students being the centre of what we do, and we all agree on that.

Both teachers are genuinely interested in how I can achieve all that this survey seems to imply with planning, assessing and implementing, and with student input so evident.

They believe doing all that the survey suggests is expecting far too much of them. I am unable to allay their concerns. At this point, I have lost my own understanding of what constructivism means to my pedagogy and to me. I thank the teachers for looking over the CLES and for their thoughts on the pedagogical change implied by constructivism.

(Personal Journal, 29/6/10)

At the conclusion of our discussion I felt that I was unclear about what constructivism meant and what it looked like in practice. The CLES scales were vague to me and I seemed to read them like a science fiction book, where I could appreciate and enjoy the story but not really expect it to ever happen in my world. The two teachers wondered how all the 'new stuff' could be achieved in today's already crammed curriculum and time deprived school day.

Their fears of a pedagogy expecting more of me echoed Cohen's (1988) warning that this pedagogy does ask more of a teacher (see Chapter 3). My personal journal entries (29/6/10) -"What does the first principle of constructivism really mean? What does it mean when someone constructs knowledge?" - reflect the view that I needed a greater understanding of the theory before I could go any further. These questions about the meaning of constructivism led me to "find some constructivist lessons that I can use in the classroom" (see Chapter 3) (Personal Journal, 29/6/10). My need for some discrete teaching practices, irrespective of the manner in which they are delivered, confirms the warnings of Richardson (2003) and Windschitl (2002) about teacher's having an absence of epistemological understanding of constructivism as a learning theory. I was attempting to outsource my pedagogy to a web search seeking a list of constructivist activities and lessons to enact in my classroom.

A Measure Of My Established Classroom Learning Environment

For the purposes of transforming my mathematics pedagogy I had identified three teaching experiment pedagogical focus areas: (1) a collaborative learning environment to encourage meaningful communication between the students and me; (2) learning activities that are relevant to students' real-world experiences; and (3) assessing students' developmental learning (formative and summative) by means of teacher-student interviews, learning journals, peer-mediated discussion, performances, and physical constructions (see Chapter 3).

My early concerns about my inadequate understanding of the five Constructivist Learning Environment Survey (CLES) scales – *personal relevance, student negotiation, critical voice, uncertainty, shared control* - resulted in my desire to better understand their practical application in my mathematics classroom.

Reading the research literature on the design and use of the CLES helped me to recognise a close relationship between the five CLES scales and my three constructivist focus areas (Aldridge, Fraser, Taylor & Chen, 2000; Taylor, Fraser & Fisher, 1997; Taylor, Fraser & White, 1994).

The first pedagogical focus - building a collaborative classroom environment that encourages meaningful discussions between myself and students - is directly associated with the CLES dimensions of 'Critical Voice', 'Shared Control' and 'Student Negotiation'. Notions of effective communication between students and between students and the teacher are evident within these dimensions. Expressing opinions, negotiating social norms, co-designing the learning environment, sharing viewpoints and presenting ideas to others are all characteristics found within the descriptions of these dimensions and are clearly related to my desire to develop meaningful communication.

The second pedagogical focus - presenting activities that are relevant to students' real-world experiences - is associated with the CLES scales of 'Personal Relevance', 'Mathematical Uncertainty' and 'Student Control'. These dimensions are characterised by connectedness to students' everyday out-of-school experiences and values, understanding that mathematical knowledge is evolving, and joint planning of students' learning experiences.

My third pedagogical focus - constructivist assessment - relates to the CLES scales of 'Personal Relevance', 'Shared Control', 'Critical Voice' and 'Student Negotiation, which are characterised by joint student-teacher co-constructions in planning assessment, moving beyond rote-recall of rules and laws, and critically questioning the manner in which student assessment is developed.

As discussed previously (see Chapter 3) and prior to the introduction of my planned constructivist teaching experiment, which was scheduled for the commencement of term 3, I administered the CLES (i.e., CLES 1) to both the class and myself. The questionnaire was completed in the final week of term 2, and the results (see Appendix G) provide a quantitative overview of the existing learning environment of my mathematics classroom.

These results suggest that my typical mathematics lesson had a strong behaviourist orientation (see Chapter 3 for an explanation of this concept).

It is evident that both the students and I assessed each constructivist scale – *personal relevance, mathematical uncertainty, critical voice, shared control, student negotiation* – as occurring relatively infrequently in our mathematics classroom (i.e., as indicated by mean scores less than 3.0). These results did not surprise me. The results confirm the largely teacher-centred nature of my established pedagogy; an assessment of the classroom learning environment that I already had already arrived at through self-evaluation of my teaching and learning activities and the dimensions of the CLES.

At that time; however, I did not use these results in a substantive manner to plan my constructivist teaching strategies. I noted only that the constructivist learning environment scores were very low and that the class and I shared similar perceptions.

My Planned Pedagogical Changes

I used the time after my meeting with Ann and Gavin to consider what constructivism meant to me and to my classroom teaching, and I felt confident as I prepared for a meeting with the school Principal. During the final week of term 2 (2/07/2010), I met with the Principal (Susan) to discuss my proposed research for terms 3 and 4. Susan's office was located in a separate building from the classrooms, and adjoins the staffroom and administrative staff offices. Educational publications, NSW Department of Education and Board of Studies documents were neatly presented in the large bookcase next to her organised but 'busy' desk. The walls of her office displayed departmental policies, school planners, school rosters, children's work samples and 'quality teaching' posters advocating best practices in teaching and pedagogy. Susan invites me have a seat as we discuss the planned classroom changes.

> Susan informs me that she will be taking long-service leave commencing week 6 of term 3 until week 8 of term 4. She advises me of the appointment of acting Principal (Bill) over that time and assures me that she has discussed my proposed research with him and that he is very keen to assist in any way he can. He has indicated that he will support the arrangements worked out by Susan and me and is happy to meet me on a regular basis.
>
> Susan explains that she has a keen interest in the theoretical underpinnings of the constructivist approach and we have a brief conversation about constructivism, culminating in Susan asking me how this will look in our shared classroom. In reply, I identify the key points that I would like to concentrate on.
>
> I explain to her that I hope these key points will assist me in implementing constructivist practices and hope they will develop a more constructivist learning environment. Specifically, I identify putting the students' tables together into small groups in an attempt to develop collaborative work. (see Chapter 5) (Interview, 2/07/2010).

On reflection, I note with some interest that at this crucial point of our discussion I opted to provide Susan with an action that I was going to implement rather than advise her of the overriding goals I had identified. The notion of collaborative work created through a change of seating was my first foray into constructivist reform. In hindsight, my first planned pedagogic change of rearranging the desks in the hope that collaborative work would spring forth seemed more hopeful than strategic. Susan pointed out that the students seemed happy with the present seating arrangements but that she was happy for me to make the change if it assisted my teaching and the research.

> As we continue our discussion, I present to Susan my initial goals of building a collaborative classroom environment, engaging in meaningful discussions between students and myself, and presenting activities that are relevant to students' real-world experiences.

> I advise Susan that I am developing a different assessment practice to the usual Friday assessment. I inform her that I have nothing concrete to share with her at this stage and will continue with my current assessment practices until I have researched this aspect further. However, I express to Susan that my review of assessment practices will involve asking the students how they think they should be assessed.
>
> I show Susan further examples of my proposed changes including minimal use of worksheets and textbook, rotational activities using the newly created groups, students' mathematics work samples displayed around the room, greater use of the school's mathematics resources, a desk at the front of the room to display mathematics resources, and student reflective journals for use after mathematics lessons. I tell Susan that it is through these changes that I hope to develop my stated goals for the classroom and that they represent my view that these specific actions will be the vehicle by which I can achieve my goals. (Interview, 2/07/2010)

The issue with textbooks and worksheets addresses the possibility or likelihood of them not necessarily being at the students' current conceptual understanding. Further, they may not be of sufficient interest to students to make them a worthwhile activity, nor did they present multiple viewpoints of mathematics.

The texts often did not approach students with real-world experiences nor present real-world contexts. I wanted to show greater appreciation of the student's mathematical work and also make their environment more relevant to them by displaying their work around the room.

> Susan agrees that all proposed changes sound positive for the class and for learning. We discuss the students' need for more reflective practices and how a journal could satisfy this educational and developmental need. However, Susan notes that the use of a textbook across the school provides a comprehensive approach to curriculum planning and reduces the possibility of content gaps between years or stages.

Susan does not advocate students working only from textbooks, but she believes it provides a focus that can be adapted by a teacher for student needs and that textbooks allow students to access a concept at their level and provide examples for students to use for concept consolidation, both at school and at home. She asserts that textbooks provide a focus approach to the teaching of mathematics. She explains that when she left the room for the three days, the replacement teacher knew where students were up to, and what concept is being covered.

Further, unplanned absences are more easily accommodated for a replacement teacher, as they only need to open the textbook to know where the students are up to and how well they are coping with the concept.

Textbooks from grades or stages above and below any particular year level could also be used for students who are currently below or above expected conceptual development. Susan explains that if the concept being addressed in the book is not, in the teacher's opinion, a worthwhile activity, then it can be skipped and supplemented with something else. This is a professional judgement call made by the specific teacher concerned.

Additionally, Susan believes that students can take home their textbooks and allow parents to become involved in their child's current mathematics work. Nevertheless, my naïve belief at this stage is that a pedagogy that is reflective of constructivism has no place for textbooks and worksheets.

Susan indicates to me that she wanted me to continue to focus on the measurement sub-strand of mathematics. This focus had been identified by Susan and the staff prior to the commencement of term 1 based on previous NAPLAN results and school assessments. She reiterates that the students from the Year 5 and Year 3 classes of 2009 had not performed well with respect to the measurement questions; in each of the four measurement questions at least 75% of the students answered the questions incorrectly.

> Susan feels that it would be beneficial to the students and school if measurement remained a focus of the class for terms 3 and 4 and that a different teaching approach might yield improved student results in measurement
>
> Susan directs me to the N.S.W. mathematics syllabus support document, '*Teaching Measurement: Stage 2 and Stage 3*' (NSW Department of Education and Training, 2004), '*Teaching Measurement: Early Stage 1 and Stage 1*' (NSW Department of Education and Training, 2003c) and '*Teaching Angles: Stage 2*' (NSW Department of Education and Training, 2003d).
>
> She feels that these publications will provide guidance for me in the development of a constructivist learning environment according to the theoretical guidelines of constructivism. These documents present conceptual development of increasing difficulty through six levels and allow for all students to engage in the activities at an appropriate level. She argues that through sustained and thorough use of these support documents their strengths can be identified that will be of benefit to other teachers who wish to use the resources. Susan indicates that at times schools 'forget' about great resources that are available to teachers. (Interview, 2/07/2010)

It was apparent to me that Susan had a strong appreciation of the benefits of a collaborative team approach. The benefits of the collaboration between the Principal and me were significant, as I was previously unaware of these important and helpful syllabus support documents. The support documents provided a wide-ranging source of activities within the measurement strand. These support documents suggest the physical involvement of students in measuring parts of their bodies or using their bodies to create measurement units. They require the use of a range of hands-on resources from the school's resources storeroom to engage the students actively in concept investigation.

The activities were designed for small-group rotations or whole-class investigations and presented the possibility of 40 activities in Stages 1, 2 and 3 within each sub-strand of measurement (i.e., length, mass, volume/capacity, area and angles). Mathematics lessons initially introduced the relevant mathematical concepts with a variety of activities that allow students to rotate with a degree of choice.

These activities were designed to engage each student at all levels and to provide assessment concerning the student's current conceptual development that enables the appropriate selection of learning activities for subsequent lessons.

The aim of the lessons was to allow students to move through core activities that permit widespread participation in whole-class discussion. These core lessons provide opportunities to assess the students' conceptual understandings and to provide guidance for subsequent learning experiences. The initial activities present mathematics in a fun, hands-on approach, with many activities requiring work to be completed outside of the classroom. Each of the sub-strands of the measurement strand is to be completed over a three-week period.

Table 2 below provides an overview of the scope and sequence for my teaching of mathematics over terms 3 and 4, and a plan that was largely maintained with very few changes (see Chapters 5 and 6). Taking into account the desired focus on the measurement strand and the activities in the support documents, Susan and I jointly constructed the scope and sequence. The last week of teaching a sub-strand was the initial introduction of the next mathematics sub-strand. An optional major activity was set for students to complete in the final week of teaching a particular measurement sub-strand.

Table 2. *Term 3 and 4 Mathematics Scope And Sequence*

TERM 3	TERM 4
Week 1 – 3 Length / Fractions Review ❖ equivalent fractions, decimals ❖ length in cm, m, mm	Week 1 – 3 Angles/Length ❖ features of 2D shapes, angles ❖ length in cm, m, mm ❖ perimeter, distances
Week 3 – 5 Area ❖ cm2, m2, mm2 ❖ informal units ❖ walls, floor	Week 3 – 4 Fractions and Decimals ❖ - + fractions, convert decimals, percentages ❖ equivalent
Week 5 – 7 Volume and Capacity ❖ difference of terms ❖ informal measurements ❖ displacement ❖ litres, capacity, cm3, m3	Week 4 – 6 Mass ❖ kgs, grams, tonnes ❖ mass vs volume ❖ formula
Week 7 – 9 Mass ❖ mass vs volume ❖ measurement instruments ❖ informal units- paces, hands	Week 6 – 8 Volume and Capacity ❖ prisms ❖ displacement ❖ litres, informal units ❖ formula
Week 10 Review of the covered activities	Week 8 - 9 Area ❖ area of triangles, rectangles, squares, irregular shapes
MAJOR ACTIVITY Week 3 – Body measurements Week 5 – Space Shuttle scale model Week 7 – Complete quote for the painting and re-carpeting of the Year 4/5/6 classroom or Calculate the volume of rubbish generated by the school that week Week 9 – Identify ten animals of different masses and size and research mass of each, quantity of food needed for each	Week 10 review Week 1-3 Local Triathlon Course

As we conclude the meeting, Susan notes that the ideas and strategies I have presented regarding constructivism are potentially beneficial to all students and that this could be an area for all staff to be made more aware of. I indicate to Susan that I was happy to provide readings for all the staff on constructivism as it relates to school education, a suggestion that Susan is very happy to see enacted in a staff meeting in term 3. (Interview, 2/07/2010)

Although beneficial in many ways, the meeting with Susan left me with a feeling of uncertainty about what I was attempting to do. My personal journal indicates my anxiety about my theoretical knowledge of constructivism and epistemology. This was a similar feeling to the one I had experienced as I discussed my planned pedagogical change with Ann and Gavin.

I had been able to advise Susan of my goals and some actions that I believed assisted me in achieving these goals; however, I didn't feel that I was thoroughly prepared for what lay ahead.

In my journal (2/7/10) I wrote: "Should I consider how to implement a lesson influenced by constructivism or just look at pre-prepared constructivist lessons? What is it that I need to do before and during these lessons to be constructivist?" I began to consider deeply exactly what is meant by the term 'constructivism':

> Knowledge not being passively received but actively constructed (von Glasersfeld, 1989) is a concept that starts to slip from my grasp. What does this mean to a teacher? What does this principle mean for the changes that I propose to make in the classroom? If constructivism assists learning then should we not in our own learning be using the principles of constructivism? The approach from the Principal in modelling how we all can learn through professional interaction and further develop our skills and knowledge is both a show of faith in current theories of learning and also an example of how it can be enacted in our professional lives. (Personal Journal, 2/7/10)

At that time, I felt as though my understandings of the theory behind constructivism were superficial as I had trouble clearly expressing to Susan the theory behind my proposed pedagogic changes.

The concrete foundations on which I had set my research goals seemed to be starting to crumble. As I prepared for the pedagogical change in the two-week break between terms 2 and 3 I recorded in my journal.

> But what is a constructivist lesson? What makes a constructivist lesson just that? Are there constructivist lessons out there or do I have to create them? (Personal Journal, 12/7/10)

I made a note in my journal to search the Internet and relevant databases for the terms 'constructivist lessons'. From the first days of my planned pedagogical change, doubts about my understandings began to creep in. I continued to have a desire to find the ideal constructivist lesson that I could implement. It was very much like the notion of truth for the positivist. I was looking for the constructivist lessons 'out there' waiting to be discovered and to then implemented it in the classroom.
I seemed unable to move past the lesson content in order to focus on pedagogy, or how the lesson was to be delivered. Contrary to the warnings from the NSW Department of Education and Training (2003, p. 4) regarding the meaning of pedagogy, I was separating 'what' one teaches from 'how' one teaches, leaving the 'how' to the results of an online search engine. My journal again reflects this view:

> I have what appears to be a weak conceptual understanding of constructivism. (Personal Journal 14/7/10)

Understanding constructivism in a shallow way caused later problems for my pedagogical change. It was apparent to me, as I reviewed my journal entries, that I moved from certainty to uncertainty quite often throughout the ensuing two terms. My journal shows times of great confidence in what I was doing and the way I intended to implement changes. On other occasions; however, I seemed confused about what I was meant to do and how I implemented changes.

My Constructivist Pedagogy

In this chapter I have reviewed the process of negotiating my constructivist pedagogy. The discussions I held with my colleagues was helpful in identifying issues and difficulties raised by my proposed pedagogical change. I was at times challenged by the views of my colleagues and left to feel unsure of my own understandings of constructivism.

Susan provided insight and encouragement as I formulated a plan to implement the changes in the classroom and necessitated the identification of my initial focus areas strategies that I proposed to use in implementing the planned change. This process was a refinement to the general overview I had developed. Notwithstanding my naivety and confusion regarding constructivist strategies, I was confident that my three focus areas provided a strong foundation on which to base my planned changes. In summary, my planning for the initial stages of my pedagogic change focused on three areas:

Collaborative learning environment and meaningful student communication

- Students to work in groups
- Rotational cooperative learning groups for mathematics.
- Student journals
- Student interviews

Real-world experiences

- Use of resources that are from the real-world of the student
- Use of questions and scenarios from the real-world
- Activities/tasks that take an extended time to complete
- No text books

Constructivist assessments

- Formative assessment as students work in rotations – listening and observing students in learning groups

My constructivist pedagogy focus areas (see Chapter 3) provide insight into my understanding of a constructivist perspective. Certainly, an argument can be raised to keep changes small and manageable (Taylor, 1996), and my focus areas provided me with a clear and concise pathway for what I believed to be small but achievable change. The scene was set for the commencement of term 3 and the implementation of my plans for pedagogical change.

CHAPTER 5

THE TEACHING EXPERIMENT - TERM 3

Introduction

The implementation of my constructivist pedagogy was a difficult and at times counter-intuitive process. The various facets of constructivism and their implications for my teaching began to unfold before my eyes and before the eyes of my students. Indeed my developing understanding of constructivism as a pedagogical referent, rather than a teaching cure-all, also revealed itself through my personal experiences and on-going scholarly readings. In this chapter each of the identified focus areas (see Chapter 4) and the evolving results of pedagogical change as they occurred in term 3 are presented and discussed. This chapter provides vignettes and excerpts from student and teacher journals that provide rich, thick description of the classroom environment and interactions.

I present in this chapter my experiences in implementing my constructivist focus areas - developing meaningful communication, providing real-world learning experience and constructivist assessment practices. The pedagogical focus areas represent three interwoven strands that co-occurred during term 3. In this chapter I have separated out each focus area and analysed and reflected on the students' and my experiences in each focus area. The sequential presentation of the focus areas does not imply a chronology of events.

The first section focuses on my attempts to create a collaborative learning environment and develop meaningful communication, which were significant pedagogical changes. Creating a collaborative learning environment contributed to development of meaningful communication between students and between the students and me. Naïvely, I initially believed that simply placing students in small groups created a collaborative environment. Equally naïvely, I believed that meaningful communication was more a student responsibility than a teacher consideration, and that it was enhanced simply by assigning students to small groups.

The second section focuses on the development of activities that represent a real-world context for the students. My initial strident desire to keep textbooks out of the learning environment is discussed. Real-world activities enabled students to begin to show initiative in their use of resources and in their explanation of methods of approach to problem solving. The classroom slowly became less teacher focused and more student focused. The interrelatedness of meaningful discussion and real-world contexts is highlighted.

The third section focuses on constructivist assessment. The difficulties I initially faced in leaving behind my well-established summative assessment tasks are identified. Constructing an environment that asked for and listened to student views assisted me with pedagogical change. I was to slowly realise the value of informal formative assessment through the establishment of group work, and this assisted me in breaking my behaviourist shackles. The thoughts and ideas of students showed graphically that I had been ignoring their valuable input. This section presents the start of this change.

The fourth section is a reflection on my experiences in term 3. My journey as a teacher with a behaviourist epistemology who started moving towards a constructivist epistemology and subsequent pedagogy is discussed and provides the setting for the further development of a constructivist classroom learning environment in term 4 (see Chapter 6).

Creating A Collaborative Learning Environment And Meaningful Communication Through Group Work

My focus in the period between the conclusion of term 2, 2010, and the commencement of term 3, 2010, was predominately on the group-seating arrangements for the class and how this was organised within the classroom. Little consideration was given to the structure of lessons in mathematics as I planned to closely follow the support document '*Teaching Measurement: Stage 2 and Stage 3'* (see Chapter 4), which provided extensive lesson plans and details.

The students experienced my initial pedagogical change through new classroom seating arrangement which I believed reflected a collaborative learning environment for developing meaningful communication. The previous conference/horseshoe style seating (see Chapter 4) was substituted for a permanent group-seating layout. Year 4, Year 5 and Year 6 students were arranged into separate groups within the classroom (see Figure 2). These seating arrangements were implemented prior to the students' arrival on day one of term 3. The impact of the changes was obvious from the start.

Figure 2: *New Seating Arrangement - 3 groups.*

The morning assembly bell rang bringing the students to their class lines on the covered playground area. After the welcome back messages from the Principal and the usual house keeping notices, classes were dismissed ready to enter their rooms, ready for another exciting term of learning. My Year 4/5/6 class was asked to stay in their class lines and await further input from me. After greeting the students and receiving a warm reply, I announced to the class the new seating arrangements for the classroom. I explained that there was a Year 4 group, a Year 5 group and a Year 6 group, and that the desks were pushed together in a rectangular fashion. The large grouping was for the Year 6 students and the smaller grouping was for the Year 4 students. Year 5 students were to be seated at the remaining desks. My personal journal records the reaction of the students that day (20/7/10):

> "WHAAAAAAT!" is the almost unanimous response from the students as they sit on the ground looking at me and then turning to see the look of anguish on the faces of their peers.
>
> "Why are you doing this", seems to be the utterance of almost all students who are not lost for words.
>
> "Well", I respond, "you will be able to choose who, within your year group, you would like to sit with".
>
> The students turn to each other then to me and then back to their class friends. Heads shake in disagreement or perhaps in shock. I attempt to calm the students by telling them not to be concerned. However, this does not seem to ease their anxiety about the proposed change (Personal Journal, 20/7/10).

My response to the 'whys' and 'what fors' of the students was quite simple. I ignored any further protestation, assured them all that this was how it was going to be and asked them to forward in and take their seats. My first constructivist move was enforced from a behaviourist perspective that this was to be the new social reality, and I was simply transmitting the reality to them.

Student input, control or negotiation were not aspects of a constructivist learning environment that I allowed to impede my transforming pedagogical direction. Or was it simply that I had not understood the true meaning of student input, control or negotiation? At this early stage constructivism was not being used as a 'referent', a theoretical term whose definition I knew but application of which was sadly absent from my plans (see Chapter 3) (Lorsbach & Tobin, 2005; Tobin & Tippins, 1993).

I allowed the students 10 minutes to organise their seating within groups. This was, in most cases, begrudgingly accepted. Students seemed to be able to sit next to a friend; however, they complained about not being able to manage sitting next to all their friends, some of whom were in different grades and therefore at different desks. Initially, I attempted to have all Year 6 students in one group; however, the size of the group ultimately led to the creation of two Year 6 groups, and a total of four groups (see Figure 3).

Figure 3*: Revised Seating Arrangement – 4 Groups.*

These seating arrangements - one Year 4 group, one Year 5 group and two groups of Year 6 students - remained for the rest of term 3. The students did not greet this arrangement with enthusiasm.

Nearly all students seemed to feel that the original (horseshoe) seating was the better arrangement. Journal entries of the students indicated that, of the 16 students who commented upon the new seating arrangements, 15 were negative and one was positive. Negative comments reflected a feeling amongst the students that they were not consulted about the changes, and their journal entries of 27/7/10 (week 2, term 3) reflected their concerns.

Sammy (year 4) *- I don't really like the idea of moving. I was OK with my old seat. I didn't get a say in this. It's not fair. I hope Miss A (the Principal) will let me move back.*

Brie (year 5) *- I am on a desk with Year 5 students. I don't like being away from my best friend and I'm now on the side with all the boys. Some people get what they want and others don't.*

Milly (year 6) *- I had to move, it sucks at first but then I got used to it a little now but still liked my old seat. It's OK ….NOT. But I want my old seat back.*

Thomas *- We had a big argument where we sit in group and we all had to move a lot and Year 6 had to be in 2 groups and I hated it because one person didn't want to be in the group and it was difficult and I hated it so much.*

Nathan (year 4) *- I have to sit with all the year 4 people and I'm the only boy in year 4. I don't think the way the tables at the moment because I have no one to talk to and I'm really bored. I have no friends near me.*

Kate (year 6) *- We all have just had a massive fight about moving seat. There was one person that was not happy so now we have to sit with people we don't particularly like anyway. I have a feeling this not going to work in the end. I HAVE A BAD FEELING ABOUT THIS.*

Madison (year 5) *- I don't like the desks where they are because you don't get to sit next to your friends.*

Follow-up interviews in the next week (3/8/10) with these students as a group confirmed their feelings of not being able to decide where and with whom they sat. I later read (Davis & Sumara, 2003) that many students feel that this type of seating serves more of a social outcome than an academic one. However, my students seemed to be upset more about the enforcement of the seating than whom they were seated with. When they responded to my question of what they didn't like about the groups, students suggested that it would be better if they had chosen them and had not been forced into their groups.

Sammy (year 4) *- I was happy where I was and you didn't ask me, why did we have to move anyway?*

Teacher *- I thought you might work better with all the other Year 4 students rather than just with the one student you were sitting with.*

Sammy (year 4) *- But some of them I don't like and don't talk to. Can Mrs. A move me back? (Mrs. A is the Principal that I share the class with).*

Teacher *- I would like to see you working with more people and so would Mrs. A. I think this will be better for you so can you give it a bit longer to see how it goes?*

Sammy (year 4) *- OK, but it won't work.*

Kate (year 6) *- Why is it that friends can't sit together? If people don't get along then move them to other seats but leave the good workers alone. Today was good (group work in Maths) but that was the fun stuff not the group.*

Teacher *- You might make more friends and find that you work really well with others too?*

Kate (year 6) *- But what if I don't, what if I have trouble and you don't understand stuff because of them?*

Teacher *- Could you try the arrangements for a little bit longer? You know how I said I was changing things so that the class might be even better at learning?*

Kate (year 6) *- No, you said other stuff but not sitting differently. I don't like this. When can we go back?*

Teacher *- At least until the end of term, Kate, then we can look at it again. Ok?*

Kate (year 6)*- Hmmmmm.*

All the students interviewed expressed a dislike of moving, and they especially took exception to the move not being discussed with them or decided without their input. My subsequent review (later in term 3 and term 4) collaborative work within a constructivist learning environment led me to believe that, at that time, I held a superficial (or developing) understanding of collaborative learning. Student concerns about seating arrangements caused me to seek guidance on the notions of collaboration through scholarly readings. My idea that collaboration in the classroom equated with group work slowly evolved and developed into a more sophisticated understanding of the concept (see Chapter 6).

Student perceptions of the new seating arrangements became more positive as the term progressed. Student journal entries reflected a growth in their understanding, or meta-awareness, whereby they critically reviewed their relationships with others in their learning experiences within the learning environment. This seemed to be a result of working in these groups:

Bronwyn (year 6) *- All of the group helped me with my work today. I learnt how to estimate and I thought the group worked well together and it was better than I expected (Student Journal 4/8/10).*

Kate (year 6) *- I think the group thing isn't as bad as I thought it would be. It's getting us to work together and help each other. It's great now. I have learnt heaps about m cm mm (Student Journal 4/8/10).*

Ben *- People in our group have helped me to understand stuff (Student Journal 22/910)*

Brie (year 5) *- Milly helped me and so did the group. I think that working in a group is better than being independent in maths because other people say different theories and you can prove them (Student Journal 22/9/10).*

Group work operations

I initially planned for the class to operate as 5 separate learning groups based on their year level. The mathematics learning group operated as one Year 4 group, 2 Year 5 groups and 2 Year 6 groups. Year 5 students, whose desks faced each other, were able to operate as 2 groups of four within one larger seating arrangement.

It was important to provide the mathematics learning groups with tasks and activities that supported my focus on meaningful communication and collaborative group work. The planning for the learning group activities was drawn from the NSW mathematics syllabus support document *Teaching Measurement: Stage 2 and Stage 3* (2004) (see Chapter 4). An example of the various group activities is presented in Appendix H. Using this syllabus support document I designed a mathematics program that involved the students moving through a series of task-oriented activities in their learning groups.

The learning groups used a reciprocal teaching strategy (see Chapter 3) to manage the learning task requirements and report back to the whole class at the conclusion of the lesson. My role was to introduce the topic or lesson for a short period of time, present some examples, answer any questions from the students and have the groups work cooperatively on the tasks. Learning groups moved through each of the activities over a two-week period. The final ten minutes of each lesson was a whole-class sharing opportunity.

Within particular mathematics sub-strands (e.g., volume, mass) I developed three activities (one for each year group) that covered content, skills and understandings from the stage 2 and 3 mathematics syllabus. Additionally, an Internet research activity, focusing upon the concept being covered, was included in each session.

The learning activities provided me with information about student conceptual development and served to inform my planning of subsequent activities. My planning of activities developed to the point where I prepared up to eight activities for each content area across stages 2 and 3 of the syllabus.

In these early stages, when I planned activities for subsequent lessons, I too often selected activities for whole groups based on the observations/comments or conceptual understandings of one or two students within a group.

This resulted in me focusing on the movement of groups through particular activities rather than the allocation of activities to particular students. This changed as students took more control of their learning and requested particular activities to work on (see Chapter 6).

While students were involved in the mathematics activities I obtained evidence (audiotapes, personal journal and observations) of task-orientated discussion between students and with me as I moved around the groups. My audio recordings of the mathematics group work throughout the third term recorded students with happy and task oriented voices actively engaging in mathematical tasks and task-focused interactions with the other students. I have few records of students being off-task or not working towards the goal of the lesson or group work, as was found by Davis and Samara (2003).

Exceptions were Jeff, Toni and Madison (Year 5 students) who had difficulty remaining on-task for the period of the learning group investigations. Similarly, they did not engage with their learning journals (see this Chapter). These students raised with me issues regarding group work that centred on personal relationship problems with other group members. It was these relationship problems that seemed to distract them from effectively engaging in cooperative or collaborative work. These observations are similar to those experienced by Davis and Samara (2010) and Windschitl (2002), which ultimately led to a reduction in learning opportunities as student learning was negatively impacted by social factors and histories. Nevertheless, these three were the only students who came to my knowledge as having their group learning experiences affected in this way. An interview with these students (Interview, 21/8/10) provided some reasons for their reluctance to share within their groups:

Teacher - *Do you like working with others in a group for mathematics?*

Toni (year 5) *– I don't like asking others. When I do maths I get this thing in my head saying I can't do this. I get butterflies in my tummy and get goose bumps. I feel dumb.*

Toni seemed to equate working with others as having to ask others for help. As Toni was a student who was not achieving at her year or stage level, she seemed to have a concept of group work as being publicly made to feel inferior. Jeff expressed concern about how he was viewed in the group, as he too was not achieving outcomes for his year or stage level:

Teacher *- Do you like working with others in a group for mathematics?*

Jeff (year 6) *- Yes, but sometimes I like to work alone. And sometimes I like to work in a group. When it gets hard I don't like it and I feel stupid because I don't know anything and they do but that doesn't help.*

My interview with Madison highlighted social aspects of group work and negative dynamics that can emanate from relationships:

Teacher *- Do you like working with others in a group for mathematics?*

Madison (year 5) *- No. I hate having to deal with Leigh. People say I ask for it but she comes near me and says names to me or at me so I say it back.*

Teacher *- Do you work well with the others in your group?*

Madison (year 5) *- Yes but I'm always fighting with Leigh and I hate working with her.*

Madison was clearly agitated by the prospect of working with a particular student and found it a difficult situation to deal with. Her work within the learning group was at times productive but more often than not she stopped the group's work as she dealt with a social incident that had occurred earlier in the playground.

Leigh and the rest of the group were able to move on without her; however, the distractions and upheavals often caused the group's enjoyment of the activity to diminish. After a subsequent meeting with Madison I moved her to the other Year 5 group while I attempted to work on developing in these students more effective ways to deal with their frustrations and upsets.

However, there still remained times when members in Madison's new group told Leigh that they wouldn't play with her at lunch time in fear of Madison's retributions.

This presented a challenge for me that encompassed all of school life rather than just those components of the constructivist learning approach I was implementing. My answer to the problem was to move Madison to another group. This approach changed in term 4 as I included the students in my decision-making and sought their input on where they worked best in group situations. However, at this point I believed that it was my role to find a solution without consultation with the students.

Madison portrayed how classroom learning activities are filtered through social experiences in this environment (Davis & Sumara, 2003). I learned later in term 3 that it is through the recognition of problems that may impact group work within the classroom that strategies can be implemented to alleviate negative aspects (Windschitl, 2002). Skill development of the students is important so that their feelings and backgrounds are accepted and appreciated within the group. However, the classroom mathematics group work was proving to be well received and productive for the majority of the class.

Jeff and Toni expressed heart-felt personal feelings that impacted negatively on their learning opportunities in group learning, as perceived by them. Both Jeff and Toni presented destabilising elements of collaborative group work in a constructivist classroom that had been identified by Windschitl (2002). Feelings of inadequacy and of being publicly identified as 'dumb' were of very real concern to them.

My reflections at that time highlighted my feelings that I needed to more fully understand collaborative group learning and the issues associated with its successful implementation (Personal Journal, 7/9/10). I was coming to the realisation that collaborative learning was not merely group learning and that considerations of the groups' instructions, make-up, size, behaviours and member interactions played significant roles (Gupta, 2008; Panitz, 1997). Subsequently, in week 8 of term 3, my goal was to more closely monitor the groups where Toni and Jeff operated and to guide and facilitate the acceptance of the views of all students.

From the literature I learned that group members need guidance on differentiating between defending one's ideas and defending one's self (Windschitl, 2002). These skills assist students to accept not knowing as a legitimate part of developing an idea. The process of socialising students into acceptable forms of discursive practices is important in order to avoid students considering themselves to be 'stupid' as a result of either not knowing the answer or giving the wrong answer, and subsequently withdrawing from collaborative work. I became aware of the importance of developing in students a belief in their participatory rights and obligations in order to ensure the success of all students within the group and the class (Walshaw & Anthony, 2008).

It became apparent throughout term 3 that students were differentiating between mathematics group work and general (non-mathematics) classroom group work. Although the makeup of the groups remained the same, the students expressed positive views of their mathematics groups but maintained a negative disposition to the general classroom group seating. At the conclusion of the term (discussed later this Chapter) the students asked to keep the mathematics groups but wanted more options for seating arrangements in the non-mathematics subjects.

The mathematics group seating arrangement was accompanied by other changes that were not always used for the groups throughout the rest of the day. The mathematics groups were assigned cooperative learning style activities that were introduced or revisited in a whole-class session. Each activity had a card with written instructions for future reference, and the activities were often an 'out of your seat' activity, with some completed outside of the classroom.

The groups used the previously discussed reciprocal teaching framework (see Chapter 3) whereby the activity was broken into a series of steps. Reciprocal teaching was primarily used in a literacy activity; however, I have found the skills and strategies within it transferable to the group learning activities within mathematics lessons. The strategies of summarising, questioning, generating, clarifying and predicting were developed in a dialogue between the students and me.

This led to students independently using the strategies in their learning groups (Reilly, Parsons & Bortolot, 2009). The reciprocal mathematics groups operated with a designated student reading out the activity's instructions and aims to the group.

If students were unsure of what was required of them, they sought clarification from the group. Questions could be asked of me only after they had been put to the group and a satisfactory answer not received. Next, the students discussed how they could approach the activity and assigned roles to each student. Finally, the group waited for me to check with them that all was OK before commencing their investigations. This type of reciprocal teaching was in operation in other key learning areas throughout the year, and the students were familiar with the process and its objectives.

The reciprocal teaching process acted as a scaffold (Vygotsky, 1978) for students to use in engaging with the mathematics learning group activity, and allowed them to develop a common purpose rather than engage in an unplanned 'free for all'. It also acted as training for the group members in how a group could approach problems and problem solving, as it encouraged discussion within the group. Initially, I made my way around the groups checking that the process was occurring and that the groups were happy to commence their tasks. Usually this took only a matter of minutes. I continued to walk around the groups observing and discussing with the students their findings and what they might mean. Where groups seemed 'lost' in their understanding of an activity's purpose or their approach to it, I asked the group to pause and go through the reciprocal teaching procedure again. This enabled me to further develop the reciprocal teaching procedure to ensure more successful implementation at later times.

At the conclusion of the activity period, groups briefly presented their findings to the whole class. During this sharing time students started to provide 'hints' to other groups that they believed assisted them with their engagement in the activity but did not provide answers.

Small-group cooperative and whole-class collaborative work was used in the classroom, with each lesson generally experiencing both forms. In this way student conceptual development was open for all to see and discuss.

For example, after an activity on constructing a variety of 24cm^2 rectangles, a student, Jess, identified the development of her own and her group's current conceptual understandings. The following episode (Personal Journal, 17/8/10) shows the findings of her group:

Jess (year 4) *- We did one rectangle that was 2 on the top and 12 down and that makes 24. If you use the times tables on the back of your workbook you can find all the possible ways to make a rectangle using 24cm^2. Times tables are for multiplication and other things too.*

Beth (year 4) *- so I started looking for answers that were 24 (in the times table chart) because they would be the sizes of the rectangles to make.*

Scarlett (year 4) *- but I don't know if 2 long and 12 wide is the same as 12 long and 2 wide.*

Beth (year 4) *- well they are different times tables so they must be different shapes.*

Jess later stated in a whole-class discussion that she didn't know what the "little ^{2}" meant (as in squared or cm^2). This prompted Milly, who had been working on a different activity to ask: 'What does the little ^{3} stand for? I've seen them in a test. What are you supposed to write and how do you say it?' (Personal Journal, 19/8/10).

Many students voiced their interest in better understanding what these symbols stood for in mathematics. I wrote 2 examples (4^2 and 2^3) on the board for students to look at and then discuss in their groups. Students then offered solutions to the questions. Most students multiplied the two numbers together to arrive at 8 and 6, respectively. After some input from me about three-dimensional and two-dimensional shapes and how volume and area are calculated, the students tried some of their own. The following episode shows the diversity of class interactions that occurred as a result of a student asking a question and a teacher guiding but not lecturing the class on the answer. The interactions with respect to the students attempting to answer 2^3 were recorded in my personal journal (19/8/10).

Chris (year 6) *- the answer is 8. 4 X 2 is 8.*

Kate (year 6) *- But…how come your timesing it by 4.*

Chris (year 6) *- because 2 x 2 = 4 then 4 x 2 = 8.*

This represented a major change in roles for these two students. Kate was usually the dispenser of information and correct answers. Chris was a student who struggled with mathematics concepts and considered himself 'not very good at maths'.

Milly (year 6) *– I'm bracketing the first number (her book showed (2 x 2) x 2).*

Milly (year 6) displayed evidence of a working understanding of the use of 'order of operations'. Classroom discussion was proving to be a valuable source of information about students' conceptual understanding and not necessarily in the lesson's focus area.

Teacher *- if anyone needs a calculator please come and get one (Students start entering the numbers in the calculator to check their answers).*

Milly (year 6) *- can we try 2 fourthed?*

Teacher *– that is called 2 to the fourth power I think Milly, we will have to look it up.*

Kaidance (year 6) *- I like fourthed.*

Milly (year 6) *- its……16…2 to the fourthed is 16.*

Kate (year 6) *- I still don't get it.*

In the background of the audiotape Nathan is heard showing Darnell and Thomas how 2^4 can be represented as 2 X 2 X 2 X 2.

Nathan (year 4) *- the first number tells you what to multiply and then the little number tells you how many times. So this 2 has to be multiplied 4 times like this 2 x 2 x 2 x 2.*

Milly (year 6) *- (starts to show Kate her working out.)*

Kate (year 6) *- I still don't get it.*

Arthur (year 6) *- I just checked 2 x 2 x 2 x 2 on the calculator and I'm right. It's 16.*

Teacher *- I am writing up on the board how I did it. 2 x 2 = 4, 4 x 2 = 8, 8 x 2 = 16*

Nathan (year 4) *- I don't put it down that way.*

Mary (year 6) *- I did it 2 x 2 = 4, then 2 x 2 = 4, then 4 x 4 = 16.*

Teacher *- (writes Mary's way on the board) [aaah I should have let Mary write it up and explain her understandings].*

Milly (year 6) *- That's how I do it.*

Nathan (year 4) *- Me too.*

Kate (year 6) *- I like Mr. W's [teacher] way.*

This episode shows some of the benefits of a collaborative learning environment and the way current conceptual information could be gathered from productive and focused discursive practices. Order of operations, powers, and multiplication all stemmed from a question regarding cm^2. This led me to include activities in the following weeks (week 6 and 7, term 3) that required students to build three-dimensional rectangular shapes and calculate out their volumes. The students counted the number of blocks in each shape and then applied the formula for volume. Previously, students had looked at 3 dimensional shapes on a page in a textbook and attempted to imagine the blocks they could not see. Now they were in a position to investigate the shapes and not be confined to abstracting meaning from the pages of the worksheet or textbook.

I noted in my personal journal (20/08/10) that we had covered the concept of 'exponents' in terms 1 and 2 and that students had not asked these types of questions about the symbols ^{2} and ^{3} when we covered mass and volume previously. Perhaps the learning environment was starting to transform.

Content coverage and understanding

Group and collaborative work appeared to slow down the quantity of work the class completed. My initial program goal, to rotate groups through a concept area (length, area, volume) in a one-week period, proved to be unrealistic and set curriculum coverage above understanding. The concept area of Length was scheduled for the first week of term 3; however, it became apparent that the activities could not be adequately investigated in this period. In order to use the activities to identify students' current conceptual understandings and to move forward required longer than the previously allocated time. I changed the timetable so that each concept area was covered for a two or three-week period.

The third week was used to introduce the next concept area and to finalise the activities in the previous week's concept. There was a change of focus from the curriculum, or the scope and sequence of learning activities, to a more student-focused conceptual understanding approach.

Prior to my pedagogical changes, students had to fit in with the pre-planned teaching program, whereas this approach sought to have student understanding as the desired outcome. It was a pedagogic change that saw the learning needs of the students out-weigh the timetable constraints placed upon my programming.

History of mathematics

I had previously programmed very little time for cultural aspects of mathematics and its development throughout history. I was aware that number systems from ancient civilisations was covered in textbooks, but matters that went to the mathematics of other cultures, its evolution over time, and the impact of human values and opinions was not a consideration of mine when I planned mathematics learning experiences. I introduced, to the rotational group activities, an activity that required research into the history of different aspects of mathematics. Initially, this research centred upon the development of measurement through time.

The tasks were teacher directed (cooperative learning) through a series of questions that needed to be answered after viewing web pages and other online resources. The students seemed to enjoy learning about ancient measurement systems that led to the introduction of the metric system that they were familiar with. The history of Measurement was wide-ranging and continued for many weeks. Students were willing to discuss their findings within their group and with the wider class.

In an interview with the Principal (19/8/10), Susan commented on how the students had raised with her interesting facts about the history of measurement. Susan confirmed that this appeared to be a worthwhile learning activity as their language development with respect to mathematics prefixes was providing an understanding that could be transferred to different areas of mathematics and other subjects.

She noted that students' use of the prefixes 'mega' and 'giga' had developed from measuring water (giga-litre) to hard drive space involving bytes (giga-bytes). The students were interested in discovering where our current mathematics units originated as a result of their appreciation and investigation of other measurement units.

The CLES had a role in developing my understanding of the cultural aspect of a constructivist perspective. It was not the average score of CLES scales regarding the relevance of mathematics to the students and the development of mathematics that I found significant. It was the language in the CLES questions that alerted me to a discrepancy in my understanding of a constructivist perspective. When I looked over the CLES I noticed the references to cultural and historical aspects of mathematics. At the start of Term 3 I believed that mathematics was primarily about the recall of facts and formulas. My scholarly readings indicated that my initial belief about mathematics was contrary to the beliefs a teacher implementing a constructivist referent held.

Interviews (3/8/10) with students provided examples of where they believed mathematics from other cultures had been covered in class. Ben, Tim, Stephen and Toni all recounted the brief coverage of Roman and Egyptian numbers in the mathematics textbook as an example of this. They did not believe I had ever mentioned mathematics outside of the direct lesson they were completing and they had never considered mathematics from other cultures outside of various number systems. I asked students (Interview, 3/8/10) about cultural and historical mathematics in our classroom:

Arthur (year 6) *- We never hear any of that in class, it's just the maths from the book all the time.*

Teacher *- Do you recall working on Egyptian and Roman numerals?*

Ben *– Sometimes but not much and it's the same all the time. You do that maybe once a year.*

Sammy (year 4) *- I didn't know there was other maths I thought there was just the stuff we did in class.*

Teacher *– Maths has not always been the way we show you in the book. It changes and continues to change.*

Sammy (year 4) *– Nah, we never talk about that or do stuff about other countries and history.*

Nathan (year 4) *– We never really look at other maths from other places. You said there was Aboriginal maths, but I've never heard about it. Can maths be different in other places?*

Kate (year 6) *– That could be fun to see how other people do maths in different countries and stuff, but we have never done that here.*

As term 3 progressed I felt confident that students were beginning to understand the cultural aspects of mathematics a little better than just remembering the symbols for Roman and Greek number systems. Listening to student discussion about measurement highlighted the importance of understanding as opposed to recall.

Group-work skills

Successful and productive group work requires students to be given experiences and training in the mechanics of productive and on-task group work (Windschitl, 2002). I used whole-class collaborative activity sessions to model what I believed were the social skills and attitudes needed for productive group work.

The rotational group activities designed for the students throughout term 3 assisted in developing a more productive collaborative environment. The significant change to the classroom was to provide opportunities for students to share their work with others and to move from the reciprocal teaching model used in English and broaden this to mathematics.

Whole-class discussion provided a scaffold in listening to multiple perspectives, justification and hypothesis. I was able to monitor any negative response that tended to put students down and encourage and model questioning, probing and acceptance of different views (Walshaw & Anthony, 2008).

As I introduced individual, small-group and whole-class discussion the idea of negotiation and the role of each person in this process started to become clearer for all involved. Students and I started to listen to the various viewpoints that existed within the classroom. The variety of class groupings (whole-class, small-group, pairs) provided greater opportunities for all students to have their opinions voiced, and to listen to other opinions. Kate (Audiotape 22/8/10) observed about collaborative work, 'it's easier to agree when there are less of you in the group'.

Mathematical language

I felt that a positive aspect of developing meaningful communication was the subsequent development of students' mathematical language. At the start of a particular activity Beth referred to square centimetres as 'little squares' (Personal Journal, 29/7/10); however, when I revisited the group over the course of the next week her language had developed to the intermittent use of 'square centimetres'. Her uncertainty with the language of mathematics may have stemmed from her lack of understanding of the language and the symbols used in area, similar to that of Jess (^{2} and ^{3} - discussed earlier in this Chapter) who was in the same group. Again, at this early stage, I was not asking students about their understanding of concepts or their use of language. This aspect of my pedagogy, of more comprehensively assessing student understanding, was still developing.

Further language development was observed in Milly, who referred to square metres as 'those big things'. These 'big things' were the cardboard constructions of the outline of a square metre (made of cardboard and dowel) that students used for a measurement activity. Most students within the class used similar language and it was in hearing student discussion and discourse that I began to notice and assess their use of appropriate canonical language. I cannot remember ever focusing so intently upon the students' use of language in my mathematics lesson. As each group discussed their work and findings I was invited into their current language usage and was able to introduce the canonically correct mathematics language to them.

My observational notes, recorded in my personal journal throughout term 3, reflect my awareness of the students' growing use of mathematical language.

I started to record anecdotal records of students' use and development of language in mathematics. These formal records found a marked increase in the positive development of language in mathematics by each student. I had not made any notes about the students' use of mathematical language in terms 1 and 2; however, I had recorded developments in the mathematical language of 16 students throughout terms 3 and 4.

I do not believe that I was specially focused on this aspect of their learning; however, I experienced more first-hand examples of the students' use of language as I moved through the groups and as the opportunity for students to speak was increased. Students started to 'correct' each other in the groups and in whole-class discussion. This episode (Personal Journal 7/9/10) from group work after a series of activities in the concept area of mass shows this language interaction.

Stephen (year 6) *- I used a 2-gram thing to weigh the beads and you needed two beads for the 2-gram thing.*

Emily (year 6) *- You mean 2 gram weight.*

Stephen (year 6) *- Yeah the 2 gram weights. We put them on one side of the long thing and the beads on the other.*

Emily (year 6) *- That was the equal arm balance we used.*

Stephen (year 6) *- Yeah I know ….the balance.*

Arthur (Audiotape, 26/8/10) asked me if we could find more 'test tube thingies' for his group to use. When I was unable to understand his request he went back and found a 'test tube thingy' to show me. I was then able to find more plastic measuring cups for his group to use. Arthur explained to me that he didn't know what to call them but would do so from now on use the correct name for them so as to be understood. He returned to his group and informed them of the correct name for the resource.

One small-group activity for a lesson on volume and capacity asked the students to discuss and record what they thought 'volume' meant. Students could be heard to discuss a series of different definitions for volume.

Students raised the idea of volume as the switch on their music playing devices and TV, and they accepted these different views as possibilities. Very few students were capable of providing what could be considered a coherent mathematical view of volume. Stephen suggested that the teacher was asking for the' maths volume not the sound volume'. Arthur felt I had not made this perfectly clear (Audiotape, 26/8/10). Many students confused the mass of an object and its volume. I was beginning to appreciate and realise that a great deal could be gained from listening to the students' explanations of volume and how I became aware of their confusions and current conceptual understandings.

This marked a clear step away from my normal lesson on volume where the definition was placed on the whiteboard for all to copy down and memorise for recall on the Friday assessment. Never before did it occur to me to seek a personally meaningful understanding of what volume actually meant to each child. I used this student interaction to prepare lessons for the subsequent week that focused on drawing a difference between mass and volume within the mathematics learning activities.

Seating - A critical review

At the conclusion of term 3 students were asked to indicate to me via their journal or in an interview how they wanted the classroom to be arranged for the following term. I gave no indication that their ideas would be accepted, but that their views would be considered and discussed before any changes were made. Every student indicated a desire to return to the conference style seating that existed prior to my pedagogic changes; however, 23 students requested that the mathematics groups remain, with no changes to them. They enjoyed working in mathematics groups but they did not want this as a permanent arrangement.

Group work evolved throughout the course of my study. The variety of activities allowed students to engage in different activities where their current conceptual understandings could be developed and probed. As I interacted with groups I began to see a need for the movement of students amongst groups as they requested engagement in investigative learning activities that I had not set them.

Darnell and Chris who were in different groups asked me if they could join the group who were currently working on estimating the amount of mulch needed for the school vegetable garden (Personal Journal, 13/9/10). My initial concerns were that these students really wanted to be outside the classroom (this was an outside activity) for the wrong reasons; however, my observations and discussions with other group members confirmed that they had brought ideas from home that they wished to share with the group. They both worked diligently to draw a model of the garden and then went about calculating the volume of the area needed for mulching.

Students expressed a desire to have a more individual learning space available to them, and the opportunity to move to group work when it was required. My own thoughts on this were still superficial and lacked a deep understanding of collaborative learning. My personal journal (20/9/2010) reflected my view on this seating arrangement and the need to keep it permanently. Fortunately the introduction of student journals and student interviews was presenting me with the students' view. This was a view that I was beginning to request and respect, and that I saw as being of value to their learning.

Even after the conclusion of the third term, I still believed that the seating arrangement determined the success or failure of group work and that the group seating needed to be permanent or else it was not promoting a constructivist perspective. There was no longer any doubt in my mind about the benefits that could be derived from the effective use of groups in a cooperative or collaborative setting. But could this be achieved only by sitting in groups all day long? At that time I read that collaborative group work refers as much to student-teacher collaboration and paired student collaboration as to small-group work (Karagiorgi & Symeou, 2005; Sullivan, 2011; Walshaw & Anthony, 2008; Windschitl, 2002;). Thus, I came to realise the need to move away from identifying and using so-called constructivist strategies and look at using effective strategies from a constructivist perspective. This seems a small point; however, to suggest that a certain strategy, such as brainstorming, is per se a constructivist strategy is a fallacy. It is how brainstorming is used that determines whether it fits a constructivist perspective. This also applies to group cooperative and collaborative strategies.

Richardson (2003) and Windschitl (2002) had pointed out warnings with respect to a teacher identifying discrete practices in an attempt to create a constructivist learning environment. This was a warning that I had glossed over; creating in me what they suggested was a superficial view of pedagogy.

After considering the student requests to change the general seating arrangements of the class, and their desire to maintain the mathematics groups, I agreed to change the classroom seating back to its previous formation for the commencement of term 4. The previous horseshoe arrangement allowed for the easy movement to learning groups as required. Part of this change was a desire to respect the students' reasonable requests and to allow them to see their opinions being considered, valued and at times, acted upon.

My Role In Creating A Collaborative Learning Environment And Developing Meaningful Communication

Throughout the first two weeks of term 3 I listened to audiotapes of my mathematics lessons. I reviewed these tapes to ensure that the lesson and student discussion was audible. The audiotapes were functioning as expected and discussion could be heard so that transcripts, analysis and coding could be made. However, upon listening to these audiotapes it was evident that there was little classroom discussion within each lesson. From the beginning of the teaching experiment, the audiotapes recorded a behaviourist teacher who continued to transmit knowledge to students. I commenced mathematics lessons with direct instruction to the students. I presented examples of the concept to the class who were politely directed not to ask questions while I was giving the instruction but to keep questions for the end of my input.

For each lesson children sat silently for up to 15 minutes as I explained concepts or procedures to the class. I seldom provided students about the objectives of the lesson. If the students raised questions I told them to ask them at the completion of my lesson introduction.

There were occasions where my answers and further examples took an additional 5-12 minutes (audiotape 22/7/10, 23/7/10, 27/7/10, 29/7/10).

The total length of time that students had to wait before they commenced the learning activities was between 20 and 27 minutes. This represented between 45% - 60% of the mathematics lesson. I had viewed myself as an effective teacher who didn't bore students with long-winded lectures. To my great surprise the audiotapes provided a completely different picture. My supposed constructivist pedagogical changes had lengthened the amount of time I spent talking and not, as I had hoped, increased students' active and meaningful participation in the learning experience. Now I was presenting input on four or five learning activities. While many benefits were starting to occur when learning groups went about their work, I seemed to be doing my very best to make sure that this time was very short.

In those initial audiotapes it was possible to hear students attempt to enter into collaborative discussion with others or me. But I realised that I held the view that collaborative work should commence after I had finished. Furthermore, the audiotapes indicated that students were willing to provide me with information about their current conceptual understandings by offering their thoughts to the class and to me. Sadly; however, I asked them to be quiet while I continued lecturing the class. The following comments were recorded during a mathematics lesson (Audiotape, 22/7/10):

Beth (year 4) *– Mr. W, I thought the bottom number was whatever you wanted it to be and the top (numerator) stayed the same.*

Tim (Year 6) *– Do you pick any number to multiply the bottom number or does it have to be the top number?*

Unidentified Student *- Yeah I don't get that either.*

Arthur (year 6) *– The bottom is different in different numbers…why is that?*

I ignored these comments and asked Beth, Tim and Arthur to keep quiet whilst I was talking. It was not until I reviewed the audiotape that I actively listened to their input and realised that the opportunity to identify and probe their current conceptual understandings was missed.

The unidentified student's comment remained unidentified and alas unattended. My response to the students may have been acceptable within the context of the lesson, but I did not go back to Beth, Tim or Arthur to discuss with them their understanding of the denominator in a fraction, or indeed to share it with the class so that more views on this difficult concept could be elicited from the students. I had not offered the students an opportunity to assess or discuss their current conceptual understandings. I wondered how many students I had ignored over the previous two terms, who now did not bother to voice an opinion. Did they stop asking questions? The audiotapes recorded a high number of instances where students offered to share how they solved problems or where they were experiencing difficulties, but I either ignored them or cut them off and did not return to them either in class or privately.

Even after I had opened up communication opportunities for students, I did not always act on the student input. One student, Arthur, advised me in a personal interview (26/8/10) of his concerns:

Arthur (year 6) *- some students learn things quicker than other students and they want to do something else. I find this happens a lot, you just don't understand but you move on to the next things.*

Teacher *- Do you mean I move the class on to new things before some are ready?*

Arthur (year 6) *- Not always but if some of the kids get it you move on to something a little harder and some of us are still working the other stuff out and it gets confusing.*

Teacher *– Thanks Arthur, I will have a think about what I can do about that.*

While I had intentions to act upon this suggestion, I did not return to Arthur to further understand his ideas about what could be done to help those students. The communications channel was open, and that was a good thing, but I still needed to act on the suggestions in a meaningful manner.

Teachers studied by Cohen (1988) and Taylor (1996) continued a traditional teaching approach with the teacher being the centre of the learning experiences even when they believed they were moving towards a more constructivist pedagogy (see Chapter 3).

I had read these accounts of teachers implementing 'constructivist teaching' with great interest but seemed not to have learned from their identified failings. These teachers were in fact…….ME! This lecture style need not be abandoned completely, but certainly required a balanced approach and an increased constructivist perspective.

As the evidence showed, I was not attending to establishing the children's current understandings or the development of a truly collaborative classroom environment in any of the lessons in the first two weeks of term 3.
Instead I was interrupting students as they offered their current conceptual understandings because their input did not fit my planned lesson. The audiotapes reflected a teacher who did not allow the students' views to be heard, and confirmed my view that the students' role in learning was to listen to me as I transmitted knowledge to them. I believed that it was important for students to hear my thoughts, but it was not important for me to hear theirs. This reflected an 'old school' view of education. I realised that despite my scholarly readings I hadn't changed much at all. The biggest change I had made was that I now lectured children seated in a group-seating arrangement as opposed to them sitting as one large group. This was not constructivist pedagogical change; this was tinkering around the edges of pedagogy.

The audiotapes provided a tangible critical review of my professional practice. They did not allow my established 'beliefs' about how I normally teach to mask my critical appraisal of my teaching; rather, they presented a 'warts and all' review of what actually happened in the classroom. I gained many insights after listening to the audiotapes of my mathematics lessons, and I was able to evaluate my actual epistemological beliefs rather than my epistemological ideals. My behaviourist tendencies were there for all to see. Similar to Mrs. Oublier (Cohen, 1990), I had genuinely believed that my teaching reflected a constructivist perspective in the mathematics classroom, yet the reality was far removed from this pedagogical ideal. The audiotapes opened my eyes to the need for careful reflection on the learning experiences I was presenting to my students. I am grateful that I was able to hear these episodes which allowed me to amend my behaviourist approach to pedagogy.

My reflective notes, taken as I listened to the audiotapes, are littered with similar sentiments - 'just be quiet and listen' and 'stop talking' (weeks 1 and 2, term 3). They provided a critique on my classroom input and impact. Listening to those initial audiotapes caused me to want to yell out to this teacher to stop talking and allow the students into the lesson. This was a clear assessment of my dominant role in the class. I was not creating a collaborative environment but rather a lecture. However, this situation which was previously hidden from my uncritical view, was now in the open, and led to a series of initiatives that had a positive impact on my pedagogical change process. Somewhere deep inside of me was a behaviourist who did not allow the best intentions of this would-be constructivist out.

In week 3, after hearing the audiotapes, I read Hattie's (2009) review of research into expert teaching habits and strategies that found non-expert teachers could spend 80% of the mathematics lesson time talking. My own quantitative analysis of my talking time in class seemed to reflect this finding. Hattie's review found that expert teachers had the children engaged in 'doing' rather than 'listening', which was the opposite of my classroom in those first two weeks. The audiotaping of my lessons provided the most powerful reflective tool I had used in my teaching career. Listening to my lessons was a sobering experience, which pointed out areas that could be very quickly improved.

My personal journal (14/7/10) recorded 'reflection and seating are the easiest constructivist strategies to implement'. These comments represent my early priorities for pedagogic change. 'Reflection' referred to the students completing their journals and 'seating' referred to the group setting I had changed. These were changes that the students were required to make; my own transformative changes appeared some way off. My first pedagogic priority was to develop group work seating arrangements and I did not fully consider my existing epistemological beliefs or pedagogy. These groups could be implemented but effect very little in pedagogic change. I was still able to transmit knowledge to these students regardless of how I arranged the classroom furniture. In fairness though, I didn't have a 'real' understanding of epistemology, and in those early weeks of term 3 I certainly didn't feel that it applied to me.

As my journey continued, it was classroom moments and personal reflections that caused me to seek greater understanding of epistemology and educational constructivism through journals and other readings. Knowledge of 'constructivist practices' was simply not enough. I had to understand the practices, the theory and the implementation of them. This deepening understanding grew very slowly as the research continued. But, as each mistake was reflected upon, a better teacher emerged.

Later, I was to learn that no single pedagogy could provide 'the answer'; my role as a professional is to discern when to use which pedagogical approach. However, when I commenced planning the case study aspects of my research I did believe that one single approach to teaching was appropriate.

Sharing control

On returning to the classroom in week 3 of term 3, I explained to the students that I had listened to our mathematics lessons and all I heard on the tapes was me talking. During a class discussion students were happy to confirm to me that I did talk a lot in mathematics and other subjects (Personal Journal, 3/8/10).

I asked the students how long they believed I should talk in explaining the lesson to them. After some general discussion the class decided that 5 minutes should be plenty and if they needed further help they could ask for it.

Kate (year 6) *- If you still don't get it then you should see those people and let us do our work.*

Teacher *- Sometimes it helps if all students listen to the questions because they may have the same question or they may be able to help the student understand it better. I know sometimes I confuse some of you.*

Milly (year 6) *- What about a few minutes for questions and then we get on with it? About 5 minutes. Then we can help people if they ask us.*

The class discussed a better arrangement than me talking for long periods. Many were concerned that they could be left not knowing what to do and students provided ideas about how the mathematics lesson could run.

I collected the ideas as they were suggested and grouped them on the whiteboard for student consideration and to clarify my understanding of what they were saying. Now that was a new approach!

The final proposition for our mathematics classes suggested by the students was for 5-minute teacher input and 5-minutes of questions. If students needed more time to ask questions they should ask a peer first then come to me with their questions. The students noted that this was similar to reciprocal teaching (see Chapter 3) used in English lessons and we discussed how this arrangement could now be used in mathematics lessons as well. The class agreed through a show of hands to implement the new arrangements.

My intention was for group activities and reciprocal teaching techniques to assist with reducing my 'lecturing'. As it currently stood, I explained each group's activity and then became bogged down in detail and organisational matters.
To assist me in keeping to my 'contracted' time allocation, the starting time of my mathematics lessons was recorded on the whiteboard and I endeavoured to keep to the two 5-minute arrangements. This did create some 'clock watching', but after a few weeks students were familiar with the procedure. Initially, I felt a desire to continue talking past the five minutes, as my desire to 'tell' the students more about the activity, how I would approach it and suggestions as to how they could approach each task remained strong within me. It was a sobering experience to limit my input. There was a slow realisation that the lesson moved on effectively without my lengthy input. I also found that my experiences and thoughts were not lost for all time because of the arrangement, but were expressed in a more targeted and appropriate manner in small-group discussions.

Audiotapes from week three of term 3 onwards confirmed a major reduction in my lecturing to the class. Obviously, by reducing the lecture time from 15-minutes to 5-minutes allowed for a 60% drop in my lecturing. Initially, I had trouble keeping to the 5-minute input and asked students for special consideration so that I could speak for longer than my allocated time. This special consideration happened three times in week 4 and twice in week 5.

However, in seeking special consideration I was bringing the problem of lecturing to my immediate attention and was able to focus firmly on being brief and moving the lesson towards student activity. Rather than only becoming aware of the matter at home after the lesson (via audiotapes), this new approach allowed me to adjust then and there, that is, reflection in practice (Schon, 1983). Students were only too happy to keep me to our arrangements.

Andrew (year 5) *- Mr. W, your time has gone over.*

Teacher *- Sorry class, I promise to be brief.*

Darnell (year 5) *- You went over but not by much. I think you are getting better and better with this (after the completion of another 90 seconds of instruction).*

Kate (year 6) *- Yesterday was 2 more minutes so by next week you should get this right.*

Teacher *- Thank you for being so patient…. I am trying to keep to the 5 minutes but it is difficult.*

(Personal Journal 10/8/10)

Eventually the mathematics learning group routines became familiar to the students and myself. I found the need to have direct teacher input in each lesson reduced greatly, and the collaborative group sharing at the end of each session reduced further my need to continually explain things. The shared student experiences provided opportunities for discussion about how tasks and activities could be approached and how they had been investigated. This provided my first planned attempt to allow multiple perspectives to be encouraged and to be evaluated and discussed. My lectures became localised to the small group I was working with, where I initially continued to dispense knowledge and did not seek to identify and evaluate their understandings. This, too, in time passed, as I walked amongst the students probing their understandings and approaches to the tasks. My actions proved to be a good example for other students, as they watched an 'expert' ask questions of the 'apprentice' and even learn from the apprentice. It was through this increased student-teacher interaction that meaningful communication could be developed.

The students started to gain control when their suggestions for certain activities were incorporated into our classwork. Activities that were set as optional activities proved to be very popular amongst the students. The student construction of a full-size outline of the space shuttle was one activity that was developed after consultation with the students. This activity was well received by students. It stemmed from a science activity that the students wished to investigate after it was raised in the media. Students discussed amongst themselves the scale that was written on the worksheet and how this was used to make a scale model.

After building a scale model that was made of paper and flown, the students discussed the real space shuttle and how big it was. This ultimately led students to suggest whether it was possible to draw the actual outline of the space shuttle on the school playground. I showed the students the scale and designed some activities that investigated scale models. Following the student discussion about the size of the shuttle and the difficulty they had in imagining its size, I took the opportunity to plan learning experiences that had the students reconstruct an outline of the space shuttle on the school playground. Many students had built model planes and boats at home and were familiar with a scale model, and this activity drew on their experiences.

Tim (year 6) *- We couldn't do that here, its way too big.*

Milly (year 6) *– I think it will fit in the playground.*

Bronwyn (year 6) *- Can we try it Mr. W (teacher) and give it a go, it sounds fun?*

Chris (year 6) *– That would be unreal, we could sit inside it and walk through it.*

(Personal Journal, 23/7/10)

The class discussed the merits of the task while they finished building the paper model of the space shuttle. From here the class embarked on a task to draw the outline of the shuttle outside. The task became a real-world activity that took four weeks to complete. The outline of the shuttle was represented by 'witches hats' placed every 10-15 metres. However, the students hadn't finished yet. They asked whether the groundsman could draw the outline of the shuttle using line-marking white powder, which he obliged us with.

These were great examples of student ideas being asked for, listened to and accepted. Why hadn't they suggested these ideas earlier?

When the whole school came outside to view the shuttle the students asked whether they could lie down along the white outline (see Figure 4).

Figure 4: *Student Outline Of Space Shuttle*

The students became drivers of the curriculum, negotiating the task and breaking it down into achievable tasks. The Principal was very encouraging of the activity and commented that the students mathematical minds were working on the problem long after the lesson had concluded. This task involved many concepts and skills that I had not foreseen, and the freedom of adjusting lessons and outcomes allowed it to be a great educational success. However, this type of activity was rare in the course of my research, and indeed had not been planned but served as an add-on to the proposed mathematics activity rotations. I believe that the students acknowledged the change of their role in co-designing this particular mathematics activity. This was an improvement, but was not a regular occurrence. Certainly the planning of the activities in each of the sub-strands was taken from the syllabus support documents with no input from the students.

Over time (see Chapter 6); however, students in consultation with me were allowed to decide within the various activities which activities and concepts they wished to investigate.

Student and teacher communication

The introduced student journals, reflections and interviews provided a valuable source of information that I had not previously been accessing. Unfortunately, my initial reason for adopting these particular strategies was to enhance the research methodology of this study and allow for triangulation of data within the research findings. At this early stage, I did not expect these to be sources of valuable information that informed my professional practice. However, the development of communication between student and teacher proved to be the most rewarding aspect of the research. It became apparent to me that the students did not simply operate in a mathematics lesson in a vacuum unaffected by their environment.

Journals, interview responses and reflections often went outside the mathematics domain to introduce relationships, personal events and other concerns which impact upon the students within the classroom. I had inadvertently provided an avenue or outlet for many students to express their feelings in a host of different areas of their lives. This information allowed me to take into consideration the impacts on particular students of situations in their lives and to adjust learning and teaching activities or expectations.

Effective communication allowed me to discover more about the students, which in turn fed my ability to set learning tasks appropriate to the students in their 'zone of proximal development' and current personal situation (Vygotsky, 1978).

Initially, the students had difficulty in using their mathematics journal. Initially, I had difficulty in introducing this new aspect of their mathematics learning and expected students to be fully conversant with the notion of 'reflective practice' in their approach to their learning. I provided scaffolding and prompts for them to use when writing in their journals - 'What do you think today's lesson was about? What did you learn today in mathematics?

What do you think was the outcome for today's lesson? Was it achieved?' Of all the new strategies implemented, this was the least well received and did not show any large-scale improvement in overall use, depth of writing or enthusiasm to complete. My journal entries record the class-wide moan whenever I asked students to make an entry in their journals, as it was viewed as more work at the completion of the lesson. Students were more accepting of having interviews with me in their lunchtimes than making entries in their journals in class-time.

Many students (Interviews, 14/9/10) expressed to me a dislike of writing in the journals and considered it hard work. Nathan, Brie, Kate, Kaidance and Arthur told me that they completed the journal tasks only because it helped me with my assignment (i.e., this research). All expressed a greater willingness to have a discussion that was recorded or noted by me rather than them having to write. 'We all like telling you stuff, we just don't want to write about it', explained Brie.

However, the journals provided an opportunity for students to privately record their feelings about mathematics (and other matters). Students recorded problems they experienced in mathematics lessons, in their group interactions or in the class in general. Seating arrangements received considerable comment throughout term 3; however, this ceased in term 4 as the seating and grouping arrangements changed. A collaborative classroom afforded students another opportunity to reflect on their understandings and procedures which, coupled with the reflective journals, presented me with a more comprehensive understanding of each student.

Student interviews - Now there's a good idea!

Communication was improved by offering students the opportunity to have an interview with me at lunchtime during the 15-minute eating period (the first 15-minutes of lunch required students to sit in the lunch area and eat their lunch prior to playing). These interviews could be conducted individually or in a group. Students requested interviews in each week, from week 3 of term 3 until the conclusion of term 4.

Not all interviews involved mathematics, but of the 34 interviews 27 pertained to mathematics in one form or another. Students raised matters relating to seating arrangements, mathematics concepts, mathematics homework and class routines with respect to mathematics.

In an interview with Arthur, Kate and Brie (10/8/10), the students explained that they had questions that did not always get answered for a variety of reasons. They asked if they could have an area of the classroom to place 'sticky notes' with questions written on them that I could address throughout the week. When these were addressed they could be removed. The students felt that a visual alert of the need for me to answer their questions might allow all of us to be more aware of the unanswered questions and that this was a polite reminder for me. They suggested that I should review the sticky note area at the beginning of each day with a view to removing a number of questions each day.

Additionally, the students felt that homework, which was previously given out on a Monday and collected on a Friday, should be collected on the following Monday, giving students the weekend to complete it. I had collected homework on a Friday so I could look over it on the weekend, but the students wanted to be able to complete their homework over the weekend. This was a clear indication of routine decisions being made based on only one perspective - mine. These suggestions were presented to the class after the lunch break and were adopted with the full agreement of the class. Without an avenue for students to raise matters of concern with me these wonderful ideas may never have been heard or addressed. This is an example of students taking some control of the classroom and represents the growing change in student teacher relationships within my classroom. Thus, it was increasingly evident to them that their opinions were valued by my actions in firstly listening to them and subsequently implementing them.

This changing relationship in the quality of communication was evident in a follow up meeting (7/9/10) where Arthur pointed out that the 'sticky note area' had many 'sticky notes' on it that referred to homework of 2 and 3 weeks ago that were not addressed quickly enough by me.

The students felt that I needed to be more regular with feedback about these student concerns and needed to review the 'sticky area' daily. Arthur suggested that as I write up the daily class timetable on the whiteboard each day, which outlined the plan for the school day, I could incorporate 'sticky notes' on that daily timetable. He had noted that I marked off each timetabled activity as the day progressed and this should remind me of the notes each day. These points I attended to with greater mindfulness over the rest of the year, and I benefited from the input of students about my interactions with them. An interview with Nathan (Interview, 28/8/10) highlighted the benefits that some students had identified from these innovations.

Nathan (year 4) *– I like the short teacher talk time, then question time and our student discussion. We all get a say. And I like the question board (sticky notes). I haven't used it yet but I reckon it's good.*

I too used student teacher interviews as an opportunity to delve into the thoughts of students about aspects of the classroom. In an attempt to gain an insight into how students thought mathematics lessons should run in the classroom I interviewed (6/8/10) Scarlett and Beth.

> I ask both students to describe a typical mathematics lesson. They reply that teachers come in and tell you 'stuff' and then give you a whole heap of questions about the 'stuff'. Beth explains that each mathematics lesson is meant to be difficult to understand because the work is hard and 'if I understand it then it is too easy'. Scarlett tells me that it is really funny for me to be sitting at her desk and asking her questions about how I can help her in mathematics and not be showing her how to work it out in her mathematics book.
>
> 'I don't know, that's your job', Scarlett states when I asked her how I could help her with mathematics. When I tell Scarlett that learning is her responsibility the two girls disagree and tell me that learning is the teacher talking and the student listening. 'If students don't understand it's because they are dumb probably'. I ask if either of them at times feels dumb. They say that sometimes they are and sometimes they aren't. I ask the girls if I make them feel dumb. 'Of course, you're the one asking the questions' replies Beth.

> ‘Sometimes I know stuff but you don’t ask me that. You usually ask me stuff I don’t know. But lately you are asking us things about how we like the class and how can it be funner. You are being really strange doing that.’

The interviews proved to be a useful two-way strategy for developing a flow of information. My journal notes throughout the term reflected the benefits I received from devoting time to hearing student views in a one-on-one (and group) situation, where I could ask questions and attempt to understand better the students’ perspectives and concerns.

Innovations such as regular student/teacher meetings, sticky notes and student journals, provided students with additional communication opportunities with me, and these were appreciated and used extensively by the students. These communication avenues opened up the possibility of hearing the critical voices of the students in a non-threatening manner.

Nathan, Tim, Ben and Darnell all mentioned the increased ways they could talk with me about a range of matters, but mainly in mathematics, as being beneficial. Nathan claimed that although he had not used all opportunities at that time, he did think they were a good idea and showed students I was willing to listen to them (Interview 27/8/10). Student journal entries allowed me to identify any concerns students had regarding mathematics (and other areas of school or home) and to initiate conversations with students when appropriate.

Diagnostic teaching

A further pedagogic strategy that improved student-teacher communication was providing a concept introduction session prior to the formal commencement of activities that developed the concept. This introductory lesson was designed to better establish what the students already knew about each concept. Commencing in week 4 of term 3 students were asked to write down what they knew about the concept that was to be addressed in the following week and to then discuss in pairs or small groups their current understandings about the concept.

After the group discussion, the students were involved in whole-class collaboration where they shared what they currently knew about the concept. The discussion served to provide me with information about current conceptual understandings and language use, and provided a basis upon which to design learning activities. Over time, I took note of students who did not share their thoughts and I later followed up with them. The following whole-class collaborative discussion occurred after small-group discussion on the concept of mass (Audiotape, 9/9/10).

Teacher *- Ok so you have had a chat about next week when we will be investigating mass. What do you already know about mass?*

Arthur (year 6) *- I don't know what mass is…. I think that mass is something to do with volume but it might not be.*

Nathan (year 4) *- I don't know either, I thought mass was capacity. Mass is all about weight I think.*

Milly (year 6) *– Maths has something to do with the weight of an object.*

Nathan (year 4) *- Its not maths I don't think its mass, maths is all of it'. Isn't it Mr. W?*

Teacher *- Yes we are talking about mass which is a part of maths. Pretty confusing though.*

Bronwyn (year 6) *– We thought it was the area and the weight of something.*

Darnell (year 5) *– Its weight times size.*

The students offered a wealth of information to me as they expressed their current conceptual understandings. My usual practice was to plan activities in isolation for the children in an attempt to teach them about a concept. Their current conceptual understandings did not play any significant role in my planning.

However, this easily enacted practice of asking the students to discuss amongst themselves and to then share their ideas provided me with valuable insights into their thinking. These were insights that 'cold' answers on worksheets could not provide. This was a teaching strategy that I continued to use throughout the remainder of term 3 and term 4.

Real-World Experiences

Providing students with lessons that could be described as 'authentic real-world learning experiences' was an interesting task. This was a concept that evolved as I continued my scholarly research and as I reflected on my own research experiences. As with other elements of constructivist pedagogy, relevant literature claimed that a constructivist learning environment reflected real-world teaching and learning experiences (Walshaw & Anthony, 2008). I initially understood real-world learning experiences to mean students should not be directed to opening a page in a textbook that provided an explanation of a concept, followed by consolidation of the skills expressed either within the book or by the teacher.

I maintained the view throughout term 3 that there was no place for textbooks in the constructivist classroom as they might not engage students within their conceptual zones of proximal development. Nor did textbooks normally use real-world and personally relevant contexts. At that stage I felt that the use of textbooks prevented me from assessing students' current conceptual understandings and prevented me from presenting experiences that moved them on from their current levels. It was the textbook and not a student need that normally set the planning of learning experiences.

However, I came to realise that this prejudice against textbooks was not supported by any evidence I had come across, but was an incorrect extrapolation by me of constructivist theory and strategy. Indeed, the research on constructivism (see Chapter 3) indicated that textbooks could be a part of the teacher's toolkit and used when appropriate. The textbook was the driver of the learning experiences in the classroom only if the teacher allowed this to occur.

Nevertheless, my belief at that stage was that a pedagogy that is reflective of constructivism has no place for textbooks and worksheets, but instead should draw examples of concepts and problems from the real world which could not be found in textbooks.

I was quite certain that little of my current mathematics lessons at that time drew on the real world, other than by chance from the textbook the students used. In many ways, I understood that use of the students' world meant that instead of asking students to add 15 and 30, I needed to ask 'if you had 15 toys and added 30 more toys how many toys did you have?' This superficiality in understanding key elements of constructivism was clearly an impediment (Richardson, 2003) to my successful implementation of pedagogical change. Authentic tasks bring the real world to the classroom and have little to do with changing the wording of a question or explanation or reduced use of textbooks.

As I explained in Chapter 4, the school Principal identified the mathematical sub-strand of Measurement as a weakness in Years 4, 5 and 6. The results of the Australian Curriculum, Assessment and Reporting Authority's (ACARA) 2009 NAPLAN assessment of mathematics supported her findings that the Measurement sub-strands of length, area, volume and capacity were below acceptable standards. The school Principal directed me to the Department of Education's resource, '*Teaching Measurement: Stage 2 and stage 3'* (NSW Department of Education and Training, 2004) and said that I might like to use it when planning teaching and learning activities. This resource claimed to assist teachers in developing a teaching program that is both practical and meaningful. The activities in it encompass six levels of increasing difficulty in each sub-strand of measurement which focus on developing student knowledge, skills and procedures. These measurement activities continued in my classroom throughout term 3 and term 4.

It was the students' active engagement with real-world resources – rulers, measuring cups, containers, trundle wheels, scissors, building blocks, grains, food, square metres, water and hectares - that was most conspicuous in the lessons.

The students were required to use items from their personal experiences, such as their school bags (mass), bodies (length, mass, volume), school and local environment (length, area), personal equipment (books, pens, pencil case), classroom (area, length), pets and livestock (area) and their own name's initials (area). These activities were supplemented with a Measurement research activity (discussed earlier this Chapter).

Students investigated all measurement concepts in a tactile manner, and this engagement provided me with valuable feedback through their group learning and whole-class collaboration. Students engaged in activities in the covered outside learning area, the floor of the adjacent computer room, the playground and the classroom. They worked initially in small groups and investigated the concepts of measurement. The activities allowed me to tailor the progression of groups through different activities as I assessed their current conceptual knowledge. However, I found that many students requested that they be allowed to complete all available activities. When this was not possible, students elected to catch up on missed activities at a later time.

After 3 weeks of the measurement rotational activities student journals started to reflect a more positive attitude towards mathematics in general and to the measurement activities specifically.

Leigh (year 5) *– I love measuring the bits of my body and checking with others. My wrist is way smaller than I guessed (Student Journal, 4/8/10).*

Kate (year 6) *- It was fun because we weren't all packed together and copying off the board we had to go outside and work together. Its great now I have learnt heaps about m cm mm (Student Journal, 10/8/10).*

Arthur (year 6) *- I really liked today's lessons we learn more like today than in the classroom. I found out that the bigger the bucket did not matter when you put things in it, it went up by the same amount (Students placing different objects in water to investigate volume and displacement). If I learned like that everyday I'd want to come to school (Student Journal, 17/8/10).*

Arthur (year 6) *- The scales are all different. One says you weigh 50 kg and the other 56 kg what's right? I got a rock and then estimated volume, mass, weight and found how much water displaces. I thought it was really interesting about it and I had a lot of fun working out the stuff (Student Journal 23/8/10).*

Emily (year 6) *- Actually doing this maths teaches me more than just doing work sheets. We should do it more often. I learned what hefting was and how to work out how much space an object occupies (Student Journal, 7/9/10).*

Milly (year 6) *- I had heaps of fun with the initials. (Students making their initials in square metres in chalk on the playground) I learned to never underestimate size. We found the* $12m^{2\ was}$ *huge (Student Journal 13/9/10).*

Interviews (3/9/10) with Bronwyn, Kaidance, Beth and Nathan supported my view that there was growing enjoyment and engagement by the students with these activities and their perceptions of the benefits of these types of learning experiences:

Teacher *- You wanted to see me about the mathematics activities we are doing?*

Bronwyn (year 6) *- Yeah we wanted to do more of them.*

Teacher *- Are these activities more enjoyable than the way we were doing the maths last term.*

Kaidance (year 6) *– Heaps, you get to try out what you think is happening and see for yourself. If you have fun you remember it more than by writing it down. Writing it down is boring.*

Bronwyn (year 6) *- But you learn more by doing…when you're actually doing it.*

Teacher *- How do you know that?*

Bronwyn (year 6) *- Because when you write it down you don't really read it, you just write it down.*

Nathan (year 4) *- You're just copying what you are doing. Yeah copying is boring.*

Teacher *- You can always ask questions if you are not sure about things.*

Bronwyn (year 6) *- Because when you're listening and doing it at the same time, you learn more about it.*

Nathan (year 4) *- You might remember about three of the words you have written but that's about it. You are not seeing it.*

Teacher *- What do you mean seeing it.*

Nathan (year 4) *- These activities you get to see and do it, when you copy your stuff you don't see or do it.*

Beth (year 4) *- It's better because you're actually doing it. Outside work has been really exciting and not boring stuff at your desk.*

Another meeting on 7/9/10 with students Thomas, Arthur and Milly further supported the students' view that their learning was enhanced through these types of activities:

Teacher *- So you want to talk about maths. How exciting!*

Arthur (year 6) *- Never thought I would be wanting to talk about it but it's really good.*

Teacher *- You seem to enjoy the activities we are doing on measurement? What do you enjoy?*

Arthur (year 6) *- We don't have to copy stuff off the board and do worksheets.*

Teacher *- What didn't you like about copying maths off the board? Some things just have to be written down so you can look at them later.*

Thomas (year 5) *- I just write it down, I don't read it.*

Arthur (year 6) *- Nobody actually reads it Mr. W.*

Milly (year 6) *- When we are doing stuff I remember stuff but if you asked me after lunch what I wrote down without looking at it I wouldn't be able to tell you what I wrote.*

Teacher *– OK Milly, I am going to ask people after lunch what they learned today in their groups. But you can't go out and tell people what I'm going to do. Do you guys think people will have learned real mathematics from the groups?*

Milly (year 6) *- Yep, sure.*

After lunch I asked the students to put up their hands to tell me what they had learned today in their mathematics groups:

Ben (year 6) *- I learned 450mL is the same as 450 cm3.*

Kaidance (year 6) *- You know how no one thought that 1 litre would come out of the water (displace) if you put a thousand cube in it. It did. You have to make it to believe it and I proved it.*

Mary (year 6) *- I learned how to use a displacement tub. I'd seen these and used them for other stuff but didn't really know how to use it properly.*

Stephen (year 6) *- It was interesting to see that wooden MAB blocks didn't sink, they floated. We tried different ways to get them in the water, but none really worked.*

Jeff (year 6) *- My mouth holds more water than anybody else in the group.*

This episode was a powerful indicator to me that students were engaging at different levels within the concept area.

These activities provided a stimulating environment that involved resources that students were surrounded by in their school environment. It was through these activities, investigations, questions and interactions that I started to experience the current conceptual understandings of the students. It also caused an awakening in me that viewing these two focus areas (developing meaningful communication, and real-world learning activities) in a synthesised manner, and not as separate activities, could be a beneficial constructivist approach.

Mary's observation that she had used a resource (displacement tub) for activities other than measuring displacement was evident in other groups. I observed Ben, Chris and Tim as they researched the history of measurement (Personal Journal, 9/9/10). The students had come across an image that showed how bow calipers and inside calipers (although they were not named in the image) measured different objects and spaces. Ben came over to me and asked me to look at the measuring devices. I took this invitation as a request for me to explain to him and his group all that I knew about calipers (which was not very much). I had again walked into the group as the expert ready to transmit knowledge to these students. The thought of me asking them questions still did not occur to me. The behaviourist view of my role as a teacher was still evident in my teaching. I didn't believe that there was anything that Ben or his group could offer in this discussion. Discussion? There was no discussion.

Ben patiently waited until I finished and asked if he could get the school's pair of these 'things' and look at them. Ben told me he had seen them in the mathematics resources area, and had played with them in another class, but now wanted to use them to measure things in the classroom. Ben retrieved both the inside and outside calipers and commenced an investigation with his group in an attempt to understand how they worked. This group continued to report back to the class over the course of the week, which included how the calipers were used and what sorts of things the calipers measured. I hadn't realised we had these resources in the school.

Many students benefitted from these group reports (as I did) and the calipers were made available in the classroom for students to inspect and use.

Further, students discussed measuring devices at home and reported their parents owning calipers. On occasions students brought to school measuring devices used at home. Students, such as Ben, provided helpful insights and experiences that could be used by the group and shared with the class in a truly real-world collaborative context. In this instance it was the use of real-world tools and implements that was the catalyst for meaningful discussion that benefited the class as a whole. A light was starting to burn more brightly in my pedagogical wasteland. These students did have something to offer, and I needed to learn how to access their information. Scrawled across my personal journal (9/9/10) in capital letters I had written ' LESS OF ME MORE OF THEM!'

As my understanding of the notion of real-world learning experiences developed and students improved their skills in measuring length and area, I introduced an activity that I hoped allowed the students to work for a sustained period, as was in keeping with the characteristics of real-world activities (see Chapter 3) (Herrington & Herrington, 2006; Mantei & Kervin, 2009; Oblinger, 2007).

Students were required to apply the skills they had been developing to the problem of completing a quote for the re-carpeting and painting of the classroom. This task required students to use real-world resources and instruments to measure real-world objects and solve problems using the resources available. Students brought to school pamphlets from local media that advertised carpets and paint. They also brought in sample paint strips from hardware stores. I incorporated an Internet research activity where students investigated carpeting and painting. Some students discovered paint coverage on corporate sites and in advertisements while others found underlays for carpets. Discussions were held about these findings and insights, and understandings developed. Answers from me were becoming less expected as the students themselves became increasingly involved in the activity. Audiotapes (2/9/10) indicated that I had started to listen more to groups as they engaged in activities. The audiotape records a teacher who ceased joining group discussions to solely provide solutions and preferred problem solving methods and strategies for students to use.

This newly emerging teacher collaborated with individuals and the group and listened to ascertain what their thoughts and understandings were and where guidance could be best used. I was realising that while my input could be extremely important, so too was the input of the students.

> Chris asks me if they (his group) have ordered enough carpet for the classroom. 'Well I'm not sure' I reply, 'that depends on the size of the classroom'.
>
> 'We think it's about 42 square metres' says Ben.
>
> 'Then how much carpet will you order?' I ask the boys.
>
> 'Derrrrrr! 42 square metres', Chris tells me in a sarcastic voice. (I know that the room is approximately 7 metres by 8 metres and that amount of carpet wont be enough.) ' How did you work out your area?'
>
> 'Are we wrong?' Andrew pleads. ' What did you get? I thought it was bigger but I'm not sure. Lets check it again, because I didn't think it was right.'
>
> 'How many people measured the room?', I enquire of the boys.
>
> 'We all did' states Tim.
>
> 'But I thought we measured the length wrong because we didn't go under the computers' (the computer tables are at the back of the room and could affect an accurate measurement) adds Andrew.
>
> Audiotapes (2/9/10)

The boys go back and measure the room again. They are particular about measuring under the computer tables. Chris goes on the ground and moves under the tables to the back wall. He holds the metre rule against the back wall while Andrew marks the length.

In group-sharing time, I ask the group about their method of measuring under the tables. As Chris explains what occurred, the hands of a number of students go up immediately, requesting time for input into the discussion. After the boys complete their input I ask Brie to share her thoughts on the boys' method.

> ‘We shut the door to the computer lab (at the back of the room next to the computer desks) and measured from there. It’s the same distance as under the tables but easier.’

A chorus of agreement meets Brie’s suggestion; others explain how they too measured from the back wall but from different places along the wall that were more easily accessible.

> ‘I like going under the tables’, retorts Chris, ‘It’s fun’.
>
> ‘So boys, how much carpet are you going to purchase?’, I ask.
>
> ‘60 square metres’ answers Tim. He explains that they had measured the room correctly (7 metres by 8 metres) but multiplied incorrectly (Personal Journal 3/8/10).
>
> Oh, and the extra 4 square metres was for mats and repairs that Chris’s mum had ordered when they recarpeted the lounge room at home.

Students’ initiatives

As student communication developed and their lack of formal experience with everyday measurements became apparent I brought more of the school’s resources into the room. Just as the calipers proved to be an effective measuring resource once the students were aware of them and how to use them, students were invited to bring to school containers for display in the class. Students brought to school and labelled (1000 mL, 1 Litre, 150 grams) a variety of liquid containers of different sizes. The students velcroed them to the classroom walls for student referral and consideration. Students asked to display (velcro) a 30cm school ruler and a metre ruler on the wall so that they could refer to them. The students thought that having them on display helped them to access and estimate measurement more easily (Class Discussion, 14/9/10). Students also suggested to me that we should display cm^2 and m^2 as they found the items displayed in the room useful when they had to imagine areas and the measurement of area (Personal Journal 14/9/10). The students were devising their own scaffolds to assist them to move from concrete to abstract thinking. They were very much determining their learning environment.

It was shortly after the cm^2 and m^2 had been displayed around the classroom that some students asked how many of the cm^2 covered the large m^2. I am pleased to report that I did not answer them directly, but instead used this as an opportunity for an investigation that occurred within the usual measurement activities. The students agreed that they wanted to investigate this problem and we assigned the task for the following week as a rotational activity.

I asked the students to estimate what they thought was the answer and to discuss their thoughts in their mathematics groups. Discussion revealed difficulties in estimating a large area using a small unit. One group attempted to use the 'length times width' formula that they had investigated in their area activities in previous weeks. During the class discussion it became apparent that many students experienced great difficulty when attempting to multiply in units of 10. This particular group and class discussion highlighted the need to work with the students in multiplying by 10, 100 and 1000 and investigating the patterns of such multiplication. Further, this emphasised the value of collaborative and small-group discussion in identifying concepts and areas for future mathematics lessons.

When the groups worked on the investigation in the following week they used a variety of methods (Personal Journal, 20/9/10). Some groups drew an area of 1 square metre with chalk and placed 100 multi-attribute blocks within the chalk and counted them. Another group asked me to provide them with photocopies of the 1cm grids in their mathematics workbooks so they could place them on a piece of cardboard that was 1 square metre. My journal entries take note of the heightened engagement of students that I put down to 'their approach to solving real problems' (Personal Journal 23/9/10). I was starting to see a development in the responsibility of students as they played an ever-increasing role in the determination of the activities and concepts in negotiation with me.

The accuracy of mathematics in primary school

The questioning of the accuracy of mathematics came to be a significant factor for all the class.

But it was of particular interest to eight students who after some unsettling experiences in measurement wanted to verify all measurement devices in our school for accuracy. They pondered the problem of knowing if any instruments were accurate and the validity of checking one device against another.

> 'What if they're both wrong', exclaimed Arthur who seemed to enjoy the fact that everything was not as certain as he was led to believe.

This awakening, regarding the accuracy of mathematics resources and instruments, occurred in the class activities that focused on students drawing a square metre and covering it with square centimetre grid paper. The lesson formed the catalyst for a discussion about the accuracy and the truth of mathematics. After one group of students made mental calculations of the amount of square centimetres in the square metre, the students drew a square metre using the classroom metre ruler on a large piece of cardboard. They set about covering the square metre with cubic centimetres multi-attribute blocks (MAB), hypothesising that there needed to be 10 000 to cover the square metre. As resources were short the students used the 100s MABs, 10s MABs and the ones MABs. Many students were happy to have approximately 10 000 MABs cover the square metre but eight students were perplexed that there were less of the blocks needed than was expected. A transcript of group work (25/8/10) presents these student insights:

Arthur (year 6) *– This can't be right, there isn't 10 000 squares.*

Ben (year 6) *– We must have measured the square metre wrong because its definitely 10 000 I checked it on a calculator.*

Brie (year 5) *– But you could have got that wrong, I'll check the calculator, can you check the square is right?*

Thomas (year 5) *– '100, 200, 300, 400, 500, 600, 700, 800, 900, 1000, 2000, 3000, 4000, 5000…. (Thomas adds the row of 100 MABs then adds rows of 1000) He rounds the area up to 10000 but then acknowledges that it is less because some of them are over the outline of the square metre and shouldn't be counted.*

After some checking and cross checking the group continues their discussion.

Arthur (year 6) *– No it's wrong. There's not enough little squares.*

Stephen (year 6) *– I counted the squares and there is about a row of 10 missing from the bottom. So about 90, no 100 short.*

Arthur (year 6) *– I'm checking the ruler.*

Ben (year 6) *– That's the class ruler, its right.*

I left this group to continue their investigation of the square metre. The group discovered that the wooden 100 MABs were not exactly 10 cm square, and although only out by a few millimetres, this was enough to make a difference when added as a total. From this point on these students checked the accuracy of every measurement device they used. Firstly, the students checked their own 30cm class rulers. They measured the 1cm grid paper in their mathematics books and cross-checked the class metre ruler against their rulers and the grid paper. They set about checking if the wooden rulers were the same as the plastic rulers. The issue of the accuracy and certainty of mathematics spread across each sub-strand, and few lessons were conducted without comment being made regarding accuracy.

When we investigated the mathematics sub-strand of mass, Stephen and Ben found the scales used to measure their own mass provided different answers. Stephen found his mass to be recorded as 30 kgs on one scale and 35 kgs on another scale (Audiotape, 14/9/10). This presented an opportunity for the group to check that the scale initially read zero and was adjusted as required. The students decided that this reading needed to be checked before any measurement could be accurately made. However, the scales still reported different results, and the group considered how they could ascertain which scale (if any) was accurate. The students made a presentation to the whole class about their experiences, and this created further discussion about any claim made regarding absolute accuracy within the classroom.

When the students were working on completing a measurement activity, I had told Arthur that one revolution of the trundle wheel was the equivalent to one metre in length. Arthur found that the revolution of different trundle wheels resulted in different lengths being recorded and that none of them were the one metre.

Many students in the class attempted to check the measurement of the trundle wheel, and the method of measuring a circular shape proved to a worthwhile group activity.

Emily, Mary, Kate and Milly became quite interested in the problems that measuring a circle posed them. I watched with interest as they tried to use a flexible rubber ruler and string to measure the distance around the trundle wheel. Arthur explained to them that he had marked a spot on the ground and when the wheel made a full revolution he marked that spot on the ground and measured the distance between the two marks.

These students continued to investigate the circle and allowed me to arrange a series of activities for them to complete that led them to investigate the formulas for the circumference of a circle. The students remarked that having a variety of methods to measure gave you confidence in your answer if they were all very similar. This was a further example of the students developing a meaningful understanding of a concept, as opposed to them listening to me state the fact for them. My input as to the direction of the investigations became less and the students' input increased. I was able to witness first hand some of the more 'difficult' aspects of a constructivist learning environment developing before me.

Constructivist Assessment

Mathematics assessment prior to implementing my constructivist pedagogical changes consisted of diagnostic texts found in mathematics textbooks. These were used at the conclusion of the term's work. Additionally, I created a Friday weekly assessment, of approximately five questions, that covered the mathematics concepts explored that week. I also used anecdotal records of my observations of the students throughout the term. Results of these assessments were recorded in spreadsheets, and graphs of student performance were generated. My anecdotal records generally recorded areas that I had perceived as weak or strong based upon student responses to verbal questioning in class. If a student gave an incorrect answer to a question this was duly noted. However, the students' current understandings, including how they arrived at an answer, were not recorded. These records were used to supplement my quantitative records from the spreadsheet.

These weekly assessment tasks were purely fact-based assessments that asked students to calculate or recall 'times tables' or formulas. Students were given a mark and this was recorded in an assessment folder and used for grades and report cards that made use of a common grade scale from ' (A) to Limited (E)' (see Appendix D). I used assessment tasks to record students who were experiencing difficulties in particular concept areas. I recorded these students in my program so that they could be assisted when those types of skills and knowledge were required in later lessons.

The interviews I conducted with students in week 4, term 3, provided me with insights into their views regarding assessment practices in the class. Bronwyn, Brie and Nathan confirmed that they did not believe they had any involvement in designing class assessment tasks. After hearing the students' view I put the class assessment procedures up for discussion in the class collaboration at the end of the mathematics activities during that week:

Teacher *- Do you remember the question in the survey (CLES) about me letting you make decisions about your assessment?*

(general chorus of Yes)

Teacher *- How could I involve you more in the class assessments?*

Madison (year 5) *- I think we should get the assessment back so we can look at where we went good and bad.*

Arthur (year 6) *- Yeah, can we see the assessment?*

I was struck dumb by these students' suggestions. It was at this point that the notion of assessment as understood by me became perfectly clear. This was an assessment for me and not for the students. The idea that the students wanted to know how they went in the test and perhaps to ask questions of their peers and me, was clearly not as important to me as my desire to have quantifiable statistics recorded for the purpose of reporting to parents. We immediately decided that assessments be returned to students for their consideration. Structures were developed to allow students time to review their answers, and to seek conceptual development using their peers, other classroom resources or myself.

Time was allocated on Friday afternoon or Monday, after the assessments had been corrected, for students to review their results. However, my enlightenment about assessment from this student interview did not end there:

Mary (year 6) *– Could we make a comment at the end of the assessment like 'I'm having trouble?*

Milly (year 6) *– Yeah, at the bottom of the maths sheets, kids could write down where they are having trouble.*

Arthur (year 6) *– If 10 people don't know something they need to know then you have to help.*

Leigh (year 5) *– You could take them at lunchtime.*

Thomas (year 5) *– Or when they are going good at something you could take them then.*

Milly (year 6) *– You could take them down to the floor when others are learning different things.*

The students seemed to have a better understanding of the value and use of assessments within the learning cycle than I did. They understood the need for conceptual development and were offering alternative solutions. It was again obvious the practical value that arose from bringing students into the discussion regarding their learning. It also served to remind me of the pedagogical implications of allowing assessment and reporting to impact on teaching and learning. I needed to make assessment part of their learning, and not distinct from it. They do not need to be mutually exclusive and serve to show the added value of embedding the assessment within the teaching and learning activity. I came to the belief, after reflecting on my teaching experiment, that I had moved assessment to primarily an isolated action. I had also isolated the assessment results from teaching and learning.

A number of students expressed the belief that the setting of assessment tasks could not involve students as it defeated the purpose of them. When I asked students if they could be involved in setting an assessment task I received an insight into student beliefs about assessment:

Bronwyn (year 6) - *I wouldn't know what we should know and you have to have test secretly because then we would know the answers.*

Kate (year 6) - *You need to check if we have been listening to you.*

Teacher *– Is that what a test is about do you think?*

Mary (year 6) *– If you have listened to the teacher you will get the answers, if you muck around you wont know stuff. All the kids who muck around go bad in the tests.*

Teacher *– Maybe they don't understand the mathematics in class and get confused.*

Mary (year 6) - *and then muck around…. maybe, but you are better off listening.*

(Personal journal, 12/8/10)

Further discussion on assessments occurred in week 4, term 3, regarding how the students felt my Friday assessment could be improved. I did not consider removing this assessment or replacing it, but rather sought student assistance in improving this fact based, behaviourist, and summative assessment. Some positivist influences remained, anchored to my epistemic beliefs:

Kate (year 6) - *Can we assess ourselves on the Friday assessment?*

Arthur (year 6) - *We can tell you how we think we went, what we know and don't know about stuff.*

Milly (year 6) *– There are lots of things we learn but you don't ask us about it.*

Jess (year 4) *– If we have the test and you ask us about things we don't know what are we supposed to write down? In the test you are going to mark something wrong but I don't know what I did wrong. You should ask us about the things we learned not the things we don't know yet.*

There appeared to be a desire of the students to provide me with information about what they had learned during the week. I advised the students that I would put a five-point scale similar to their end-of-semester report cards ('Outstanding to Limited') at the bottom of their Friday assessment. This could be used for students to indicate to me their understandings of the mathematics concept covered that week. Additionally, a few lines were made available at the bottom of the assessment for student comments about the assessment and their conceptual development.

That all seemed simple enough, and showed the benefits gained from hearing the students' opinions and views.

The error of this assumption is discussed in Chapter 6 when the students discuss with me the meaning of the 'Outstanding to Limited' scale that I used for reporting on their learning. Concerns about the students' understanding of the 'Outstanding to Limited' scale should have been identified at this point; unfortunately, I provided the answer to the students' problems, when in fact they had a more workable answer. I just didn't ask them. I had discussed with Kaidance the opportunity I gave her to complete a school report on herself, so that she could tell me how she thought she was going in class:

Teacher *– Kaidance, you have recorded that shared control of the classroom didn't happen a great deal in the class. Can you tell me why you scored it the way you did?*

Kaidance (year 6) *– You said it was about us planning what we do in class. But that doesn't happen much. You say we have to follow that book about maths (Syllabus).*

Teacher *– What about tests and reports, I gave you the report card to fill in about how you think you went?*

Kaidance (year 6) *– That was boring, it doesn't have how I went only all the letters (*'Outstanding to Limited'*). Everybody thinks they are an Outstanding, but they aren't.*

Teacher *– Do you think you are 'Outstanding' in maths?*

Kaidance (year 6) - *Nah. I'm pretty good but not the top, others are smarter than me.*

Teacher *– But if I think you are a 'Sound' but you think you're a B doesn't that give you a chance to tell me.*

Kaidance (year 6) *– Yeah I suppose so, I didn't think about that.*

(Audiotape, *25/8/10)*

This discussion should have alerted me to Kaidance 's and possibly the class' understanding of the *'Outstanding to Limited'* scale for reporting achievement. Unfortunately it didn't.

From week 5, term 3, in addition to the students answering questions I set them about a mathematics concept, I invited them to write about or draw an illustration of something they had learned in mathematics that week and to complete the 'Outstanding to Limited' scale.

This was an attempt to allow the students to share understandings/knowledge/skills that were not covered in my specific assessment questions. This was designed for students who felt that the questions did not reflect their understanding appropriately. In the first week of this approach, 11 students used this optional element of the assessment.

I was being provided with insights about students that I had not previously experienced. At times I nominated understandings within particular sub-strands (area, volume) and other times I used the general heading of mathematics. Generally, all students used this aspect of the assessment, and this particular approach was to prove effective in eliciting valuable information from the students and showed me clearly the aspects of mathematics that were noteworthy to them:

Arthur (year 6) *- I learned that square centimetres (in mathematics book) are not a centimetre by a centimetre they are about 2 millimetres off. And there are 10 000 so called centimetre squares in a square metre (maths assessment week 5, term 3).*

Sarah (year 5) *- The ruler doesn't start at one so you don't measure from it. You start at the little 0 (week 5, term 3).*

Andrew (year 5) *- Mass is not the same thing as volume but I'm not sure why (week 9 term 3).*

Leigh (year 5) *- I weighed the same when I put only one foot on the scales (week 9 term 3).*

Leigh (year 5) *- I learned that measurement can be time (Leigh was referring to the timing of the maths activities rotations and the fact that time was a measurement) (week 5 term 3).*

Nathan (year 4) *- I learned that 1 cm equals 150 cm2 on a space shuttle (week 6 term 3- scale lesson).*

Madison (year 5) *- The playground is way, way bigger than I thought. I didn't know how to measure it before but now I do (week 4, term 3).*

Scarlett (year 4) *– I learned about Greek measurement and the metron (week 3, term 4).*

Mary (year 6) *– Length X Width = Area (week 9, term 4).*

Further insights into the students' views about assessment were developed when I asked two groups what they believed we could do for students who did not go well on Friday's assessment. I received a great variety of answers:

Kate (year 6) - *They should go on detention and have to do more work. They are not listening to you.*

Brie (year 5) - *Give them homework on all the things they get wrong and let them all work together.*

Nathan (year 4) *– You could put those who have trouble with people who know what to do.*

Ben (year 6) *– You could do the questions again with a friend and see if you can get better.*

(Personal journal 23/9/10)

There was certainly a realisation from the students that peers could assist in developing conceptual understandings. At no stage did students suggest that peers should give them the answers, but there was a belief that working collaboratively could assist in developing deeper understandings. Kate's belief that students who fail the assessment are not listening to me provides some further understanding of the didactic role some students continue to believe the teacher has in the room. This was a role that I was initially only too happy to confirm for them with my constant lecturing.

The relevancy of assessment attracted great attention in week 7 of term 3. The students had worked on moving towards the mathematical formulas for establishing volume and capacity. The class had completed activities outside of the classroom using regular 3D shapes and measured volume and capacity using water, containers and multi-attribute blocks. In the last week of their investigations they compared their findings with the use of V = L x B x H.

I presented the students with an assessment worksheet on the concepts for them to complete which was based completely on the use of the formula for volume. After I had marked the assessments and returned them to the students for pair discussion and then class collaborative discussions, the following exchanges took place:

Teacher *- How was this week's assessment boys and girls?*

Kate (year 6) *- Stupid. It was boring.*

Brie (year 5) *- It was ridiculous. No water, no blocks, no outside. This week was fun but that wasn't.*

Nathan (year 4) *– We are learning everything out there (outside) then we have to put it on a piece of paper.*

Ben (year 6) *- I got 2 out of 2 for volume but I don't get it. I just multiplied numbers.*

Nathan (year 4) *– When you're outside there you're actually not being shown how to do it you're figuring it out yourself, instead of trying to write the rules. (After discussing his comment in an interview, Nathan said he had completed the mathematical formula but felt this didn't show his understanding).*

(Audiotape, 3/9/10)

The students were showing discernment between following rules in completing a mathematical formula and having an understanding of a concept.

My reflections at this time showed an apparent contradiction between my formal assessment of their understandings and what I was hearing from students in their explanations and thoughts. My formal assessment of volume and mass had shown almost all students to have a sound understanding of these concepts. 'How can this be?' (Personal Journal, 10/9/10)

I found that the students knew how to multiply the dimensions given to them in questions of area and volume. I asked two students to explain their confusion with the concepts of mass and volume compared with their ability to obtain correct answers in worksheets. Interviews (19/9/10) with a group of students confirmed this apparent dilemma between my assessment and their understanding.

Tim (year 6) *- You just multiply them (length, width) or in the tables you fill out the numbers that make the answer correct.*

Andrew (year 5) *- They're easy you just do multiplication and you get the answer and fill out the table.*

Arthur (year 6) *- All I know is you just multiply the numbers and then guess the missing one by trying other numbers.*

Kaidance (year 6) *- You don't have to read the question, you know what you have to do, they're easy.*

The 'tables' the students referred to were the common volume questions that present columns with length, height, width and total mass or volume. The question provides three values and asks the student to work out the missing value. I found that students answered these questions almost perfectly. My increasing request of students to express their understandings shone a light on my assessment practices and the conclusions I had been drawing from them.

Unfortunately this insight did not fully develop until term 4. At the conclusion of term 3 (Personal Journal 26/9/10) I recorded this contradiction as 'strange'. The notion of the acquisition of knowledge and considerations of what is meant when we say we know something was starting to be critically considered in my deliberations about my professional practice. How could a student get a near perfect score in a test but not be able to express an understanding of the concept? I didn't have an explanation at that time, but this led to a review of my own understanding of knowledge and the claims I was making about a student's knowledge.

The idea that students could get the 'right' answer by following a formula, yet have no understanding of the concept was further supported by the students who were asked over a two-week period to define the terms volume and capacity. This was generally completed very well with students recalling a rote-learned definition. The following week students were asked to write or draw how they measured the mass and volume of a rock. Eight students were able to provide the correct definition. They also answered questions requiring the application of a formula or reading the level of a displacement tub. Interestingly, the same students wrote that both volume and mass could be measured when the rock was put on scales.

With respect to area, 10 students could not calculate area when presented with the dimensions of various rectangles; however, each of these students was able to calculate area when rectangles were presented on $1cm^{2\ grid}$ paper. In both cases the full extent of a student's conceptual understanding could not be fully assessed through the use of my pen-and-paper assessment; however, coupled with a qualitative assessment a more detailed picture began to emerge.

In the volume and capacity assessment (week 7, term 3), Jess and Sarah did not perform very well. When the assessment was returned to them they asked if they could take the test paper outside and attempt to answer the questions whilst using the resources and equipment outside. They took with them a learning buddy (Mary) and spent 25 minutes working their way through the questions. On returning to class, both students and the learning buddy agreed that the hands-on aspect was much easier to complete than the pen-and-paper test.

Mary acknowledged that when she assisted the students in understanding what was required of them it was easier to explain with the concrete resources rather than with the pictures on the worksheet. Mary also noted that the students seemed to 'get it' when they had the resources to help them.

Student journals also served to provide an avenue for students to externalise their understandings and concerns within the mathematics sub-strands, which allowed me to delve deeper into their currently held conceptual understandings. It became common for students to self assess their mathematical knowledge and to write comments that guided my future lesson planning:

Jess (year 4) *- I learned that times tables are useful in area, but I need to do better with my times tables (Student Journal 3/9/10).*

Andrew (year 5) *- Capacity and volume are very close, but I know why mass is different and I didn't use to know that (Student Journal, 10/9/10).*

Tim (year 6) *- I understand the paint coverage on the tin, because we measured the walls in the same way in square metres (Student Journal, 3/9/10) (- This referred to the advertised paint coverage indicated on the tins of paint used for the classroom paint quote activity).*

It was through the development of a constructivist learning environment that the opportunity to gather assessment information became more and more apparent. I am not sure that this quality of assessment information is available, or at least not as visible, when students are only answering questions in textbooks. Discussion is by nature an externalising of conceptual development that is now visible for all to see. Whilst this can be a threatening experience for students it provides insights for the teacher's pedagogical plans (Windschitl, 2002).

Term 3 - A Reflection

Term 3 raised in me a critical awareness of my beliefs about knowledge (epistemology), and my current and preferred teaching practice. I proved to be largely a behaviourist teacher and my term 3 experiences had shown an initial preference for transmitting knowledge to students.

Additionally, my classroom experiences throughout the term led me to believe that I was also a behaviourist learner. I committed to memory the names and definitions of important concepts and terms, then recalled them (rote like) when required. It was as a learner that I saw more clearly the difference between a behaviourist and a constructivist. With respect to all the key concepts of constructivism I possessed a shallow understanding. Scratch beneath the surface of the definition and I was found to be unclear about what I was trying to do.

Given this existing position, it was not hard to see why, when asked to apply my knowledge, I experienced difficulties implementing changes. I was without any real belief in the theoretical underpinnings of the pedagogical changes and, like so many teachers before me, I attempted to apply constructivist strategies with a behaviourist perspective.

However, in recognising these inadequacies, I had started on the road to a deeper understanding. This developing reflection upon my practice and beliefs was a positive development.

The skill of meta-cognition and self-reflection and awareness was a significant development in my teaching practice that continues to serve to benefit me as a professional each day. Throughout term 3, I continued to read about constructivism and how it could be applied to the classroom. I continued to review my identified constructivist principles and considered how these were evident in what I was trying to do.

The changes that were occurring in the classroom made me consider the term 'referent' more closely. For me, a constructivist perspective or referent was going to become the bridge between the use of discrete teaching strategies and constructivism as learning theory (see Chapter 6); I just didn't know this at this time.
I was beginning to converge on a synthesised understanding of theory and practice. My term 3 experiences show my growth in the use of a constructivist classroom perspective and the development of the pedagogical changes in the classroom.

The notion of 'theory-practice gap' (Allsopp, DeMarie, Alvarez-McHatton & Doone, 2006) was not something I was familiar with at that time, yet it was something that I was experiencing each day of my proposed pedagogical changes. My developing reflective practice had identified this gap in professional practice, I just wasn't aware of the universal acknowledgement of this as a significant problem for teachers. Having started to identify some of the difficulties I was able to target my academic readings in an attempt to understand better my experiences.

My constructivist focus areas (see Chapter 4) had seen a process of introduction, reflection/review, refinement and further reflection. This was a sound basis to implement further changes and provided for significant and meaningful development of my practice and understanding. As a result of the application of theory to practice I started to see how these changes looked in the classroom. The students proved to be a major factor in my pedagogical development, as their interaction with and discussion of my changes brought a much needed second opinion, or multi-perspective, to the study. An appreciation of the benefits that could be gained from inviting students to play a meaningful and active role in my classroom had taken root. I started to see their involvement impact on assessment, seating, teaching and learning activities and programming. Initially I wanted to ask their opinion because

that is what a constructivist teacher does. However, I hadn't at that early stage given any consideration to the value that could be gained from their input.

I felt that my constructivist changes within the focus areas had started to be implemented. Further review and refinement was the goal of the next term.

Constant evaluation of my practice was needed to ensure that when I sought to implement a more constructivist approach this was done free of behaviourist influence or a least with a recognition of the influence it could bring to my teaching. More was to be achieved as the move to a deeper understanding of constructivism as a referent for teaching evolved.

It was the growing realisation that I had a great deal more to learn about constructivism and many of the practices that fall under the constructivist umbrella that allowed me to grow in understanding and effective implementation of a more constructivist pedagogy. The term 3 break allowed me time to reflect on my practice and my scholarly readings as I sought to become a more effective teacher.

At times I felt lost in my pedagogical change process. Unsure of the most effective way to implement the changes, and uncomfortable when I seemingly, became less influential in the classroom activities. This too was a misunderstanding of my role in the learning experiences of the classroom. I was, in fact, reducing certain aspects of my teaching while I increased others. I had used my voice and my thoughts almost exclusively throughout the day. As I listened more and considered the students' feelings and perspectives I was able to realign the aspects of teaching used in my professional practice. I was beginning to understand the 'why' more substantively and subsequently I started to adjust the 'how'. This approach brought the powerful concept of epistemology firmly to the forefront of my thinking. I was now able to reflect on my professional practice in theory and practice. I was able to make the next step as I moved in to term 4.

CHAPTER 6

MY CONSTRUCTIVIST TEACHING EXPERIMENT - Term 4

Introduction

The preceding chapter examined my initial efforts to introduce constructivist teaching strategies into my classroom. The learning environment was changing - some planned, some unplanned, but nevertheless it was changing. My previously identified constructivist pedagogical focus areas (see Chapter 3) began to evolve as I continued to implement and refine them. I too was changing. The realisation that I was not completely 'on top' of this constructivist teaching concept became increasingly apparent. During the term 3 break, I rushed back to my scholarly readings endeavouring this time to read for deeper meaning. I listened to audiotapes of term 3's lessons and I reviewed student and teacher journal entries, seeking a deeper understanding of constructivist practice. I realised that my ability to recite the definition of terms such as pedagogy, referent, epistemology, real world, collaborative and constructivist was a living example of how a person can appear to be quite well informed yet have a shallow and limited understanding of a profound concept.

Constructivism was becoming a referent for my teaching, but not quite yet. The move from the theory of a teaching perspective to its use in practice had commenced in term 3. The more experiences I had with the application of constructivist strategies the more my understandings had grown. However, I still had the underlying belief that so-called constructivist teaching strategies necessarily constituted meaningful learning experiences for students. Although, at the end of the journey, I was able to denounce this belief, I wasn't always able to stop myself from seeking a prepared 'constructivist' lesson. Nevertheless, each foray into my constructivist pedagogical focus areas (see Chapter 3) provided me with practical experiences of what to do and what not to do. Term 4 was to be a success, one that was built on the foundations laid in term 3.

The first section of this chapter describes my continued efforts in developing my constructivist teaching in relation to my identified constructivist focus areas, the first of these being the creation of a collaborative learning environment and meaningful communication through group learning. In term 4 the seating arrangement returned to the original horseshoe/conference style seating. Mathematics groups were maintained but not as a permanent arrangement for the entire school day. Indeed, the seating arrangements became more flexible allowing for the emergent needs of the individual, small-groups and the whole-class.

The second section considers the relevance of mathematics learning experiences to the lives of the students. My strongly held belief that textbooks should not be part of a constructivist classroom is abandoned. Similarly, the use of a greater range of resources used in the world out of school is emphasised and encouraged. The idea that it is the use of the resource and not the resource itself that is important is identified. Increasingly, as the learning experiences become episodes that happen with children, rather than to children, students' involvement is accentuated. The students begin to critically review concepts and ideas that are put before them. Students seem to feel that they can initiate learning experiences as part of their mathematics lessons.

The third section records my grapple with assessment in the classroom and my understanding of it. My behaviourist desires to place students neatly into assessment categories and to have them self assess using this system is confronted. The clash between my behaviourist epistemology and my constructivist ideals becomes evident as I try to implement a constructivist assessment practice (i.e., self reflection) using a behaviourist tool (i.e., A - E categories). My abandonment of this strategy is a sign of the distance I have come during this research. I recognise the situation and am able to reflect critically on the assessment's worth and viability in relation to what I want to achieve.

In the fourth section I present a reflection of the episodes that occurred in term 3. I reflect on the changes made to my pedagogy and the effects these had on my professional practice and the classroom.

Creating A Collaborative Learning Environment And Meaningful Communication Through Group Learning

Deep considerations about the make-up of collaborative and co-operative learning groups were not paramount at the time of my pedagogical planning. As discussed previously (see Chapter 3), because collaborative group learning was a common characteristic of constructivist learning environments in the literature I was convinced of the need for collaborative groups. It seemed to me that group learning was a requirement of constructivist teaching, and so I arranged the students into groups (see Chapter 5). However, my desire to foster student collaboration through permanent group seating had, inadvertently, trampled over student self-direction and autonomy. By failing to adequately explain my reasoning to the students and, indeed, by failing to include them in my planning of their learning environment I had ignored their needs and reduced them to passive receivers of my teaching strategies.

Furthermore, if the view is taken that small-group learning will be necessarily beneficial to student outcomes; an intention to group students only on their year group without consideration of student ability fails to take into account the research presented in the National Numeracy Review Report (Commonwealth of Australia, 2008). The report claims that ability grouping, or streaming, can have a detrimental affect on student achievement and motivation. Placing students in groups based on their year level is not a position supported in the research cited by the review where grouping of small heterogeneous groups is strongly recommended. I came to realise that it was important that I learn to ask myself what evidence I had to support any pedagogical changes in my classroom. This evidentiary practice slowly developed as my research continued. To this day, I reflect on all the practices that I use in the classroom (new and old) and ask myself why I use them.

My journal reflections at the end of term 3 (27/9/10) prompted me to ask how my teaching changes related to the first principle of constructivism, as identified by von Glasersfeld (1996). Specifically, I reflected on how the enforced group seating arrangements assisted students to construct their knowledge.

I realised that there was no need to have students learning in small groups for the entirety of the day, nor was there a necessity for the students to learn in small groups for every mathematics lesson. I found that permanent group arrangements are not a position supported in any of the research I had read.

When I look back on this earlier emphasis of my pedagogical transformation I am astounded by my refusal to understand collaborative learning as anything other than small-groups of students collaborating. Davis and Sumara (2003), Walshaw and Anthony (2008) and Windschitl (2002) identified both small-group and whole-class discussions as being examples of collaborative learning. The importance for these researchers was not the structure of the groups but the practices encouraged and displayed in the collaborative activity.

Seating - Back to the future

I believe that the initial change to classroom seating arrangements in term 3 detrimentally affected not only communication, but the legitimacy of the students' expression of a critical opinion.

This enforced pedagogical change had significant ramifications for the students. It was a decision that I initially made without consultation and I was not willing to engage in conversation about my reasons for making the change. The fact that in term 4 we changed back to the original seating went someway to redressing the perception that students' views were not important to me.

In an interview with Year 4 girls (15/10/10) I asked if they were happy about the change back to the horseshoe seating arrangements.

Sammy year 4 *- I told you this was the best way, but you didn't listen. Now we are back there again. It was a waste of time all that…. when you changed us.*

Beth (year 4) *- I don't think anyone liked it. But at least we went back. I like this better. It was hard to read and work quietly.*
Teacher *– I wanted to see if the groups worked that way. You like the maths groups don't you, they help you understand maths better?*

Beth (year 4) *- Yes, it's fun and people help you and I help them, but not all the time. I like to have my area.*

Scarlett (year 4) - *What will we do with the maths groups now?*

Teacher *– Still have them, just form groups when we need to, and we can change the groups if we need to.*

Beth (year 4) - *Can we decide who we work with this time, and then go back to our desks?*

Teacher *– I think that's what we could do, I will ask the class for their ideas too.*

Sammy year 4 *– They all agree with me. No more groups all day, just [for] maths, we promise we'll be good.*

Scarlett (year 4) *– Yes, we promise to work hard.*

And so it appeared for some of the students that I had sat them in groups as a form of punishment for not working well. It was apparent that I had not adequately explained to them why I had changed their seating arrangements. Many students may not have been listening to my explanation but were preoccupied with the new groups and trying to work out whom they sat with.

When the Principal returned from leave we met to discuss aspects of the class. Susan raised the changed seating arrangements with me and asked if I had given it enough time (Interview, 29/11/10). Susan restated her belief that the horseshoe seating was the best for this group of students; however, she was happy to see how the permanent groups functioned. I discussed with Susan my misunderstanding of the collaborative and cooperative groups, and how there was a great deal of research that suggested a variety of seating plans (Hastings & Wood 2002; Sullivan, 2011).

I discussed the manner in which I changed the seating and my indifference to the students' feelings and their learning environment by enforcing this new pedagogical strategy. This was, as Susan put it, the development of experience and, like the students, we hope to learn from actions that do not prove successful. Susan was happy to see me continue with the old seating arrangements and transform the old with the new groups as required.

The following week Susan met with me again and raised the fact that students had expressed to her their delight in returning to the horseshoe seating, and they were happy that I had listened to their concerns and sought their opinions. Susan had told the students that she did not make me change the seating (as some of them felt) and that she was happy for the groups to stay. Students commented to her that being able to communicate with me was a great improvement and they felt very much an active part of the room.

Flexibility and group learning skills

The group learning arrangement became less structured through term 4. The groups from term 3 were maintained, but slowly students gained the confidence to suggest changes to the existing arrangements. I lost my need to maintain strict guidelines regarding the groups and was open to any reasonable request. Groups afforded the students and me the potential for change whenever the opportunity and need arose. Whereas in term 3 I was reluctant to see students change groups, I was now of the belief that this was something that could be discussed. The groups continued to collaborate productively, with my weekly journal entries reflecting my pleasure at the way the groups were operating and how the groups generally remained on task. Students moved into mathematics groups with little or no fuss, and they started to move within groups (change group personnel) in a way that proved to be beneficial to their learning.

Managing the classroom seating organisation had changed from being my role to a student/teacher responsibility. Students went from a rigid and enforced group arrangement to a flexible arrangement that better enabled group and individual learning. The arrangement of groups being assigned learning activities and the groups learning in a reciprocal teaching model was maintained for the initial part of each lesson. I had advised the students that in consultation with me they could ask to change mathematics groups or work alone if that was going to beneficial to them for an aspect of the activity. Students seemed happy to remain in the mathematics groups established in term 3.

I was observing (12/10/10) a group sitting on the classroom floor as they planned how to calculate the surface area of the walls of the classroom when a student, Thomas, left his desk and sat on the floor next to the group of students on the floor. At the time Thomas was engaged with another activity regarding the concept of area. I was about to admonish him and ask him to return to his group when a serious 'bout of constructivism' came over me and I closed my mouth and observed him for a few minutes. Thomas listened to the group's discussion about how much paint they needed to paint the classroom walls. Thomas started to offer to the group his estimates for the area of the wall, which they were happy to receive and discuss.

Later I asked Thomas why he had joined the group for that part of the activity, and he told me that "I didn't get to do that activity last term. I just wanted to listen to how they solved the problem. The question is more interesting when they talked about it". I enquired further about Thomas's comment and he told me that the question seemed too hard for him to answer but when he heard the other students talking about it he understood the question better and that the question was an interesting one (Personal Journal, 12/10/10). Interestingly, when the measurement of the wall was made Thomas's estimate was the closest to the actual measurement and the group commented on how Thomas had arrived at his estimate and how effective his method had been. Thomas visualised square metres across the width of the classroom and its height and counted them in rows using the newspaper square metre that was displayed in the room (see Chapter 5).

My experiences throughout term 4 confirmed that students took an active interest in more than one group activity. Throughout term 4 I recorded 11 occasions when students spontaneously came over to the group I was liaising with to discuss what they thought about the activity and offered their solutions and ideas.

Often students remained in other groups for the period of the lesson, discussing and listening to each other's points of view. It was apparent from student interviews (19/10/10) that students were involving themselves in other groups' learning as well. Scarlett and Beth explained to me that they were listening and watching Leigh measure a wavy chalk line with linked plastic chains, which she laid against a metre ruler to calculate the length:

Scarlett (year 4) *- I wanted to know if she got the same amount (measurement) that we got. We used string. It doesn't lie properly like string so it wouldn't work, I don't think.*

Teacher *- Did it work the way you thought?*

Scarlett (year 4) *- It was closer than I thought, but I don't know who is right.*

Teacher *- Are there any problems using these different items to measure with?*

Beth (year 4) *- That was a different way with the links but you couldn't measure your wrist with it. (Measuring body parts was the activity the girls were on at the time).*

(Interview, 19/10/10)

The girls found some plastic chain links and showed me why they thought it measured their wrists inaccurately. Leigh was listening to the girls and explained that she didn't measure her wrist with the chains; however, she thought the chains measured the wavy chalk line very well. The girls joined together to measure and discuss the different ways they measured length and how accurate the ways were. They compared their findings and re-measured using each other's measurement device.

In an interview (12/11/10) the relieving Principal (Bill) indicated to me that the students were more critical in their group learning than he had previously seen. Students collaborated in completing tasks rather than using the groups as a social activity.

He felt that students were more task-orientated and more collegial than had been the case in term 3. This, he believed, was in response to the change in seating where students could operate individually or in groups, and were not forced into either. Additionally, he felt that the structure of the mathematical groups and using reciprocal teaching strategies was useful in developing effective groups.

Group learning difficulties

As students became more responsible for selecting the groups in which they operated, Madison, Jeff and Toni found that selecting where and how they wished to learn was a difficult situation. Madison seemed to gravitate towards collaborating with students who she said did not make her feel welcome. My interview with Madison (28/10/10) found her to be confused about her role:

Teacher *- Madison you are able to pick a group or form a group that you think will be best for you to work in. But I do want the group to work really well, investigating the tasks.*

Madison (year 5) *- The people I want to work with don't want to work with me.*

Teacher *- You have picked some students who you said don't like you and are not kind to you. Why do you want to work with them?*

Madison (year 5) *- Sometimes they are my friends and sometimes they are stirring me up.*

Teacher *- Perhaps it would be better to work with other students, and keep those students for playtime friends?*

Madison (year 5) *- I don't have others I want to work with. I don't know the others very well. Some are year 4 and I'm not working with them.*

Teacher *- Some of the year 6 students said they would work with you in a group, why don't you try that.*

Madison (year 5) *- They're all smarter than me.*

Teacher *- I would like you to give it a go and work with some of them for a few weeks.*

Madison (year 5) *- No I don't want to work with them. I don't like them.*

I endeavoured to have Madison join groups that might help her develop collaborative skills and understand concepts. However, she removed herself from the group on each occasion and joined with the girls she experienced problems with in term 3.

Madison benefited from having peers to listen to; however, the thought of collaborating with students above her grade level or below her grade level seemed to cause her great concern.

Madison drew the conclusion that some students 'liked making me feel dumb'. She felt that these students gave answers more to show her up than to provide answers to the class or group. Working with students in lower grades confirmed to her that she was dumb.

Toni had found that collaborating with Brie suited her the best. She enjoyed Brie's company and Brie was a very capable student who didn't make Toni feel dumb. However, Brie liked to collaborate with other students, which was not a situation Toni handled well.

Teacher- *Toni, you don't have to work alone. You said you liked to work with Brie, so why not join her?*

Toni (year 5) *- No it's Ok she wants to work with the others today.*

Teacher *- You worked alone yesterday too. Do you think you work better with Brie than you do alone?*

Toni *- Yeah, she's good to work with, but the others I don't think want me to work in their group.*

Teacher *- Did they tell you that, or do you just think that?*

Toni (year 5) *- They work quick and I don't. I like talking to Brie about the stuff but she is busy talking to them in the group not me. But it's O.K., I'm happy here.*

(Personal Journal 5/11/10)

My assessment of the situation was that Toni completed more activities when she was paired with Brie. She benefitted from Brie's explanations and assistance, which was not as easily accessed when she was in a larger group. Toni completed fewer activities when she worked on her own, and as a result I collaborated more with Toni when she was not with Brie.

Brie met with me in week 5 of term 4 to discuss the possibility of working collaboratively with Toni as a pair for one activity a week. Brie thought this was a good suggestion and asked me to explain this to the students she normally worked with, as she was concerned that they thought she was favouring Toni over them. I was happy to meet this request and found the other students happy with the arrangement.

Toni, Jeff and Madison continued to operate within the small-group arrangements. They requested individual learning time more than other students; however, they did complete more of their activities in this term than in previous terms. These students particularly enjoyed individual learning time as a 'cooling off' period. In interviews (4/11/10) with them about how the individual learning was to be organised they told me the following points:

Madison (year 5) *- I like to be able to work alone when the others are annoying me. If they are being nice I can work with them but if they are nasty I can move away. It's great.*

Toni *- I like to work with someone rather than no one. Brie helps me and I like working with her but sometimes others want to work with her and I don't want to work with them. So then I can work alone.*

Jeff (year 6) *- If Chris and Tim are stirring me I can work on my own because I don't have to be with them.*

(Interview, 4/11/10)

My observations of these students noted how they adopted the role of observer and did not often present their ideas or understandings to the respective groups. In group presentations to the whole-class they rarely offered their thoughts or insights. I believe a lack of self-confidence in their ability and in their understanding of concept areas prevented more active involvement. However, my observations noted that these students were active listeners to other students' views. These students presented more written mathematics in their books than had been the case in terms 1, 2 and 3. This bookwork comprised their calculations and answers to questions.

My discussions with these students in the final week of term 4 found that they were becoming more comfortable in learning groups and that they enjoyed the chance to collaborate in learning groups or pairs or to work alone.

Jeff and Toni maintained a feeling of inadequacy when they were learning in 'difficult' concept areas with students who were 'smarter'. Toni continued with the belief that she was dumb if she didn't 'know stuff', and was embarrassed when she had to ask other students for assistance.

It was my belief that Jeff, Toni and Madison were still developing an understanding of 'collaborative learning'. They seemed to believe that they should know the answers to all questions because 'the others know them'. I felt that I needed to develop in these students a better understanding of what learning is, and what their role in the learning process might be. However, I did not find time to develop in them the realisation that learning is on-going and achieved at different levels by different people at different times.

The practice of implementing reciprocal teaching (see Chapter 3) across the school, I believe, had positive effects on the ability of these students to listen to one another, to ask questions of one another and to appreciate the views of others. The numbers of students who found sharing their mathematics learning to be a problem was small to start with, and was generally associated with three students (Madison, Toni and Jeff). These students were given additional scaffolding to allow them to transition to this constructivist strategy. The students acted as apprentices within the groups, listening to others who shared thoughts and their learning.

I asked these students to share understandings and ideas with me, and I paraphrased their understanding in whole-class discussion. These students did build their skills in these areas and they shared positive experiences with me. In interviews during the first week of term 4 I asked students how the group sharing was going:

Madison (year 5) *- I like the group and the people with me, but I don't want to change to other groups but keep this one.*

Teacher *– You thought people wouldn't listen to your ideas, has that happened?*

Madison (year 5) *- It did but not much now, Kaidance helps me too, I tell her about how to work it out and then she tells the others.*

Teacher *- Why don't you feel that you can give your answers and opinion in the group?*

Madison (year 5) *- I still don't want people to know I'm dumb, so I don't tell everybody.*

Toni (year 5) *- I like working with the others because they tell me how they are going to do it.*

Teacher *- Do you tell them what you think is the best way to do an activity?*

Toni (year 5) *- Sometimes if I know I'm right I will tell them, but that doesn't happen often. It's good getting to hear people and I use their ideas and it works.*

Teacher *– Can you tell me something someone told you that you used in the group.*

Toni (year 5) *- I couldn't guess how high the door was without using a ruler but Ben said when he was holding the ruler it came to his waist. So I reckoned it was two of those and it was right. We both were.*

Jeff (year 6) *- I don't know anything, and Chris still laughs when I say something silly. He says I'm an idiot and he and Tim laugh at me.*

Teacher *– You don't have to say anything you can come and tell me or listen to their ideas first, but they shouldn't laugh at you.*

Jeff (year 6) *- You said that and they don't do it when you are there so I don't say anything anymore.*

As a result of these interactions, I moved more often to Jeff's group and spoke with the boys that were worrying him to see if they were helping to make his ideas feel welcome.

Jeff reported back later that he still didn't want to say anything in the group because of the boys. I felt that Jeff was unwilling at that point to take a further risk of feeling 'stupid'. It was a time for Jeff to slowly regain some confidence.

Audiotapes (27/10/10) indicated that some students who attempted to learn in a collaborative situation perceived reluctance from other group members to assist them. Chris and Brie indicated to me that when they asked their group or another group for assistance they were sometimes told 'No' and the others refused to assist them. Both students felt that this was more to do with social factors (Davis & Sumara, 2003), and this indicated to me that I needed to develop in some students and groups the necessary skills for collaborative learning environments.

However, my reflective notes continued to comment on the development of on-task group learning. Students were not completing individual work in a group setting (Davis & Sumara, 2003); rather, the majority of students were explaining and exploring theories and strategies to others and assisting them in using new ways to approach their mathematics.

Students began to share their methods of problem solving and these new ideas were canvassed with other groups as they gained acceptance. This public sharing allowed me to access the students' creation of knowledge and understanding, and allowed me time to probe, through questioning, their understanding and knowledge. In one mathematics session (13/11/10) a group of students, exploring the concepts of mass, considered how they could know the number of small plastic beads needed to have a mass of 1 kilogram:

Jess (year 4) *– I put a kilo weight on one side of the equal arm balance and then tried to balance it with beads but there was going to be too many.*

Thomas (year 5) *– I put 1 bead on all the scales but it was too small and didn't move the scales at all…. it was like nothing.*

Darnell (year 5) *- When we filled the side with beads there were like thousands so it will take a while to count them.*

Ellie - *(working in a nearby group)- Can you help work out what a half a kilo would be in beads?*

Darnell (year 5) - *It's heaps. Too many to count in one lesson.*
Ellie *– What's the smallest weight you can use to get* the beads to balance?

Beth (year 4) *– I tried 100 grams and it was 102 beads.*

The group tried 200 grams, and after balancing the beads, they shared and counted them. The total was 203 beads.

Jess (year 4) *– that's 300 grams is 303 beads, I think.*

Beth (year 4) - *(tallying in maths book) that's 305 beads.*

Darnell (year 5) *– It's about 1 gram for each bead. So we need to know the grams in the kilos.*

Students referred to the measurement chart on the wall and found that 1000 grams equals 1 kilogram.

Beth (year 4) *– It will be about 1000 beads.*

Jess (year 4) *– about 1005, I think.*

(Interview, *13/11/10)*

Diagnostic teaching

My increased ability to move through the groups as a result of the restructured mathematics lessons (see Chapter 5) provided opportunities to model group-learning skills - listening to viewpoints, asking questions, learning collaboratively, reflecting on the activity. Greater student and teacher collaboration improved and developed the communications skills of the students as they cooperatively and productively solved problems and investigated concepts.

As I circulated through the learning groups, I attended to developing students' listening skills and the acceptance of different points of view. I focused on asking each group member for their views and ensured that they were heard.

I felt that it was of great benefit for the students to witness me listening to all views and probing all student ideas and the manner in which I did this.
My increased time with the students in small groups allowed me to develop a more detailed understanding of them as individuals and members of a group. Through more extensive interaction with the students I was better equipped to develop an extensive conceptual understanding of each student. My reflective notes provided me with a more detailed picture of each student. For example:

> Andrew used denominator correctly, explained that it represented equal parts Can establish equivalent fractions and convert fractions to decimals. Unsure solving a question of adding decimals to fraction- no link to establishing both in a common form as yet. Listened to others and offered opinion and strategy as appropriate.
>
> (Personal Journal, 28/10/10)

There is a generally accepted view in the literature that a constructivist classroom supports collaborative teaching and learning activities and provides opportunities for students to collaborate with one another and the teacher in the learning experience. If this could best be achieved through the use of cooperative or collaborative situations, the teacher should select this strategy from their toolkit (Taylor, 2008). I was seeing the theory become a reality in my classroom.

The activities and interactions within the group, rather than the organisational attribute of the group, was ultimately of greater importance.

The students continued to develop collaborative relationships with their learning groups throughout term 4. Students became increasingly willing to listen to others within the group and to express their changing perceptions in their reflective journals. These student comments were in response to my request that their journal could consider how others had assisted them in their groups:

Kate (year 6) *- I have learned from other people and how they solve the questions in the activities (Student Journal, 23/11/10)*

Ben (year 6) *- I am having fun since we sat in maths groups. People in the group have helped me to understand stuff. (Student Journal, 28/10/10)*

Nathan (year 4) *- people in my group helped me with work in division, showing me how to do it when I got stuck. (Student Journal, 22/11/10)*

Thomas (year 5) *- Other people have helped me understand maths this year. (Student Journal, 25/11/10)*

Leigh (year 5) *- People have showed me the rules for maths. If Mr. W is busy I can go to my group and they can help me if they know how to. (Student Journal, 2/12/10)*

Brie (year 5) *- Milly helped me and so did the group. I think that working in a group is better than being independent in maths because other people say different theories and you can prove them. (Student Journal, 2/12/10)*

Milly *- The groups were better than I expected. I learned new tactics from others in the group. (Student Journal, 16/10/10)*

Kate (year 6) *- I like the pair work because there is someone else to talk to about the answer if you are having trouble or find a different way to work it out. (Student Journal, 14/12/10)*

In an introductory lesson on the concepts of volume and capacity (held on 19/11/10), the following was recorded from a group discussion:

Leigh (year 5) *- We did capacity before and it was the amount of water that went up when we put things in it.*

Jess (year 4) *– It was placement or something (referring to displacement). We can tell the weight of it by measuring the water level after you put things in it. If it goes up by 5 mL it's 5 kilos, no grams, I think.*

Leigh (year 5) *– I don't think it's weight, it's mass isn't it. I am confused again, this is really hard why don't they make things easy.*

Scarlett (year 4) *- Mass was using the kitchen scale to measure things, it's the amount of space, I think, it's in the book. You can measure the mass and the volume of something. They are different things.*

Jess (year 4) *– I remember you had to multiply three things and not 2 to get the answer and you use the little numbers (referring to squared and cubed).*

(Audiotape, 19/11/10)

This type of discussion provided insights into the current conceptual understanding of my students. The small-group and whole-class discussion was valuable in uncovering these understandings. As a result of the introductory discussions I planned learning activities for measuring mass and volume/capacity so they could be compared and contrasted with the hope that students further developed a meaningful understanding of the concepts and showed an understanding of the differences between the two concept areas.

I found that the introductory discussions, which occurred each Thursday or Friday in preparation for the following week's concepts, allowed the students to become a part of the plans for their upcoming learning activities. I was able to gain a lot of information about the students and their current conceptual understandings. This weekly discussion commenced my assessment of the students' use of mathematical language with respect to the concept being discussed. There were three students (Toni, Jeff and Madison) who did not voice opinions in these sessions; however, these students were advantaged through the use of heterogeneous groupings where they were able to witness other students sharing ideas and observe how students, at times, politely voiced a contrary opinion (Windschitl, 2002).

Mathematical language

The audiotapes continued to reflect students' development of canonical language. Arthur's evolution from 'measurement thingies' to 'displacement tubs' was evidence of this as was the class's use of terms like 'displacement', 'mass' and a variety of units of measurement.

Student language became more sophisticated over time as they became immersed in the mathematical culture. The development of a common language further assisted with the development of discussion as we all used a common canonical language. As students considered what resources they needed to investigate activities, a developing shared canonical language made discussion clearer:

Stephen (year 6) *- The diameter of the circle can be measured with a ruler, straight across the centre.*

Andrew (year 5) *- We could use Ben' calipers too, they are in the photocopying room.*

Arthur (year 6) *- I wonder if they will measure the same, or will it be different?*

Ben (year 6) *- The calipers have big ends at the points so it wont be as good as the ruler I don't think.*

(Personal Journal, 6/12/10)

This discussion was conducted in a small-group situation, and I asked the students to share their thoughts and findings with the whole class at the end of the lesson. The class discussion centred on the size of the ends of calipers. My journal records my thoughts about this discussion:

Students are more concerned about the ends of the calipers than anything else. Not sure I considered even raising this aspect of the calipers. Not sure I would have got the calipers out. The use of diameter, centre, radius, calipers is encouraging. Students not using 'thingies' anymore.

(Personal Journal, 6/12/10)

Groups who had engaged in particular activities slowly started to use the canonical language associated with the concept. The Internet groups that researched the history of mathematics and subsequently prefixes (kilo and milli) shared their findings with their group and the whole class. The online research task continued to take measurement to new areas as the history and often the etymology was explained or introduced. Students could link existing concepts with new concepts as the canonical language was shared.

For example, Stephen (Personal Journal, 12/10/10) announced proudly to the class that just as kilogram meant a thousand grams he had found the same relationship in kilobyte. 'You know the ones we use in computers.' Language use and understanding was causing links between concepts to be made and understood.

I believe this was the result of the students' ongoing interactions with and the correct modelling of language by members of the groups and myself.

The sharing of information in whole-class sharing time provided the opportunity for the use of technically correct language. I guided the students in whole-class discussions and provided explanations and clarification when they used non-canonical language.

In retrospect

Students were more actively involved in their lessons and were allowed to design their learning experiences. As time went on and students and I learned how to involve them effectively and productively in the learning process greater enjoyment was experienced. My meetings in week 8 of term 4 with Ben, Tim, Arthur and Nathan support this claim:

Teacher *- Boys, we are going to look back over capacity and volume next week. There were some things you didn't get to finish last time. Would you like to do those activities next week?*

Ben (year 6) *- Could I do the Internet research, I still don't understand the motorbike capacity 250cc and what that all means.*

Teacher *- I would like to help you there but I don't know either. Would anybody else like to work with Ben on that?*

Andrew (year 5) *- I would like to do that too, and Jeff loves bikes so he can help us (that was significant as Jeff had extensive literacy and numeracy needs but loved bikes and these boys created a learning environment for Jeff).*

Chris (year 6) *- Tim and I didn't finish working out the volume of all those rocks you measured. You know .....the numbered ones up on the table at the front of the room (this referred to a displacement activity we worked on earlier in term 3).*

Teacher *– That's ok boys, you have to do the mass as well as the volume. So you will need the scales if you haven't completed that.*

Chris (year 6) *- Yeah we did that bit, we have to put them in water.*

Arthur (year 6) *– Is it be possible for us to do something else? We still haven't made our initials with the square metre in chalk on the playground. We have designed them on the grid paper but didn't get to do the big one outside.*

This exchange showed me the power of the learning groups when the activities are relevant to the students, provide a range of skills and understandings, and are flexible. These were not exchanges I have ever experienced with students before, and the group work allowed me to become more flexible and allowed the students to become actively involved in the planning and implementation of their learning experiences. Further, these learning experiences provided students with examples of the types of activities that were possible in the class learning environment.

From my experiences a great deal was gained by me circulating through small groups, listening to and observing students as they interacted with each other, resources and the task at hand. I was developing an understanding of my new role in this innovative learning environment. As I walked around the groups I could hear groups calling out 'Hey Mr. W, come and look at this' as they discovered something that related to their activity. The students' enthusiasm to share findings was important for me to hear as I could share their findings.

Multiple perspectives are a cornerstone of educational constructivism and what better way to advocate this than to model group learning behaviour. The modelling of language was more readily applied within the small-group operations as I listened to all students interact with their tasks and resources, continually developing a deeper understanding of each student's conceptual development. Students found that knowledge was forever being refined and it was through the socialising aspect of the group that this could be achieved. There were very few problems within the group dynamics when they were working on mathematical tasks.

I found group learning outside of the mathematical lessons to be a source of much greater off-task behaviour. Indeed, students wished to have the opportunity to collaborate in small-groups or pairs in mathematics classes but they wished to have a more private and personalised seating arrangement for the general day-to-day classroom activities.

When groups did experience difficulties that appeared to impede the learning experience, I liaised with the group, facilitating it, rather than lecturing about the activity.

My personal journal and the audiotapes confirm that students engaged in their activities for increasingly longer periods than was previously the case. The reduction in my direct instruction (see Chapter 5) allowed the students upwards of 20 additional minutes investigation time and allowed me extra minutes of quality collaborative time with the groups.

These arrangements were adhered to for the remainder of the year. One benefit of the collaborative group arrangement was the feedback each group provided to the class at the conclusion of the lessons. These discussion sessions alerted students to the understanding and strategies of other groups and presented them with multiple viewpoints on how the activity functioned and how it could be approached.

Students became used to my regular group visits and over time held their excitement about discoveries until I caught up with their group. Students came to know and expect my visits and so became less inclined to call out to me or leave their group and interrupt me at another group. They did; however, share their findings and excitement within the group.

I was able to probe student understandings to a greater extent than was previously possible as a result of the extra time and the extra student contact. My increased interaction with students and with learning groups assisted in developing the quality of the collaborative groups.

The small, cooperative learning groups provided me with many opportunities to engage in meaningful communication with the students. As was shown, the groups provided me with valuable information about the students' current conceptual developments and allowed me to individualise my teaching with each student or group as required. I raise this point because it was not a consideration of mine at the earlier planning stage.

My shallow understanding of a constructivist perspective was reflected in my belief that group seating was a necessity for a constructivist teaching learning environment, as it provided a way for the students to more effectively learn. This was a belief I had great trouble in removing. I had not considered that small groups could be a strategy that assisted my professional practice in establishing where a child was situated conceptually.

Student to student communication is not always conducted in isolation from the teacher. What a teacher hears between students in cooperative learning groups can be a valuable source of information. Unfortunately, I did not initially perceive these groups as providing me with anything of educational value, only serving to benefit the students as they assisted each other within the groups and afforded me the time to move around the groups. Meaningful communication was developed as a result of the group seating, and this communication continued to develop.

The strategy of listening more and probing through questioning did not always succeed and at times made students uncomfortable and upset. Student and teacher journal entries record the anxiety some students felt with my developing strategy of not giving answers but providing scaffolding for students to develop their understandings.

A small group of students requested an interview (26/10/10) and asked for assistance in multiplying 2 digit numbers by 2 digit numbers (e.g., 21 x 13). I was pleased that the students were using the interview opportunities productively and that they felt comfortable with this communication arrangement. In the next problem-solving lesson, I asked this group and other students who wanted additional help with multiplication to come to the floor with me. The groups had place value charts, times table's charts and calculators available to them.

I wrote multiplication questions on a small whiteboard and asked children to attempt the answer in any way they wished, and I observed them as they attempted to solve the questions. It became apparent that the problem lay with the position of the numbers in the second row where they did not place a zero in the ones column (see Figure 5).

Each child was multiplying the digits correctly but their place value errors created an incorrect final answer. The group on the floor commenced solving the problems in an extended form.

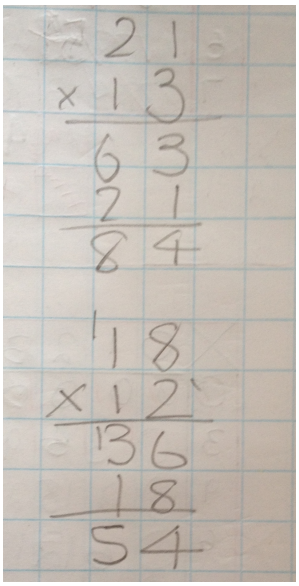

Figure 5: *Jess's Attempt To Multiply 2 Digit Numbers.*

One student, Jess, did not attempt the extended form and continued to use the contracted form which I felt was not going to assist her development of multiplication.

I felt that the extended form where each individual multiplication is addressed and recorded provided a strong foundation on which deeper understanding could be based. Despite my requests she continued to use the contracted form and continued to make the same place value mistake, but she did not attempt the step-by-step extended form with the rest of the group and me.

Jess removed herself from the group. On returning to her seat I asked Jess to write about her experiences in the session in her journal. Her journal reflected her feelings that day:

> I didn't learn anything because the teacher didn't help me even when I asked him and told him I didn't understand and he didn't help so I went to my desk.
>
> (Student Journal, 27/10/10)

My pursuit of deep understanding for Jess in what I felt was the best form of teaching came unstuck with this student. Jess told me later that she felt the extended form was for little kids and not her, and that she wanted to know how everybody else was doing it.

She was seeking a recipe for completing multiplication and I didn't give it to her. Lorsbach and Tobin, (2005) found that many students expected to be presented and filled with knowledge. I was coming to appreciate that students too had experienced the effects of teachers using behaviourism as a referent for teaching. My reflections of this episode considered that I needed to do more to show students multiple perspectives and ways of solving problems in the world of mathematics. I was grateful for the student journal entry, where Jess could write immediately what her thoughts were and have these thoughts readily accessible to me. This allowed me to better understand her feelings and experiences.

For one particular activity students were asked to construct a triathlon course around the streets of the local town using the scale provided on a local map. Students developed a variety of ways to measure the different stages of the triathlon. Students within learning groups discussed their ideas on how to approach the task and the strategies they used to solve the problem of course design. Students spent time listening to each other and incorporating those ideas in their solutions and designs. One student, Brie, approached me on two occasions during the lesson asking which was the best way to measure the course of the triathlon on the scaled map.

I explained to Brie that there were probably quite a few ways she could approach the problem and she could discuss with other students how they were approaching the activity. She felt she had done this and was not any closer to getting an answer. I asked Brie to try some of the strategies she felt were the best for a short distance and see if there were any she thought were better than others. I felt trial and error could be her best approach. I recorded this observation of Brie in my personal journal (19/10/10):

> Brie is crying at her desk, and after asking her what is wrong she said she feels she is not receiving adequate instruction from me on how to do the activity. This is not a usual reaction from Brie who normally has many ideas and is happy to experiment and try different methods.
>
> I take Brie around to four other groups and ask them to explain to us how they are approaching the activity. I ask questions about their use of the scale and how they will measure curved streets. After receiving input from the groups Brie commences the task with her partner.
>
> (Personal Journal, 19/10/10)

The following day I spoke with Brie and asked how the task was coming along. She was very positive and told me that she was happy to hear and watch other groups but she was not confident in asking questions of the groups about what they were doing, fearing that she would feel 'dumb'.

As discussed earlier (see Chapter 5), Toni and Jeff had indicated similar feelings about asking questions of other students and I had felt that this problem was restricted to those students. Brie was a high achiever and served as an example that the feeling of being made to feel dumb may have been more widespread than I first thought. I needed to consider that many students might not be expressing their fears, concerns and uncertainties, as they might believe they are a sign of weakness or ignorance.

Students having difficulties accepting a 'new way of knowing' is similar to the other findings where students showed an unwillingness to openly discuss their ideas and feelings in small-group and whole-class discussions (Dawson & Taylor, 1998).

On reflection, these are feelings most of us experience, however, I am glad that I was nurturing an environment where I could elicit this sort of information. I just had to remind myself to keep asking.

Monitoring student learning

My initial pedagogical change in this area was to introduce student and teacher reflective journals and to provide an opportunity for students to meet with me during lunch if they or I had issues that we wanted to raise (see Chapter 5). These practices provided a great deal of information about their backgrounds and conceptual understandings.

My own reflections, based on audiotapes of my lessons, classroom episodes, interviews and student journals, caused me to carefully assess my professional practice. I was becoming increasingly aware of the value of student input and of the sources of this input. My journal reflects concerns about teacher talk time, indifference to student views, lack of attention to cues about student conceptual understandings, and an apparent positivist epistemology. All of these concerns involved student-teacher communication, and when addressed contributed to an improved quality of communication within the classroom.

When provided with opportunities to have input into their learning environment the students offered many suggestions that could be easily implemented and invariably improved the meaningfulness of student-teacher communication. Complementing the student initiated lunchtime interviews were the fortnightly student-teacher mathematics meetings, which focused on student learning and student thoughts and issues. I felt there was a need to timetable and formalise at least one communication meeting with each student fortnightly. After discussing with the students and receiving their agreement about holding a formal meeting with every student each fortnight, I organised meetings during class time during term 4.

I prepared a recording sheet (see Appendix I) that guided my discussions with the students and documented their mathematics journey. The concept being covered at that time was entered on the sheet and I asked the student how s/he felt they were progressing in the topic.

Each student shared with me something they had attempted or completed during the fortnight. Students were asked to share with me their achievements, concerns, goals, and other matters that were relevant to their learning of mathematics. This interview provided opportunities for me to further uncover students' conceptual understandings and to plan new learning experiences.

Commencing in week 2 of term 4, I timetabled an interview for 4 students each day during mathematics lessons and during the 15 minute eating time at lunchtime. Generally, students seemed to be very happy to meet with me at lunchtime; however they were not obligated to do so.

At the conclusion of most interviews students thanked me for allowing them to show me their work, and I gained a strong impression that these students enjoyed the time I was spending with them. The students almost always provided detailed explanations of their understandings and strategies. They showed an ability for reflexivity as they commented on their difficulties and successes with mathematics concepts and the operation of the classroom.

Journal entries (26/11/10) support the view that this was a well-received initiative. When asked to respond about the meetings students reported:

Sarah (year 5) *- I like to show you my work, because sometimes you don't see it.*

Andrew (year 5) *- It is good to show you something we want to show. Sometimes we hand in stuff that isn't good but this way I get to pick things.*

Toni (year 5) *- You helped me after I said I had problems with kilometres.*

Beth (year 4) *- When I come up with my books I feel like you are looking at all the good stuff I can do.*

The development of this type of student-teacher interaction was an attempt to bring the students into the learning environment in a more active way. I felt that I was moving away from my lecture style teaching in a silent classroom to a much more inclusive learning supported by constructivist learning theory.

Seeking out student views and discussing their mathematics appeared to be a valuable way to do this. My personal journal (5/11/10 and 16/11/10) records:

> This is a rewarding way to talk with the students. Madison and Jeff put their hands up to volunteer for a maths meeting. They showed me their work. They were so proud to share their work with me. The meetings took only 5 minutes each and the students did most of the talking.
>
> (Personal Journal, 5/11/10)

> The students today have been very keen to share their work. Kate (year 6) shared her calculations on the school vegetable garden mulching activity.
> She has collected newspaper ads for mulch, potting mix and plants. I had no idea of the extent she has engaged with the activity.
>
> (Personal Journal, 16/11/10)

> Stephen showed me his research on the King's foot and how that was used to measure in earlier times. He showed me different cultural measurement methods (e.g. finger length, how far a horse could plough in a day). He asked if he could continue researching the metric system and why we use it but the Americans don't. He asked if I knew what everybody else used, like the Chinese and the Indians.
>
> (Personal Journal, 16/11/10)

My reflections on these meetings recorded the significant insight I was gaining through my attention to developing meaningful communication:

> This doesn't seem like teaching, yet it has assessment, meaningful activities and the establishment of each student's conceptual development. I can revisit what they currently know and use this for further teaching and learning activities, assessment or further discussions with them. Each student seems to be taking ownership of their learning experiences and they are viewing the entire activity as something they are doing rather than an observer of a lesson. There are obvious benefits to the students and me.

> I used to ask the students what answer they had for a question. They answered '4'. I responded Yes or No. Now I am witnessing the externalising of their thoughts and watching the process of learning as it relates to each student.
>
> It seems strange to think that a student would ever come up in these meetings and show me an answer like '4'. It is all but meaningless except in very limited circumstances. These meetings are developing a learning conversation that is supplemented with student work samples and thoughts.
>
> (Personal Journal, 17/11/10)

Real-World Mathematical Experiences

The scope of providing a real-world context for classroom mathematics is broad. In term 3 I took the initial steps in moving towards real-world contexts; however, further scholarly readings broadened my view that there was more to this change than simply removing textbooks from the classroom.

In the literature it is generally accepted that real-world settings can be part of an authentic learning environment, but this is just one possibility within the entire scope of providing authentic learning experiences (Herrington & Herrington, 2006; Oblinger, 2007). The notion of real-world experiences (Curtin University of Technology, 2013a) suggests learning experiences associated with terms such as collaborative, skill transferability, sustained investigation, ill-defined tasks, scaffolds, multiple perspectives and seamless assessment. Additionally, using raw data and primary resources are reported as an important component of real-world experiences. I was broadening a previously narrow understanding of the concept.

It was through monitoring closely my students' experiences that I was allowed into the contexts of their life worlds and subsequently their real-world mathematics. Discovering the life-world experiences of the students and moving from that point to create new learning experiences is important.

Seeking multiple-perspectives brought the multiple realities of students into the classroom learning environment and allowed each student to share their experiences. The students commented that they preferred rotational group activities than completing set pages in their textbooks. When asked to provide examples of what they liked about the activities they responded:

Leigh (year 5) *– I found the outside maths funner, than when we sit down and do pages.*

Beth (year 4) *– It's great using all the equipment, sometimes the drawings in the book are hard to understand. This way you got to touch the stuff you are using.*

Chris (year 6) *– I am much better at working stuff out when I can touch it. Like those cubes we built and counted for volume. I couldn't see them all in the book.*

Kaidance (year 6) *– Doing is better than sitting around watching someone else.*

Andrew (year 5) *– When I was away Darnell helped me go over what he done while I was away.*

(Interviews, 6/12/12)

My journal reflections comment throughout terms 3 and 4 on the positive reception by the students to the real-life activities they worked through. My comments refer to happy group discussions, on-task behaviours and collaboration.

Sullivan (2011, p. v) warns that teachers need to be careful about whose 'real world' they are using in the classroom context. Middle-class contexts could alienate students. Importantly the real-world component of imagination in children should not be discounted and used to rule out the use of certain examples because they are not necessarily of the physical world.

Sullivan (2011) argues that in mathematical problems it may be more meaningful for some students to think about aliens than cows and pigs. Sullivan (2011) adds that it is the diversity of learning experiences presented in the classroom that is important, because it is not possible to present all mathematics in a meaningful context to all students. This perspective further broadened my understanding of real-world authentic tasks.

I had previously thought that the use of ‘aliens’ was ridiculous in developing a real-world context. Thus I continued to reflect on my developing understanding of constructivism as a referent for teaching.

Changes to the classroom learning environment that pertained to setting authentic learning tasks continued as we developed a local town triathlon construction (length), the activity of reconstructing a space shuttle from a scale model, and the classroom repainting and re-carpeting (area) activity, all of which assisted me in bringing to our classroom real-world situations with the use of concrete resources.

Designing a triathlon course was an activity presented in weeks 1-3 of term 4, and was in keeping with the presentation of real-world, authentic tasks that required sustained activity.

The planning of a triathlon course tapped into the students’ experiences of local community environment. Students requested that they research the attributes of the course and report back in whole-class discussion time regarding the types of courses available; all of which had a variety of lengths in particular legs. The students recorded the information on the whiteboard for class discussion. This allowed students to select the course size (novice, Olympic or iron) that they wished to construct through their local town. It enabled students to engage with the activity at levels appropriate to their current understandings and interests.

Students discussed within their group, and with other groups, the possibilities for route selections. The relieving Principal commented on the way that many of the quieter students from the local area suddenly had a great deal to offer the class, as their knowledge of back streets, paths and lane ways became very important in course design.

Andrew was a student who said very little in class, yet he was suddenly an expert who knew the many lanes that connected properties throughout the town. The relieving Principal (Meeting, 22/10/10) noted that the class often asked him whether, after they had finished their work for him, they could continue their triathlon course project.

He noted that students did not 'make-up' parts of the course because they insisted that all routes had to be 'real'. They developed advertising, prize money and entry fees for the event.

The students used scaled maps similar to the way professionals design a course. They shared the location of their homes on the map, pointed out local sites, and discussed the symbols at the bottom of the page in the legend/key area.

They took delight in showing new symbols from the key and legend they had located on the map to others in the group. They found the activity engaging, as there were seemingly no questions to answer, but rather a task or challenge to be completed; there was no quick answer from the application of an algorithm. This classroom discussion provided insights into the problems that students were encountering as they faced this new problem-solving challenge:

Kate (year 6) - *I'd rather do worksheets, they're easier. This maths is too hard.*

Teacher - *What's too hard Kate?*

Kate (year 6) *– You have to have the run part finishing near the water, so do I measure from the start of the run or the end?*

Teacher *– I'm not sure, what do others think? (offering the question to the class)*

Milly (year 6) *– I don't think the run is first, I think its last, but then you have to be near the bikes.*

Kate (year 6) *– How am I supposed to find out, I've never done one (triathlon) before.*

Tim (year 6) - *It's on the whiteboard. We don't have to do it we just have to organise it.*

Stephen (year 6) *– I'm lost I don't know where to start.*

Kaidance (year 6) *– Hang on, Stephen, you can join our group and I will give you a hand, I've seen these on Emily.*

Jeff (year 6) *– I ran in one at Christmas at the beach but where do you go and how do you know where to go?*

(Personal Journal, 13/10/10)

Over the designated weeks, the students interacted effectively to develop different courses. Problems were identified and shared in small-groups and class discussion. Students found the local knowledge they brought to the activity useful in explaining their proposed course to others, and they shared a common language within the activity.

I found that the introduction of the local community context to their mathematics learning provided a number of benefits, not the least of which was their familiarity with some aspect of this difficult multi-skilled task.

I was staggered to see Toni and Brie use the scale at the bottom of the local map to measure out a length of wool that covered the total of the 3 stages of the course. I listened to them as they collaboratively developed a problem-solving strategy.

Toni (year 5) *- If 2 centimetres is ½ of a kilometre, then 1 kilometre is… um*

Brie (year 5) *- 1 kilometre is 4 centimetres.*

Toni (year 5) *- How long is the race?*

Brie (year 5) *- I think it's 26 kilometres, I'll check. Yes if we do the little one it's 26 kilometres. So we need to have a swim and a run and a bicycle bit.*

Toni (year 5) *- Work out the whole thing for each part and then put it on a big piece of paper and colour the different bits.*

Brie (year 5) *- Yeah and then we can trace it, but the paper might not be so good, we could use…*

Toni (year 5) *- What about string, but we couldn't colour that!*

Brie (year 5) *- Yeah that's good.*

Toni (year 5) *- We could put marks on the string [to indicate the cycle, run and swim lengths].*

(Personal Journal, 21/10/10)

The two students watched as others started drawing routes around town and re-drawing as their plans came unstuck. They simply placed the yarn (couldn't find string) on the streets and manoeuvred it until they had an accurate length course. Toni and Brie wanted to continue on this mathematics activity for the rest of the day. Toni told me that "maths without all the numbers was heaps fun."

Sullivan (2011) insists that, as teachers, we ensure that we are establishing the real-world contexts of the students and not of the teacher. It is up to teachers to identify their preferred form of mathematics problems and to present a diversity of problems that cover many possible contexts. The task diversity needs to incorporate relevance, metacognition and social aspects of our world.

I was able to broaden my thoughts on real-world activities. I found that through increased communication and discussion with the students I was able to modify tasks so they became more applicable to the students' life worlds. The major activities (see Chapter 3) that had been set for term 3 were carried over into term 4. When students completed their weekly set tasks they were able to move on to the major real-world activities.

Where students had not been able to complete tasks from term 3 they asked if they could be completed in term 4. I sensed that the students valued the tasks as worthwhile. Rarely have I had students continue to independently move on to tasks in mathematics. I could hear students self-evaluating as I moved about the groups:

Darnell (year 5) - *No that's not going to work.*

Teacher - *What's that Darnell?*

Darnell (year 5) - *I can't measure the height of the wall, and you won't let us get a ladder. So I thought I would measure about half and then add it again. But I think that is going to be too much.*

Teacher - *It's a great idea though.*

Darnell (year 5) - *Not if it doesn't work. Do you know how high it is?*

Teacher *- No Darnell I don't. And I'm not sure how I could find out without a ladder.*

Jeff (year 6) *- Pop reckons doors are about 2 metres tall.*

Darnell (year 5) *- It looks about a door and a half a door high.*

Teacher *- Will it matter if it is a little out Darnell?*

Darnell (year 5) *- We won't have enough paint. But it might be that we have too much paint and some left over. Anyway we could buy some more. I'm working it on 3 metres tall.*

(Personal Journal, 22/11/10)

The use of real-world learning activities allowed me to move more easily from the requirement of students to memorise and recall facts towards providing opportunities for them to make better sense of key concepts (Lorsbach & Tobin, 2005).

The previously mentioned activity centred on establishing the area of the wall, but I was witnessing Darnell's current understandings - height was important to him in calculating area, but he was stuck on establishing or estimating the height. He was making new connections to existing information in estimating height and doubling it.

I found that one of the benefits of using real-world activities was the focus on discussion and planning. Real-world activities have real-world problems, and these problems require careful thought and planning. I could see the definition or characteristics of real-world problems lift off the page they were written on and become an enacted teaching strategy and activity in my classroom.

Real-world activities establish a ready-made vehicle for the use of constructivism as a pedagogical referent. Clearly, I could have provide the height of the wall and given the area to the student and thus ruined the problem-solving benefits, as I was inclined to do previously in terms 1 and 2, and perhaps in the early stages of term 3.

However, with a developing constructivist perspective I felt that I was heading in the right direction by leaving the student to consider how the problem could be approached.

The problem could be in the calculations or in the logistics of the problem, or both. Similarly, providing students with a series of questions that required them to multiply supplied length and height values, removes any chance of the teacher discovering existing student knowledge and of observing the students make connections to their existing understanding.

Previously, I had considered the concept of area to be simply the application of '*A = L x H'*. Now; however, I was concerned about what students understood by the term 'area' and, furthermore I was concerned with how I could discover their understanding at any point in time.

The idea that using problems and strategies that actually occur in students' life worlds and using resources that are evident in students' everyday lives compelled me to make learning activities more meaningful. This formed the basis for the introduction of new resources and new learning strategies that were unfamiliar to the students. Constructivist pedagogy requires the learner to find that his/her existing schema to be wanting or to realise that a problem can be solved more quickly or accurately by using a different method.

I had moved from a teacher with a very narrow understanding of real-world, authentic, and relevant problems to a teacher who considered students' social environments and drew from their learning experiences.

The major activities that I now presented to the students were broad (see Chapter 3). I no longer expected each child to engage with each activity whole-heartedly. In fact, I changed my teaching to the point where students could choose the activity they wished to complete or to modify it where suitable.

In term 3 Ellie, Bronwyn and Mary had completed the activity of estimating the quantity of mulch needed to cover the school's greenhouse floor. In week 9 of term 4 they wished to calculate the mulch needed for their gardens and this extended to a calculation for top-dressing their school playground (which had become bare over the summer).

Toni and Brie asked me if they could include their house pets in the task of calculating the masses and consequent weekly food requirements of selected zoo animals.

Arthur, Tim and Andrew attempted to calculate the quantity of water held in the local swimming pool. These boys took measuring devices to the pool (swimming lessons in term 4) to measure its dimensions. The obvious question of how to calculate the different depths of the pool was a fascinating research project and, although not fully completed, introduced the boys to many new concepts that were not included in our mathematics syllabus but ones that they found interesting.

I stood back as most of the initiatives for calculating the pool's volume came from the students. I felt that they had to break the shackles that I had placed on them earlier in the year when I had not used personally relevant, real-world problems. They had been accustomed to my worksheet mentality rather than connecting with the surrounding world, a world that I had been preparing them for by using examples of an unknown theoretical and abstract world. Thankfully they radically changed this restrictive perspective on teaching and learning mathematics.

Questioning the truth of mathematics

Throughout term 4, I was happy to encourage students questioning of the accuracy of measuring devices used in class (trundle wheel, scales, masses, rulers) that had been so enthusiastically tested in term 3 (see Chapter 5).

I felt that this provided concrete examples of the possibilities of imprecision, similar to those raised by von Glasersfeld (1998) with respect to the constellations in the sky, the measurement of coastlines and the term 'equilateral triangle'.

The uncovering of empirical inaccuracies in almost all resources used by the students was a cause of great amazement for them and one that left them with more questions than answers.

There was general class discussion about the reliability of the measuring instruments proposed in constructing a triathlon course on a scale map of the local area in a term 4 activity. Students wished to check if the scale was indeed accurate and queried how they could be involved in proving the veracity of the claims printed on the scale map. They decided to check the length of the school front and compare this distance with that reported on the scale map.

Chris suggested that we could access Google maps to confirm our findings, and this became a computer-based research task for him to complete (Personal Journal, 11/10/10). Many others followed in completing this activity.

In student interviews (16/12/10), Arthur, Ben and Brie continued to question me about the inaccuracies they had encountered. The truth of mathematics, for them, had been shown to be a little less certain. An activity on the relative weight of students on different planets and stars in a solar system was met with great scepticism by Arthur and Ben, who both felt that the spreadsheet used could be programmed to churn out random numbers that were really unknowable as we had not been able to check the hypothesis on other planets. The whole notion of the uncertainty of mathematics and its development from ancient times through many cultures provided the students with a broader understanding of mathematics within their current conceptual understanding. They moved from querying the accuracy of rulers and trundle wheels to querying events and phenomena outside of their Earthly experiences.

The history of measurement activities continued throughout term 4 and helped create a learning environment that considered more deeply the projection of mathematics as a culturally derived and ever-changing discipline.

From my discussions with the students throughout term 4, and hearing their interest in the history of measurement and their love of discovering the imprecise nature of our classroom measuring devices, I started to appreciate the relevance this had in their lives and worldly experiences.

Student initiatives

An example of my inability to accept suggestions from students as they provided their voice to the classroom can be viewed in this vignette (Audiotape, 19/10/10). The students were considering a question from the Year 5 NAPLAN test 2010 (Figure. 6).

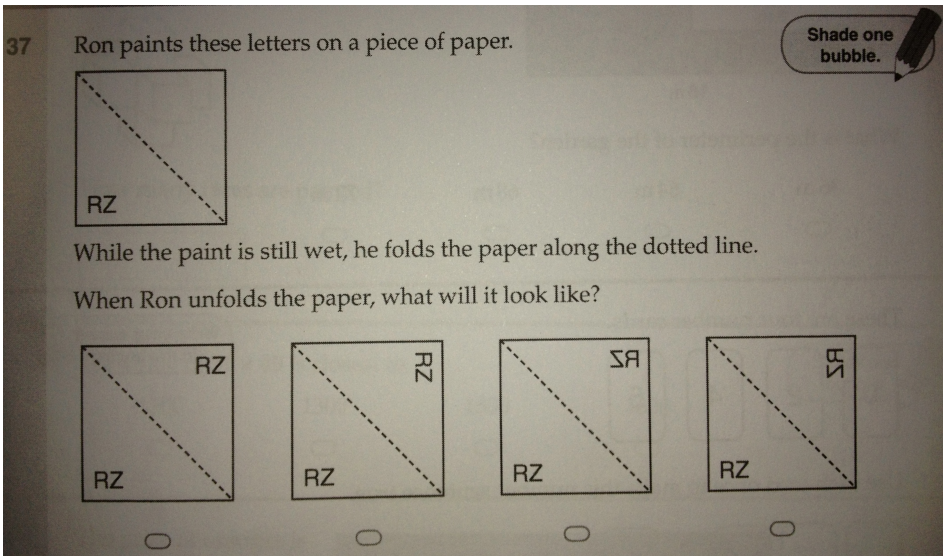

Figure 6: *Question 37, 2010 NAPLAN Mathematics Assessment*

I introduced a problem-solving session to the classroom at the commencement of term 4. This 20-minute session was designed to assist students in developing problem-solving skills using problems from previous years' NAPLAN tests. This session involved questions being considered by pairs of students followed by whole-class collaboration.

The objective of the lessons was for children to experience the thought processes and problem-solving strategies employed by the teacher and other students. This particular lesson occurred in week 2 of term 4.

I wrote this recollection of the episode from my notes and the audiotape of the lesson on the evening after the lesson:

> Arthur looks over the question and raises his hand to offer his opinion of how this problem might be approached.
>
> Arthur is a great student for starting any session off because he is a risk taker and doesn't mind sharing his thoughts with the class. "I reckon the easy way is if you get a piece of paper and just do it. We could write the letters on paint and fold it over."
>
> Milly agrees, "yes get a piece of paper and fold it in half, yes that'll work".
>
> Many students offer their support of Arthur's suggestion, which moves us away from the abstract into a more practical and easily observable solution.
>
> "I tried it with texta", exclaims Kate offering her experience of using Arthur's method.
>
> Milly supports this alternative with an encouraging reply "Yeah, you could do it with texta. Mr W can we go next door and get a square piece of paper?"
>
> Ever helpful Kate responds to Milly, "I've got square pieces of paper. Can I hand them out Mar. W"
>
> Here is my chance to use the students' suggestions and let them work on it themselves and allow class collaboration and discussion about our solution methods. The students offer suggestions and resources regarding how this problem may be solved and this is what I am after.
>
> Most of the class remains silent grappling with the problem; they twist their heads as if they are folding the paper inside their brains. Some turn the page over to see if the letters are visible. Others just stare blankly at the page unsure of what to do next.

No one in the room is sure they have the answer, no answers are being whispered, presumably because no one is sure of the answer and they seemingly have no way of proving it.

Luckily for the class some students do have a course of action. It's now over to you Mr. W.

"NO NO NO! You've got to be able to solve this problem without it", I emphatically pronounce to the class. 'It' being the materials the students were asking to use (paper, textas).

General class discussion follows, where the students discuss amongst themselves the answer they believe it is. All students are now trying to use an abstract method of working out the answer.

On reflection, my pedagogical approach appears to have been somewhat of a hybrid constructivist/objectivist strategy where I allowed students to discuss how they might answer this question, yet I denied them the use of materials that they believed assisted them in obtaining both the answer and an understanding of the concept. Understanding was usurped by my objectivist view of the notion of what is knowledge and how we construct it.

However, wait…. what is this …it's a light shining from the depths of this objectivist tunnel. A directive from the all-knowing teacher.

"I think we need to use tissue paper", I announce to all.

Milly again offers the suggestion that you can work it out just using paper, and "folding really hard to make the texta visible on the other side". A busy class then erupts as students use paper, textas, highlighters and scissors to solve the question.

Emily cries out in amazement as she works it out, and from the tone of her voice she is excited and sure of her answer, "It's the last one! It's the last one!", referring to the multiple-choice option she believes is the correct answer.

Mary confirms Ellie's discovery and has an excited tone of newfound knowledge that cannot be gained by someone telling you the answer or just transmitting knowledge. "Look it is that one!", She excitedly calls out.

Beth brings the talk back to practicalities, by informing us that we don't get to have the paper in the test and that makes it pretty hard to solve.

"My point exactly", I mutter, resigned to losing my current battle with behaviourism.

But Mary, Ellie, Kaidance, Milly and Arthur all retort that they feel they understand how the letters changed as a result of the folding and that they would be able to answer that question or a similar one later because of this experience.

"Hey, Mr. W, can you give us different ones tomorrow and we can see if we get the right answer and if we are not sure we can still use the texta?"

"Yes, that sounds like a good idea Arthur, thank you".

I reflected on this vignette after the lesson and it allowed me to evaluate the interaction between the students and myself and to realise that, at times, I was discounting student suggestions as well as discounting sound pedagogic practice in the pursuit of an objectivist agenda. In this case, I insisted that students not seek deeper understanding but find the right answer. There could be no better example of my epistemological beliefs preventing a constructivist pedagogy from occurring.

A teacher's aide at the school with a child in the Year 4/5/6 classroom explained to me that her child had reported a great love of researching mathematics from the 'olden days' as a result of the research component of the mathematics activities.
She told me that the student often explained to her how certain measurements had changed over time and how we have arrived at the current measurement system (Informal Meeting 16/11/10). My own observations record the growing interest that students developed as a result of the research into the concept being investigated.

Most students seemed to enjoy their time investigating the history of mathematics and, after initial guidance through structured questioning, students were able to investigate the concept under consideration.

Early in term 4, a core group of 10 students found this aspect of the group work particularly interesting and asked if they could continue with their investigation instead of moving to the next activity.

In most cases I directed the students to move to the next set activity; however, I provided time later for them to further explore the concept. However, I reflected on the students' requests to spend longer on some activities, and held a class discussion.

(Personal Journal 19/10/10).

We decided that students were allowed to spend two learning group rotations on research if they wished and if computers and other resources were available.

Students enthusiastically reported findings in the whole-class discussion and I observed (Personal Journal, 16/9/10) a group of four students gather together to share and discuss the information they had found regarding the development of the metric system. The students shared what they believed to be the best resources (web sites, books) for learning about the metric system. The school's teacher/librarian reported to me an increase in student interest in books dealing with mathematics (Interview, week 2, term 4).

Students self directed their mathematics research to include other areas of interest outside of my focus areas. They suggested that the research topics could be changed to any topic in mathematics that they felt interest in (meeting 19/10/10). As a class we decided that students should discuss their requests with me to ensure that topics satisfied curriculum guidelines.

Topics that students put to me for consideration in research time were: patterns (Emily and Milly, mathematicians (Tim and Chris), mathematical codes (Ben and Andrew) and Indigenous mathematics (Jeff).

Use of textbooks

In terms 1 and 2, the class mathematics textbook provided a major source of consolidation activities that students could readily complete in class. In term 4, students referred to the textbook to show me pictures of different instruments used to measure mass. They recalled having seen them in the book when we started Internet investigations on measurement. Two students brought in spring scales that they used to measure the mass of fish after seeing them in the textbook. My personal journal (2/11/10) records the observation that eleven students spent time using and discussing how these scales were used.

Sammy, Madison and Toni commented that they had seen these scales in their mathematics books but didn't know what they were or how they were used. Mary and Bronwyn found three spring scales in the mathematics resources area that we used in class.

Arthur, Stephen and Andrew said that they used similar scales quite extensively when they went fishing; however, when I asked them how the scales functioned they were unsure. These boys asked if they could research this aspect of the device and share their findings with the class. My objection to the use of textbooks was starting to come under question, albeit very late in the course of the research.

Sullivan (2011) pointed out that textbooks could provide students with purposeful tasks that develop procedural fluency and should remain a tool in the teacher's toolkit. This was an area of pedagogical growth for me. I realised that textbooks were not the evil that I had initially thought they were in a constructivist classroom. They could have a role to play and, according to Sullivan (2011), how they are used needed careful thought. Nevertheless, I knew that my use of the textbook in terms 1 and 2 was incompatible with my desired constructivist approach.

At that time I had asked students to complete textbook questions and to give their answers one by one to the whole class. Their answers were met with a 'yes' or 'no' response from me.

I have come to realise during this study that having students open a particular page in the textbook and complete it in silence each and every day, is not a good idea and is not sound pedagogic practice.

But now I realise that I had thrown the baby out with the bath water. I needed to carefully discern the proper use of the textbook and use it to address a need that I had perceived.

I now know that a textbook can be effective in the mathematics lesson. Simply because you are using a book does not exclude it from constructivist strategies. I was becoming aware that constructivist learning experiences needed to allow me to evaluate students' existing knowledge and understandings. If that was achieved using a textbook, then so be it.

It was the learning experience and not the resource that needed constructivist evaluation; and this is the essence of using constructivism as a pedagogical referent. Questions in a textbook can be used as a stimulus for pair, group or whole-class discussion. It was not the textbook that was in error but my use of it to prescribe a narrow learning activity was the problem.

Subsequently, during term 4, I was happy at times to use a page of the textbook or a worksheet to provide students with consolidation activities within different curriculum sub-strands in measurement. What had changed was my pedagogic decision to use the textbook for a particular need. The textbook did not dictate the lesson or the planning of my mathematics lessons; rather, it became one of many tools available to me.

Constructivist Assessment

In Chapter 5 I reported a desire from the students to self-assess what they had learned each week. I provided them with a five-point scale similar to the one used on their end of semester report cards ('Outstanding to Limited') so that they could indicate their understandings about the mathematics covered each week.

I felt that their record of achievement, as reported in their semester report cards, provided a common assessment language for teachers, students and parents. This form of student self-assessment had commenced in week 5 of term 3 and students diligently self assessed each week using the common grade scale (Outstanding to Limited concept understanding).

This was another situation were my hybrid behaviourist-constructivist perspective appeared. I asked students how they could be more involved in their assessment, listened to their views and provided them with my answer: an 'Outstanding to Limited' scale similar to that on their report cards appended to their Friday assessments. The problem that my solution to their concerns about assessment was to soon appear and provide far reaching insights into assessment in the classroom.

In week 4 of term 4 to commence my preparation for end-of-year report writing I provided students a blank copy of the report card. On this blank report card I asked students to complete the 'Outstanding to Limited' scale for each key learning area (subject) and the self-assessment of their effort in each key learning area. I used this activity each semester with students to allow them to reflect on their achievements and to consider what grade they gave themselves. The subject area of mathematics was broken down into substrands of the curriculum (for example: 2D, 3D, measurement, space).

My first inkling of a problem occurred when Mary asked me what each substrand referred to. As I read out each substrand, Mary interrupted me to say that she knew the words but she didn't understand what each of them covered. I asked the class who else was unsure of what each of the substrands referred to on their report cards. Twelve students declared that they were unaware of the meaning of the substrands. I wrote each of the component areas of each substrand on the whiteboard for the students' information i.e. Measurement - length, mass, volume, area. Mary was happy with this information and proceeded to complete her report card.

I asked the class to discuss what the 'Outstanding to Limited' of the common grade scale reflected about their understanding of these substrands. There was generally agreement that an 'Outstanding' was the best and that 'Limited' was 'bad'.

Most students felt that ‘Sound’ was where you should be and any lower than that was an indication that you failed the subject.

I proceeded to direct the students to page 2 of the report where an explanation of achievement was found. I highlighted for the students the key words for each achievement level i.e. Outstanding - extensive knowledge and understanding, High - thorough knowledge and understanding, Sound - sound knowledge and understanding, Basic - basic knowledge and understanding, Limited - elementary knowledge and understanding. However, this was not a workable explanation for the students who asked about the meaning of the terms ‘extensive’, ‘thorough’, ‘sound’, ‘basic’, and ‘elementary.’

Class discussion demonstrated that nearly all students were unsure of the meaning of the common grade assessment scale, and thus did not understand what and how they were being reported on to their parents/guardians. My personal journal (4/11/10) indicated that while student self-assessment comments were rich in information about their achievements and goals, I was questioning the value of the A to E scale:

> What value are these letters to the students, parents or me? What can be known about a student other than some very generalised picture of a student?
>
> Isn’t learning within any concept area a complex issue that cannot be described by the scale? Or am I misunderstanding the idea of the scale in reporting to parents and students? But if I don’t use the scale for my own evaluation and assessment, why am I giving it to them. Student comments are insightful and bring them into the assessment process. I use their thoughts and my observations. None of us ever use the scale other than in a contrived situation - reports -, twice a year and never again. USELESS!

When I reflected on the Friday assessment I set the students it appeared that they and I used their qualitative comments at the bottom of the page to identify conceptual understandings and concepts for further development.

However, neither the students nor I placed any significant value on the information provided through the informal use of the scale. The students had indicated that they did not understand the mathematics sub-strands or the codes used to describe their achievements.

However, I had a role in ensuring the students understood the nature of their report cards and what the grades meant. At that time it was clear to me that I was not fulfilling this role. My thoughts about the students' use of the common grade scale indicate my annoyance with my lack of a constructivist approach to this activity:

> What was all that about? How can this initiative have continued for so long, dutifully completed by the students each week, yet devoid of any substantial meaning to either party? This initiative is one that I imposed on the students and at no stage asked them for input about it. Why don't they feel that it is a matter worth raising with me? (Personal Journal, 9/11/10)

This episode served a number of purposes in my overall development as a more constructivist teacher. The students had indicated a desire to become more involved in their assessment. It was me that enforced the use of the 'Outstanding to Limited' scale as a way for them to become more involved.

At no stage had the students requested that they use the scale in their assessment. Classroom discussion (9/11/10) confirmed to me why that had occurred. It was not that it wasn't a matter the students felt worth raising. It was simply that I hadn't directly asked the students. I had not sought their views on the assessment change. They still believed that it was not their role to understand or be involved in everything about their learning.

Teacher *- I'm interested in finding out why you didn't say the scale on your Friday assessment didn't make any sense.*

Kaidance (year 6) *- It's on the report cards. You need it for stuff.*

Madison (year 5) *- I don't know what it means but it's always on the big reports. Mum says don't worry about it, but it's always there.*

Arthur (Year 6) *- There isn't anything else on the reports except your bit at the end of it.*

Milly (year 6) *- My mum thinks it's important. If I get 'Outstandings' I get to go out somewhere fun.*

Tim *- Me too, we get McDonalds.*

Teacher *- But why didn't you say you didn't understand it?*

Milly (year 6) *- I thought it was only for teachers to understand. 'Outstanding' means you are going great, 'Limited' means you need help. I'm going good so I put 'Sound'. I don't get it all, but I think that's about right.*

Brie (year 5) *- I don't get if you know something really well, but another bit not so good. What do you put there. Whatever you put isn't right for both things.*

(Personal Journal, 9/11/10)

My classroom was not one where the students felt completely comfortable to raise certain matters with me. The scale was something they didn't understand but were happy to fill in each week. I found it very easy to make assumptions about what the students know or should know without confirming these assumptions with them.

Terms like 'Sound', 'Basic' and 'Limited' are not easy to comprehend let alone self assess against. Brie's comment (above) is a wonderful critique of the common grade scale for substrands and one that I have not reconciled satisfactorily in my assessment of student achievement. I do not advocate the creation of a series of skills and knowledge checklist for each component or substrand of mathematics so that I can confidently assign an achievement level to each student.

However, perhaps we should not be attempting to assign these scales in the first place if we wish to provide students and parents with an accurate assessment of their child's achievements.

From week 5 of term 4 I revised the Friday assessment process and replaced its use with my anecdotal notes and work samples of student learning from their mathematics activity groups. I found the comments in the student journals, transcripts of interviews, class discussions and audiotape recordings provided me with a much deeper understanding of individual student conceptual understandings.

Whereas a summative assessment score out of 10 or 100 enables graphing and computation it lacks detail and insight into student conceptual development and can mask their shallow understanding of concepts. I maintained the end-of-term textbook tests and used them to supplement my own records for the purposes of reporting to parents.

Students continued to share their mathematical thoughts and understanding in their small groups and our whole class sharing sessions at the conclusion of lessons provided valuable assessment material. In cases where students were presenting findings that appeared to be unclear or incorrect I was able to plan and develop learning activities for the next lesson where individuals or groups of students could investigate particular aspects and concepts. Additionally, pairs or small-groups of students who were at different conceptual understandings could be grouped together to develop deeper understandings.

Student journals served to provide an avenue for students to externalise their understandings and concerns within the mathematics sub-strands which allowed me to delve deeper into their currently held conceptual understandings. It became common for students to self assess their mathematics knowledge and to write comments that guided my future lesson planning.

Thomas (year 5) *– You measure different things with different tools because things are made up in all different ways. I am not sure which one to use but I'm getting better.*
(Student Journal week 3, term 4)

Milly (year 6) *– I'm good at fractions but I don't like the ones with the different bottom numbers, that's confusing. But if they are the same then I'm really good at adding and subtracting.*

(Student Journal week 4, term 4)

Understanding the role of assessment was crucial in my role as class teacher. During term 4 I came to appreciate assessment as part of pedagogy and not as an appendage to it was transformative.

Previously I held a positivist epistemic view of assessment. This view held assessment as an instrument that dutifully serves to measure the success of the transmission of knowledge. Assessment from a constructivist epistemology asks more than the crude measurement of performance. It was my view that assessment needed to provide greater insight into students' conceptual understanding than that which could be provided by a percentage score.

I started to include formative assessment within the learning environment embedded within my day-to-day pedagogic functioning. I found this pedagogic change to be difficult as it was where my positivist views held strong. My own self-reflection continually returned to the desire for a percentage mark and accompanying average and graph. Assessment is part of pedagogy and not separate from it, so assessment can take many forms (The National Numeracy Review Report, 2008; Sullivan, 2011). During term 4 I attempted to develop a learning environment where students were comfortable to share their existing thoughts and able to embrace problem solving in order to provide me with a variety of assessment information.

I had made significant insights into my assessment practices. Certainly, in mathematics the use of end of term/year tests provide valuable summative information; however, this assessment practice must have at its heart reasoning that is justifiable to your constructivist beliefs. Assessments that are easily manipulated into percentages and graphs allow easy transferal to a report scale like the 'Outstanding to Limited' scale used in NSW. They are easily administered and provide parents with a report that they are familiar with and can digest quickly. I found during term 4 that as a source of information upon which to base individualised learning achievement it is found to be wanting.

The day-to-day classroom interactions, centred on learning activities, can be of greater use to students, and subsequently me, than any scale or percentage could provide.

It was my on-going formative student assessments that informed the grades I allocated to students in my report cards for term 4. I collected a rich profile of student work samples and anecdotal records, which I supplemented with pen and paper tests. These formative assessments provided an opportunity for me to view student achievement assessed against the NSW Board Of Studies Common Grade Scale achievement standards (Appendix D). I allocated a grade A-E for each piece of assessment that I gathered and aggregated these to compile a final achievement grade for each student in mathematics.

Term 4 - A Reflection

In term 4 I continued the pedagogic initiatives of term 3 in an attempt to consolidate the learning environment developments in communication, personally relevant mathematics and assessment. In term 4 I reflected on the 'bigger picture' of constructivism and the specific detail of my classroom practice.

During term 4 I felt that I was effectively synthesising the theory and practice of my constructivist pedagogical changes and was in a position to evaluate the success of my pedagogical transformations.

I felt a growing sense that I was starting to more deeply understand what constructivism meant in my classroom and that consequently I was in a more informed position to make decisions based on a sound theoretical basis. However, I was still aware of the threats posed by my subconscious behaviourism. Sweeping generalisations that constructivism meant group learning and no textbooks were replaced by a more considered and theoretically sound understanding. Constructivism as a cure-all was replaced by a growing understanding of a constructivist perspective.

Each of my 3 focus areas - building a collaborative learning environment, presenting relevant learning activities, and assessing students from a constructivist perspective (see Chapter 3) evolved significantly as I developed a more sound theoretical understanding of them and reflected on the implementation of strategies designed to embed them in my teaching practice.

Insight was provided through both student input and teacher reflection. The focus area of meaningful communication was invaluable to my study.

Term 4 showed that I was still capable of attempting to transmit knowledge to students and to ignore their views and perspectives. Unfortunately in most instances it was not a conscious decision that I made, but a return to former behaviours. I now wanted to decide which pedagogical practice was best suited to the identified outcomes of the lessons and the needs of the students.

Term 4 saw this enacted when classroom seating was revised and the students and I jointly developed a more flexible seating arrangement.

I came to appreciate the many benefits that improved teacher/student communication could have in the classroom. Meaningful communication even at its earliest stages of implementation was the source of information about student conceptual knowledge, assessment, mathematical language usage, classroom and teaching initiatives, group member interactions and future directions. My developing communication with the students slowly became meaningful because I sought and valued their perspectives.

Multiple perspectives were already identified as a key to successful constructivist strategy (see Chapter 3), but initially I thought it was only the students who needed to hear different perspectives. Never for a moment did I think that the students' perspectives could influence my professional practice so profoundly. I came to appreciate many of the benefits of constructivism as I witnessed the benefits rather than as a result of them being identified in my scholarly readings.

My role too had changed. Initially, I felt that if I was not lecturing students or transmitting knowledge then I had little role to play in the classroom. My mind was put at ease as I became more involved in each student's development of understanding. I was situated increasingly in their zone of proximal development (Vygotsky, 1978). This zone was no longer a theoretical term in a textbook, but a very real situation that students can find themselves in each day. I was available to guide and mentor them as they went through the process of learning because I was not occupied preaching from the front of the room.

Assessment methods changed significantly as a result of student input. It was their ideas about classroom procedures and student conceptions that drove me to seek greater opportunities to hear their views. My increased and increasing involvement with the students as they engaged with learning activities provided formative assessment that we all benefitted from. A new view of the purpose and value of assessment moved my focus from reporting grades to developing student understanding. I had learned a great deal about the role of assessment in the classroom.

More personally relevant learning experiences were developed in consultation with the students, demonstrating a synthesis of multiple perspectives, current student understanding and student learning responsibilities as activities were jointly designed. I came to appreciate the valuable input that students could have in the classroom, as long as I freed them from the shackles of being passive receivers of information. The first principle of constructivism 'knowledge is not passively received but actively built by the cognizing subject' (von Glasersfeld, 1989, p. 114), was no longer a theoretical definition to me. I was beginning to understand the implications of what this principle meant for acquiring a deep understanding. Memorising and regurgitating facts was not necessarily an indication of deep learning.

My experiences in term 4 were more about a change in my epistemic beliefs than a change in my pedagogy. I had seen first hand the many benefits that my 'simplified' constructivist strategies - meaningful communication, real-world learning activities and constructivist assessment - could provide the students and me. The movement away from the successful implementation of these strategies was more about 'rusted on' core beliefs about how students learn and how knowledge is gained that I held on to very strongly.

My attempts during term 4 to transform my assessment practices using an A to E scale that was not understood by the students, and not valued by them or me, was a stark reminder of the fight I was waging against undesired objectivist outcomes.

Term 4 was a success for me as a transformative teacher and as a reflective practitioner who was increasingly aware of the many pedagogical tools available to me and the ways they could be used in the classroom learning environment.

CHAPTER 7

SIGNIFICANCE OF MY RESEARCH

Introduction

The central themes of my research were my constructivist teaching experiment and my developing constructivist research epistemology. The preceding chapters chronicle my journey as teacher-researcher where significant insights about my development as a teacher and researcher occurred. The purpose of this chapter is to summarise the main findings of the preceding chapters and to explain the significance of my research to my current professional practice.

What Does It Mean To Be A Constructivist Teacher?

At the commencement of my research, it was my desire to become a constructivist teacher - a teacher who exclusively implements constructivist pedagogy. As evident in Chapters 3 and 4, this desire led me to believe that, among other actions, all student textbooks should be removed from my classroom, the practice of distributing worksheets to students cease and students should only sit in collaborative learning groups. These beliefs developed as a result of ideological conflict (Taylor, 2014). This notion of becoming an exclusively constructivist teacher was erroneous, and my adherence to certain procedural and structural guidelines, while well intentioned, were misguided.

The view that no one pedagogical approach should be adopted by teachers or education systems has wide support (Australian Government, 2014; Krahenbuhl, 2016; Taylor, 2014). Teachers should use their professional judgement to select from a range of pedagogical approaches to address the needs of the learning environment. This perspective is advocated by Taylor (2014, p.6) who replaces the notion of 'constructivist teacher' with ‘epistemologically astute teacher’.

To become an 'epistemologically astute teacher' I became familiar with constructivism as a learning theory and as a referent for teaching (see Chapters 4, 5 & 6). As a researcher I became familiar with constructivist epistemology (see Chapter 2).

My research documents my on-going battle against the hegemony of positivism and behaviourism. This is not to say that these approaches cannot be used for research or education (Taylor, 2014); however, it was not acceptable for me to attempt to implement a constructivist epistemology in a manner more closely aligned to a positivist and behaviourist paradigm. As demonstrated in Chapter 5, this is what initially occurred in my experiment.

In Chapter 4, I concluded that I had learned about constructivist pedagogy from a behaviourist perspective, and subsequently developed a weak conceptual understanding. Although I appeared capable of presenting a cogent and coherent understanding of a constructivist teaching perspective, I had little meaningful understanding of the concept. As demonstrated in Chapters 5 and 6, my unsuccessful attempts to implement a constructivist perspective in the classroom were influenced significantly by my behaviourist tendencies. I implemented so-called constructivist teaching strategies from a behaviourist perspective.

As evident in Chapter 5, I was not able to expertly apply constructivist pedagogy because I did not sufficiently understand what constructivist pedagogy was, or how I could implement it in the classroom. In professional practice the choice of teaching strategy lies with the teacher. Where my choice is to use a constructivist perspective, it is important for me to question exactly how the implementation of a particular teaching strategy develops students' meaningful understanding (Taylor, 2014).

As I reflect on my teaching experiment and subsequent teaching, I cannot consign this episode to history as elements of my hybrid pedagogy still exist in my teaching today. Positivism and behaviourism are embedded in my psyche. This is not an evil, but must be understood, appreciated and evaluated. If, from my teacher's toolkit, I select a constructivist teaching perspective I must be aware of the propensity for my behaviourist tendencies to affect my planned constructivist teaching strategies.

As the study progressed, my understanding of learning theory and epistemology developed, and as demonstrated in term 4 (see Chapter 6) my use of constructivist teaching strategies improved significantly.

By the end of term 4 I more fully understood that a constructivist teaching perspective does not advocate a particular teaching strategy, rather it advocates the perspective with which a strategy is implemented. It seemed to me that during my teaching experiment (see Chapters 5 & 6) I became capable of evaluating my classroom lessons more discerningly because I came to understand constructivism as a theory of learning and not a theory of teaching - this was not apparent initially in term 3 (see Chapter 5).

In term 3 I implemented the teaching strategy of group seating in the classroom because it seemed to be a constructivist teaching strategy. At this early stage I evaluated this teaching strategy as being successful because the students sat in small groups. This evaluation was naive. By the commencement of term 4 (see Chapter 6) I used group seating because it assisted students and me in developing collaborative group-work skills and practices.

As demonstrated in Chapter 5 (term 3), I implemented the teaching strategy of brainstorming because it seemed to be a constructivist strategy, and I evaluated its effectiveness as being successful simply because the strategy was implemented.

At the conclusion of term 3 I used this teaching strategy to assess students' current conceptual understanding. I considered the manner in which I implemented the strategy in terms of: did I allow students to inform me of their current conceptual understanding? did I give them my views of the topic? did I seek preordained 'correct answers?'. Evaluation of my implementation of the strategy required meta-cognitive reflexive practices. It is these practices that I continue to use to evaluate the effectiveness of the implementation of teaching strategies. Yes, I am becoming the 'epistemologically astute teacher'.

As evident in Chapter 3, I selected three key constructivist focus areas for my pedagogical change - (i) building a collaborative classroom environment which encourages and develops meaningful discussions between myself and students, (ii) presenting activities that are relevant to students' real-world experiences, and (iii) assessing students in a manner that respects the central tenets of constructivism.

Researchers have suggested teaching strategies that may assist teachers in effectively fostering a constructivist classroom perspective. However, I have come to understand it is not the teaching strategy per se that determines implementation effectiveness; it is against the characteristics, traits and tenets of a constructivist perspective that evaluation needs to be assessed. Quite simply, I should ask myself: does my selected classroom strategy allow students to actively create understanding? In term 3 and throughout term 4 I began to ask this question. It seemed to me that I was very slow to completely involve students in their own learning and in their evaluation of the learning environment (see Chapters 5 & 6).

At the conclusion of my teaching experiment I became aware that I don't wish to be a 'constructivist teacher'. Rather, I want to become a teacher who is capable of implementing a constructivist teaching perspective and a researcher who values qualitative data. I continue to aim to be Taylor's (2014) 'epistemologically astute teacher' who can, when required, implement a constructivist teaching perspective in a manner that maintains fidelity to constructivist learning theory.

My Epistemology And Learning Theory

My research documents the struggle I faced in modifying my professional practice, learning theory and epistemology (Chapters 3, 4, 5, and 6). During term 3 (see Chapter 5) positivist epistemology and behaviourist learning theory characteristics became significant to my research, as their influences on me were uncovered - and continue to be uncovered - in my professional practice. Late in term 3, I became aware, from other teachers' case studies, of signs and teaching practices that could alert me to my positivist/behaviourist tendencies. These influences remain invaluable to me as methods of self-evaluation of my intended pedagogical aims.

In themselves these positivist/behaviourist tendencies are not problems, but they became problems when they surfaced in my constructivist teaching strategies and interpretive research methods.

Assessment tasks

As a researcher it became apparent, through the mentoring process with my thesis supervisor (see Chapter 4), that I placed undue emphasis on the collection and analysis of quantitative data. As demonstrated in Chapter 4, I considered this data to be superior to the qualitative data that I had collected. I promoted the results of the CLES above all other data. I continued with this view for many months while advocating a constructivist epistemology. There is nothing intrinsically wrong with the quantitative data that I collected; however, it was the emphasis it was given in my interpretive research that indicated positivism was infiltrating my constructivist intentions. This perspective not only affected my research methods, but my classroom assessment practice too. I valued quantitative student assessment over qualitative assessment.

I noted throughout my teaching experiment that implementing constructivist assessment strategies was the most difficult pedagogical transformation that I encountered (see Chapter 5 & 6). Further, I noted that transforming my classroom assessment practices was the last significant pedagogical change I made. Classroom assessment practices offered me an insight into my deep-seated epistemological beliefs. I had believed that there existed a surety and infallibility in the results gained from quantitative assessment. Throughout term 3 I placed emphasis on pen and paper assessment tasks that were readily transferred to a spreadsheet for quick evaluative manipulations. It should have been obvious to me, from my approach to student assessment, that I had positivist beliefs and that this could influence my professional practice in other ways. My gradual movement towards more balanced student assessment tasks is demonstrated in Chapters 5 and 6. Classroom assessment practices afforded me a window to view my epistemology that was not, initially, apparent to me during my teaching experiment.

As a result of my research I now review my assessment practices regularly. I evaluate student assessments to establish the extent to which a positivist or constructivist epistemology is guiding my professional practice.

I have never lost my desire to graph students' assessment performance or calculate classroom averages, but as a result of my research I constantly review the balance of classroom assessments that I provide students to ensure an equal opportunity for students to be exposed to qualitative and quantitative assessments.

By the conclusion of term 4 (see Chapter 6) I reflected on the opportunities I provided for qualitative assessment and opportunities for students to show me what they had learned, rather than having students solely answering factual rote recall questions. Reflecting on the assessment task I set students is an opportunity to evaluate the extent to which positivism is influencing my professional practice.

Self-evaluation

As discussed in Chapter 3, the descriptions of behaviourist classrooms, from similar case studies to my own, provided me with examples of practices and behaviours that allowed me to evaluate the extent to which behaviourism was evident in my classroom. I believed the descriptors (see Chapter 3) associated with constructivist learning theory - child-centred, collaborative, big picture, meta-cognitive- (Krahenbuhl, 2016; Taylor, 2014) - to be evident in my classroom practice. However, as my research showed (see Chapter 5 & 6), I tended to identify with my desired pedagogy rather than my actual pedagogy. This was an important facet of my initial evaluation of my professional practice prior to the commencement of term 3. It warned me of the need to probe further when assessing professional practice.

Further, descriptors of a behaviourist classroom - silence, drill and practice, rote, rows of seats - were more indicative of my classroom. As term 4 (see Chapter 6) developed, it became evident that as I became aware of traits and characteristics of different pedagogical approaches I could assess my intended pedagogical perspective in terms of my implemented pedagogy. Discussions with my peers (see Chapter 4) highlighted how little I knew of the constructivist classroom perspective.

Of continuing assistance to me is the information and perspective that the CLES and audiotapes of my lessons provided. I do not currently use the CLES in a formal sense, but I regularly refer to the CLES scale descriptors (Appendix X) and use them as a basis to self-evaluate my professional practice.

The list of constructivist descriptors provided in research on the CLES was, and remains, helpful in providing a stimulus for the questions that I ask students when evaluating the classroom learning environment. Rather than asking students to complete a learning environment survey I now ask students to comment on specific constructivist scales; these are completed in journals, interviews or open classroom discussion. As demonstrated in Chapter 6, student feedback regarding a constructivist classroom perspective is valuable and creates opportunities for students to play a more active role in the learning environment.

The audiotapes of my classroom lessons throughout terms 3 and 4 provided - and continue to provide - rich feedback about my classroom practice. I continue to regularly audiotape my classroom lessons to allow me to more accurately assess the 'real' classroom. It is possible to evaluate my actual teaching and contrast this to my desired teaching perspective. I listen to my classroom discourse and that of the students and gauge the meaningfulness of classroom communication. Audiotapes allow for a non-intrusive and accurate portrayal of my lessons and provide me with valuable information regarding my success in implementing a constructivist perspective. Audiotapes provide an excellent ongoing evaluation of the power status of the room. I will never forget the initial audio recordings of the classroom in this research (see Chapter 5): I was at the front and centre of the classroom and my opinion was the only one that mattered.

This was the positivist in me reaffirming the belief that students should listen as I dispensed knowledge. Oddly enough it was the audio recording that more accurately allowed me to see what was happening in my classroom lessons.

Meaningful Communication

Of my three constructivist focus areas - developing meaningful communication, constructivist assessment practices and real-world learning activities - I found that developing meaning communication was the most effective for developing a constructivist classroom perspective (see Chapter 6).

Term 4 demonstrated the increased variety of communication opportunities that I provided the students and the development of their use of these opportunities. Further, it saw the evolution of my thinking regarding classroom communication, and resulted in much more meaningful communication being developed between students and myself and between students. In opening up lines and modes of communication between classroom participants a natural progression occurred towards constructivist assessment and posing real-world problems. Chapter 6 demonstrates the way that I gathered significant information about students by collaborating with them instead of lecturing to them. I came to learn more about their interests both in and out of school.

Students came to more freely express their views about their learning and their performance as they grew in confidence that what they were saying was valued by me (see Chapter 5 & 6). From late term 3 and throughout term 4 I discovered that the detailed information provided by students was invaluable in establishing an understanding of their cultural and social world. Additionally, I found students became increasingly forthcoming in revealing their conceptual understandings and readily identified problem areas in their learning. Meaningful communication provides assessment information rich in detail, so often absent from pen and paper assessment, and offers a valuable supplement to such assessments. Sadly, I believe that initially meaningful communication was not important to me because I did not value student input or their life-world experiences in my planning of their learning activities.

If my goal was to transmit understanding, there was no need to seek any information from the students; they just needed to listen and watch. This is the direct effect of a positivist epistemology, valuing pen and paper quantitative assessment over thick and rich descriptions of students developing conceptual understandings.

As a result of my research, I now consider deeply the ways that I allow students to communicate with each other and with me. I attempt to provide opportunities for oral and written communication and for students to be allowed to evaluate my efforts in actively involving them in their learning and the operation of the classroom. The development of open and effective lines of communication thwarts the domination of the classroom by the otherwise didactic teacher.

Further, students benefitted from the existing school-wide implementation of a collaborative-cooperative group learning skills. In this case it was a reciprocal teaching strategy. This strategy developed in students the skills and understanding of collaborative learning groups. It presented to students the elements of a real-world approach to group learning arrangements. A collaborative learning environment is complex and students need to be guided and mentored in their roles and responsibilities within it (see Chapter 3). As my lecturing time was reduced I was able to more effectively model and monitor this aspect of group learning.

Developing meaningful communication between the students and myself seemed an obvious transformative change; however, developing meaningful communication between students was not initially obvious to me. The potential that collaborative learning offers is dependent on the development of the collaborative skills of the students. It seemed to me that the focus on reciprocal teaching by this school assisted in developing these skills in the students. Teachers need to have an understanding of the mechanics of the collective and a plan to develop these skill in students before the advantages of collaborative grouping can be achieved. Reciprocal teaching is an example of how this student skill development can be achieved.

Professional Development And Mentoring

As I reflect on my research and subsequent teaching I feel that ongoing professional development, discussion and reflection on epistemology and educational learning theory needs to occur.

Significant time and resources are used to familiarise my colleagues and me with new syllabuses (rationales, support documents, programming requirements) and 'new' teaching strategies. However, the successful implementation of these policies and strategies rests heavily on our propensity to identify our underlying epistemic beliefs.

Throughout my research, I was privileged to have ongoing and frequent conversations with an eminent academic who is an authority on educational research and learning theory. It was the advice, guidance and direction from my doctoral supervisor that led me to recognise the hegemony of positivism in my initial research attempts.

Professor Taylor guided my growing understanding of constructivism as a complex concept using the principles of a constructivist teaching strategy. That is, I was encouraged to actively construct new knowledge based on my previously constructed understanding. It was in our discussions that my greatest insights were achieved. These discussions was held online - synchronously and asynchronously.

In our digital and global on-line world the experiences, guidance and nurturing by learned academics who understand educational theory and practice should be available to many teachers. These benefits extend to the processes I experienced while developing my interpretive study.

My thesis discussions with my supervisor covered many aspects of teaching that may be valuable to other teachers - perhaps academics as well - and covered important aspects of epistemology, learning theory and constructivist perspectives. They did not dwell on particular strategies, as these were only the vehicles that carried the constructivist perspective.

Similarly, reflexive practices and skills were an important aspect of my professional development as a result of my research work. These skills developed substantially throughout my research period as Professor Taylor directed me to certain practices and the possible implications on my professional practice. Professor Taylor sought to build in me an understanding of my professional practice, in theory and practice.

The majority of teachers are not afforded the opportunity to consult with an academic in an on-going relationship. I believe that the discussions similar to the ones I experienced with Professor Taylor should be made available online for teachers to use in teacher training and professional development courses.

It is important for teacher training courses to use the principles of constructivist learning theory. Experts in educational theory and practice discussing real-world classroom experiences with teachers has potential benefits for other teachers wishing to implement transformative change. Allowing access to such discussions (where appropriate) would present a sense of verisimilitude for other teachers.

I have observed and continue to observe that professional development in primary schools includes evaluation of teaching programs and classroom observations of teaching episodes.

It was evident in Chapters 5 and 6 that I was not, initially, capable of implementing certain teaching strategies with a constructivist perspective. These are teaching strategies that I have included in teaching programs for the past 30 years. It seems to me that teaching programs indicating the use of constructivist strategies are not necessarily a valid indicator of the merit of the implementation of the strategy. My experiences support the view that the best intentions of a teacher are not enough to ensure transformative pedagogic change.

Classroom observation in NSW primary schools are conducted to evaluate, among other practices, the implementation of constructivist teaching strategies in the classroom. For success in this endeavour to be achieved it is imperative that those involved in classroom observations understand what a constructivist perspective looks like in the classroom.

In my experience, too often it is the teaching strategies that are evaluated rather than the underlying pedagogical perspective. That is to say, if a teacher is observed to be using a brainstorm method or has students in learning groups then they are deemed to be using a constructivist perspective. As demonstrated in Chapters 5 and 6, this is not necessarily the case. The distinction between strategy and perspective needs to be constantly reviewed. I have noticed confusion among both new and experienced teachers and teaching supervisors regarding a constructivist teaching perspective and how this should be implemented in the classroom. Seldom, in my experience, is the notion of constructivist learning theory considered, yet it is learning theory that informs pedagogy. It is learning theory that is the foundation for self-assessment of pedagogical transformation.

It is vitally important that teacher educators, Principals and others who are involved in the development and evaluation of teachers understand the theoretical foundations of a teacher's pedagogical perspective and not simply focus on the desirable teaching strategies. Otherwise, we may see the implementation of a desired learning theory being negatively impacted by the hegemony of positivism.

Benefits Of Case Study

Of substantial benefit to me throughout my research was the ongoing opportunity to review the literature and access the experiences of other educators who had attempted similar pedagogical transformations (see Chapter 3). These case studies presented classroom observations of teaching episodes that 'rang true' and I valued them highly.

I was able to access these experiences at convenient times. During terms 3 and 4 I revisited these teachers' experiences of success and failure and compared and contrasted their approach to mine.

My research adds to the body of classroom experiences that others can refer to when they seek to understand what should and should not be enacted in the classroom. Further, my research presents the view of a teacher-researcher where educational research theory, learning theory and professional practice interact and develop.

My research speaks to the individual teacher in the classroom who is considering change, and it provides insights into educational theory that impact pedagogy. As demonstrated in Chapters 4, 5 and 6, my pedagogical transformation depended heavily on my own assessment of my beliefs about learning and teaching. Self-assessment of one's own beliefs can be difficult. In my case, it was misleading inasmuch as my actual teaching was different to my initial self-assessment (see Chapter 4). My experiences may assist teachers and administrators to look more closely at how teachers' self-assessment can be achieved.

Conclusion

My research has shown the benefits that a change to a constructivist teaching perspective can have within the classroom. It has identified key threats to successful transformation. For me, the price of constructivism is eternal vigilance against positivism. I started with a focus on pedagogical transformation but quickly learned that a focus on the learning theory that informed my pedagogy was more important. I made the same mistakes that so many of the cited case studies made.

I made these mistakes because of my indifference to learning theory and an inability to accurately assess my beliefs about learning and teaching. These two aspects only became apparent to me as mistakes were made and I sought answers for my lack of success. My story uncovers the hidden signs of behaviourism and positivism; hidden that is, from me. My story also provides an account of a teacher who overcame obstacles - visible and invisible - and transformed the classroom in accordance with a constructivist teaching perspective.

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APPENDIX A

State Education Research Applications (SERAP) Approval

NSW GOVERNMENT | Education & Training

Mr Peter Woolridge
2758 Pacific Highway
TYNDALE NSW 2460

DOC 10/90455

Dear Mr Woolridge

SERAP NUMBER 2010052

I refer to your application to conduct a research project in NSW government schools entitled *An interpretive case study of a teacher's experience implementing constructivist teaching of mathematics in a composite Primary classroom.* I am pleased to inform you that your application has been approved, and that the approval remains valid until 7 April 2011.

You may now contact the Principals of the nominated NSW government schools to seek their participation. It is recommended that you include a copy of this letter with the documents you send.

The following researchers or research assistants have fulfilled the Working with Children screening requirements to interact with or observe children for the purposes of this research for the period indicated:

Name	**Approval expires**
Peter Woolridge	07-04-2011

I draw your attention to the following requirements for all researchers in NSW government schools:

- school principals have the right to withdraw the school from the study at any time. The approval of the principal for the specific method of gathering information for the school must also be sought.
- the privacy of the school and the students is to be protected.
- the participation of teachers and students must be voluntary and must be at the school's convenience.
- any proposal to publish the outcomes of the study should be discussed with the Research Approvals Officer before publication proceeds.

When your study is completed please forward your report marked to Manager, Schooling Research, Department of Education and Training, Student Engagement and Program Evaluation Bureau, Locked Bag 53, Darlinghurst, NSW 2010.

Yours sincerely

Dr Max Smith
Senior Manager,
Student Engagement and Program Evaluation
21 June 2010

NSW Department of Education & Training – Student Engagement and Program Evaluation Bureau
Level 1, 1 Oxford St. Darlinghurst NSW 2010 T 9244 5619 F 9266 8233 E serap@det.nsw.edu.au

APPENDIX B

Parent Consent Form

STUDENT PARTICIPANT

CONSENT FORM

• I understand the purpose and procedures of the study.

• I have been provided with the participation information sheet.

• I understand that the procedure itself may not benefit my child.

• I understand that my child's involvement is voluntary and I can withdraw them at any time without problem.

• I understand that no personal identifying information like name, address or school will be used in any published materials.

• I understand that all information will be securely stored for at least 5 years before a decision is made as to whether it should be destroyed.

• I understand that updates of the progress of the research will be provided to me.

• I have been given the opportunity to ask questions about this research.

• I agree for my child to participate in the study outlined to me.

Child's Name _____

Parent/ Guardian Name: _____

APPENDIX C

Constructivist Scale Explanations And Descriptors

DIMENSION	NOTES
Personal relevance *Learning about the world*	• Connectedness of school Maths to students out-of-school experience, making use of everyday experiences as a context for teaching • Extent to which teachers relate science to students' out-of-school experiences). • Relevance of learning to students' lives • Move beyond student ability to recall rules and laws • Making use of students' everyday experiences
Uncertainty *Learning about Maths*	• Provisional status of mathematical knowledge • Extent to which opportunities are provided for students to experience scientific knowledge as arising from theory dependent inquiry, involving human experience and values, evolving and non-foundational, and culturally and socially determined. • Students experience the inherent uncertainty and limitations of mathematical knowledge
Critical Voice *Learning to speak out*	• Legitimacy of expressing a critical opinion • Extent to which a social climate has been established in which students feel that it is legitimate and beneficial to question the teacher's pedagogical plans and methods and to express concerns about any impediments to their learning.
	• Participation in planning, conducting and assessing of learning • Extent to which students are invited to share with the teacher control of the learning environment, including the articulation of their own learning goals, design and management of their learning activities and determining and applying assessment criteria, participating in the negotiation of the social norms of the classroom.
Student Negotiation *Learning to communicate*	• Involvement with other students in assessing viability of new ideas. • Extent to which opportunities exist for students to explain and justify to other students their newly developing ideas and to listen and reflect on the viability of other students' ideas. • Develop strategies that promote student/student negotiations and move beyond just working answers out together.

APPENDIX D

NSW Board Of Studies Common Grade Scale

Your child's achievement for the strands for each of the Key Learning Areas is reported using the five point Common Grade Scale. This information is then used to give the overall achievement for each Key Learning Area, using the same scale.

A	The student has an extensive knowledge and understanding of the content and can readily apply this knowledge. In addition, the student has achieved a very high level of competence in the processes and skills and can apply these skills to new situations.
B	The student has a thorough knowledge and understanding of the content and a high level of competence in the processes and skills. In addition, the student is able to apply this knowledge and these skills to most situations.
C	The student has a sound knowledge and understanding of the main areas of content and has achieved an adequate level of competence in the processes and skills.
D	The student has a basic knowledge and understanding of the content and has achieved a limited level of competence in the processes and skills.
E	The student has an elementary knowledge and understanding in few areas of the content and has achieved very limited competence in some of the processes and skills.

("Grading and reporting student achievement from 2006", NSW Board of Studies, 2006).

APPENDIX E

The NSW Model Of Pedagogy

The NSW Quality teaching model

The model of pedagogy presented in the *Quality teaching in New South Wales public schools: Discussion paper* (NSW Department of Education and Training, 2003) has three dimensions that represent classroom and assessment practices that have been linked to improved student outcomes. These three dimensions are:

1. Pedagogy that promotes high levels of ***intellectual quality***.

Intellectual quality refers to pedagogy focused on producing deep understanding of important, substantive concepts, skills and ideas. Such pedagogy treats knowledge as something that requires active construction and requires students to engage in higher-order thinking and to communicate substantively about what they are learning.

2. Pedagogy that establishes a high ***quality learning environment***.

Quality learning environment refers to pedagogy that creates classrooms where students and teachers work productively in an environment clearly focused on learning. Such pedagogy sets high and explicit expectations and develops positive relationships between teachers and students and among students.

3. Pedagogy that generates ***significance*** by connecting students with the intellectual demands of their work.

Significance refers to pedagogy that helps make learning more meaningful and important to students. Such pedagogy draws clear connections with students' prior knowledge and identities, with contexts outside of the classroom, and with multiple ways of knowing or cultural perspectives.

Each of the three dimensions of the NSW Quality teaching model is comprised of a number of elements. The 14 elements that pertain to assessment practice are presented in Table 1.

	Intellectual quality	Quality learning environment	Significance
Elements	Deep knowledge	Explicit quality criteria	Background knowledge
	Deep understanding	High expectations	Cultural knowledge
	Problematic knowledge	Student direction	Knowledge integration
	Higher-order thinking		Connectedness
	Metalanguage		Narrative
	Substantive communication		

Table 1: The dimensions and elements of the NSW Quality teaching model used in this guide

The discussion paper and other support materials related to *Quality teaching in NSW public schools* can be found on the web site:
https://www.det.nsw.edu.au/proflearn/

APPENDIX F

Australian Professional Standards For Teaching

Organisation of the Standards

Domains of teaching

Professional Knowledge

Teachers draw on a body of professional knowledge and research to respond to the needs of their students within their educational contexts.

Teachers know their students well, including their diverse linguistic, cultural and religious backgrounds. They know how the experiences that students bring to their classroom affect their continued learning. They know how to structure their lessons to meet the physical, social and intellectual development and characteristics of their students.

Teachers know the content of their subjects and curriculum. They know and understand the fundamental concepts, structure and enquiry processes relevant to programs they teach. Teachers understand what constitutes effective, developmentally appropriate strategies in their learning and teaching programs and use this knowledge to make the content meaningful to students.

Through their teaching practice, teachers develop students' literacy and numeracy within their subject areas. They are also able to use information and communication technology to contextualise and expand their students' modes and breadth of learning.

Professional Practice

Teachers are able to make learning engaging and valued. They are able to create and maintain safe, inclusive and challenging learning environments and implement fair and equitable behaviour management plans. They use sophisticated communication techniques.

Teachers have a repertoire of effective teaching strategies and use them to implement well-designed teaching programs and lessons. They regularly evaluate all aspects of their teaching practice to ensure they are meeting the learning needs of their students. They interpret and use student assessment data to diagnose barriers to learning and to challenge students to improve their performance.

They operate effectively at all stages of the teaching and learning cycle, including planning for learning and assessment, developing learning programs, teaching, assessing, providing feedback on student learning and reporting to parents/carers.

Professional Engagement

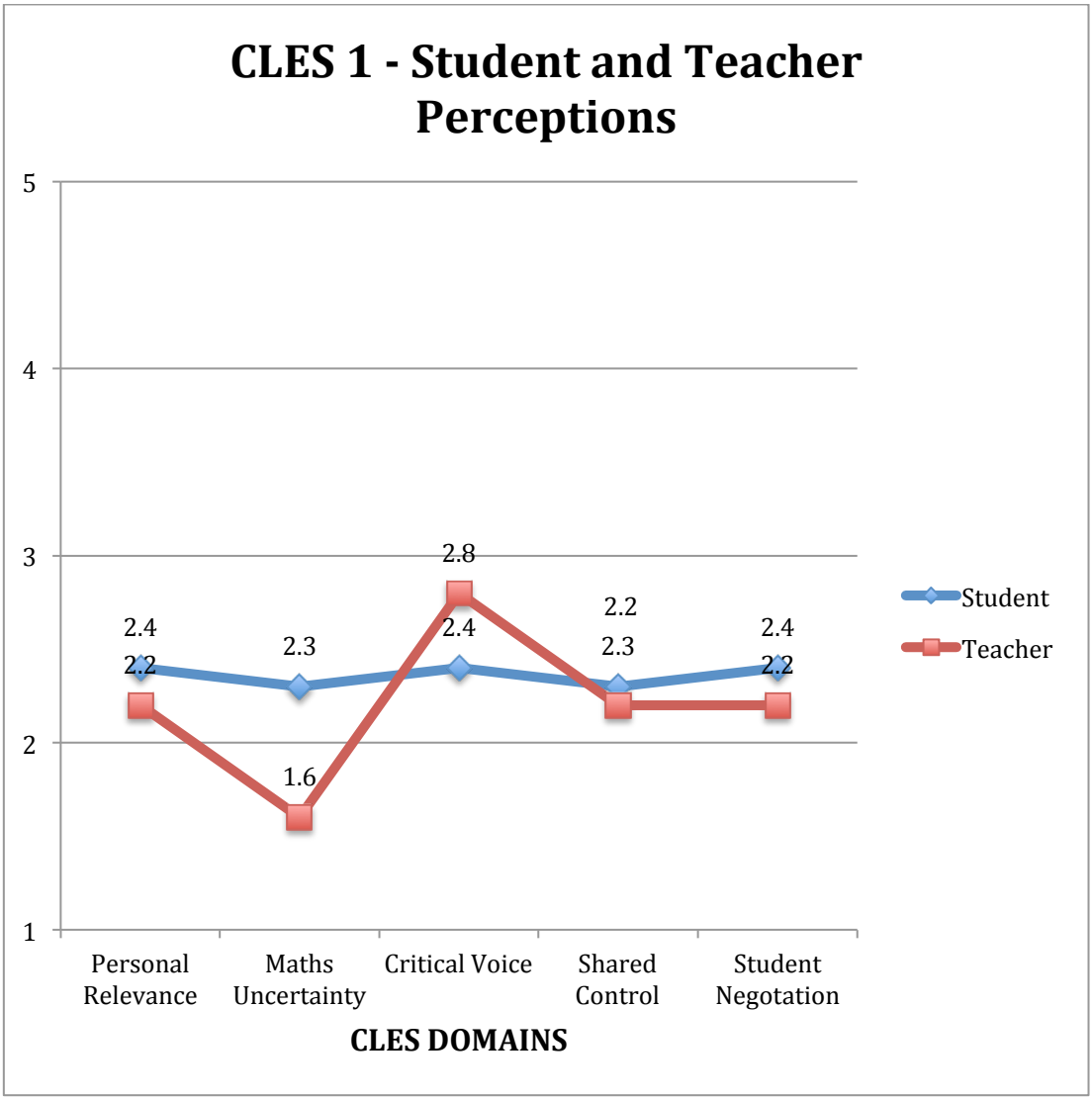
Teachers model effective learning. They identify their own learning needs and analyse, evaluate and expand their professional learning both collegially and individually.

Teachers demonstrate respect and professionalism in all their interactions with students, colleagues, parents/carers and the community. They are sensitive to the needs of parents/carers and can communicate effectively with them about their children's learning.

Teachers value opportunities to engage with their school communities within and beyond the classroom to enrich the educational context for students. They understand the links between school, home and community in the social and intellectual development of their students.

APPENDIX G

CLES 1 Student And Teacher Perceptions Of The Learning Environment



APPENDIX H

Sample Group Rotation Mathematics Lessons

Length 4.1 lesson ideas

Measure using conventional units: measure and record 1 metre

Knowledge and strategies

1. identify lengths which are approximately 1 metre
2. use a ruler to accurately make a length of 1 metre
3. label and record lengths using the abbreviation m

Concertina metre

Groups of students make a metre strip using 10 centimetre strips which are taped together, end to end. Students check that their metre length is correct with a metre ruler. Group members fold the strip backwards and forwards in a concertina fashion at the 10 centimetre marks. Students record the estimate and then the count of how many 10 centimetre strips were needed and why.

Outcomes	Materials	Knowledge and strategies
MS2.1 WMS2.2	photocopy of 10 cm strips, tape, scissors, metre rulers	1. identify lengths which are approximately 1 metre 2. use a ruler to accurately make a length of 1 metre 3. label and record lengths using the abbreviation m

Towering metres (see lesson plan)

Students work in small groups to build a tower that is 1 metre high. Students estimate when their tower has reached 1 metre, then measure to check. Students make adjustments to the height of the tower, if necessary. The group reports back to the class on how close their estimate was to 1 metre. Individual students record how the estimate was made, and the measured result.

Outcomes	Materials	Knowledge and strategies
MS2.1 WMS2.4	building objects or materials for tower, metre rulers, paper and pencils	1. identify lengths which are approximately 1 metre 2. use a ruler to accurately make a length of 1 metre 3. label and record lengths using the abbreviation m

LENGTH

(Teaching Measurement: Stage 2 and stage 3 (2004) p. 24)

The human tape measure

Students each make a paper streamer 1 metre long. Students compare the length of their streamer with three other students to ensure an accurate length.

Additional whole-class activity: students estimate, then measure, the distance of about 20 m. Students stand in a line, each holding an end of their own metre, end-to-end with the next student's streamer, until the total is 20 metres.

Outcomes	Materials	Knowledge and strategies
MS2.1 WMS2.4	paper streamers, metre rulers, scissors, pencils	1. identify lengths which are approximately 1 metre 2. use a ruler to accurately make a length of 1 metre

Rolling metres

Use a paint roller, brush or chalk to make a line or curve which measures approximately 1 metre. Check with a metre length (string or paper) to find if the estimate was more than, less than or exactly 1 metre.

Discuss and record how the metre length was estimated, and the final measure recorded.

Outcomes	Materials	Knowledge and strategies
MS2.1 WMS2.4	1 metre length, paint roller, chalk or brush, pencils and paper	1. identify lengths which are approximately 1 metre 2. use a ruler to accurately make a length of 1 metre

Ready set go!

Students work in small groups to estimate, then measure and record:

How long does it take to write and measure a legible sentence 1 metre long?

How long does it take to make and measure a line of pens (paddle-pop sticks, match sticks) 1 metre long?

How long does it take to make and measure a playdough snake 1 metre long?

Note: students may suggest alternative activities to be measured.

Outcomes	Materials	Knowledge and strategies
MS2.1 MS2.5 WMS2.2	watch, metre measure or metre ruler, paper, pencils, sticks, playdough	1. identify lengths which are approximately 1 metre 2. use a ruler to accurately make a length of 1 metre 3. label and record lengths using the abbreviation m

(Teaching Measurement: Stage 2 and stage 3 (2004) p. 25)

APPENDIX I

Communication Meeting Pro-Forma

Name _____ Date_____

Maths Concept _____

Student work sample

_____

Student thoughts about their work

_____

_____

_____

_____

Areas identified to develop further

_____

_____

_____

_____

Areas identified for more investigation

_____

_____