Developing statistical literacy with students and teachers in the secondary mathematics classroom

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Abstract

This thesis investigates the teaching of statistical literacy in the first two years of secondary school mathematics. The teachers involved in the research aim to make changes to classroom practice in the teaching and learning of statistics and statistical literacy in response to changes in the New Zealand curriculum.

An action research methodology is adopted by the research. A group of three teachers and the author undertake an action research cycle of planning, observing, acting and reflecting in three different Year 9 and 10 mathematics classrooms. The research documents the designing and implementing of strategies by a group of teachers in a mathematics department for integrating statistical literacy into teaching programmes. The research adopts framework for improving practice that utilise models for statistical literacy and thinking and principles for teaching with a language learning or literacy focus.

Data is collected through discussions with teachers, observations of lessons and interviews with teachers and students. Themes emerge from the data. They include the significance of teacher and student concepts of statistics and statistical literacy, the importance of language and literacy in the statistics classroom, the adoption of teaching principles to facilitate statistical literacy and the challenge of adopting a critical literacy stance in the statistics classroom.

The study highlights the importance of literacy and language skills in statistical literacy. The research concludes that the important changes needed for developing statistical literacy are about classroom methodology rather than content knowledge and shows that adoption of language learning principles into the teaching programme may achieve this.

Dedication

For Toni and our most wonderful daughters Millie and Isabel.

Acknowledgement

First of all I would like to thank the other participants in this research. I am indebted to all the teachers and students involved for their honesty, openness and willingness to share.

To the teachers involved I would like to further express my admiration and respect for their unwavering commitment to improving practice, for showing the benefits of collegiality and for their limitless generosity of time and ideas.

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Chapter 1: Introduction

1.1 Rationale

The initial concern that triggered this research was an assumed lack of preparedness of a group of high school mathematics teachers in the face of looming curriculum change in the statistics strand in the Mathematics and Statistics Learning Area of the New Zealand Curriculum. The aim of the teachers involved in this research was to make changes to classroom practice in the teaching and learning of statistics and statistical literacy at the Year 9 and 10 levels in response to the current curriculum, proposed draft and now new curriculum.

My own journey and experiences as a secondary school mathematics teacher in New Zealand have also largely determined the focus and direction taken by this thesis. I began teaching in the early 1990's during a period of reform or re-voicing in the New Zealand school curriculum. The *Mathematics in the New Zealand Curriculum* (Ministry of Education, 1992) was central to my pre-service training and beginning-teacher professional development. The 1992 curriculum, and its guiding principles both explicit and implicit, greatly influenced my development as a teacher.

As a teacher I have come to value lessons where learners, actively engaged in the learning process, build their knowledge through experience and negotiation of meaning through interaction with others. I believe that students need to be given opportunities to reflect on their learning and evaluate their own understanding.

As a mathematics teacher I see it as essential that we provide a broad based mathematics curriculum for all students so they are able to become active, knowledgeable and critical citizens in society. As a statistics teacher I want to prepare all students to be able to participate in decision making in the world around them based on data. I also want to share with students my enjoyment of learning and doing mathematics and statistics.

The other major influence on my development as a teacher has been my study into literacy and language in the mathematics classroom, with both ESOL[1] students and the mainstream. As a teacher in a multicultural Auckland high school I consider that the different levels of literacy and the enormously varied literacies that students bring to learning is one of the biggest challenges in education. However, I have also come to believe that the linguistic and cultural diversity of our students and teachers is in fact an advantage and a resource rather than a hindrance to learning in the classroom.

And now as I prepare this thesis we are undergoing a national curriculum review and implementation. Just as I have developed as a teacher, the curriculum also develops. There will be the introduction of new pedagogical principles and the modification or re-emphasis of others. Again the new curriculum, and its guiding principles both explicit and implicit, will influence each school's curriculum and finally what actually happens in the classroom.

I am interested in how we can prepare our students and ourselves as teachers for the new [or re-emphasized] demands of *The New Zealand Curriculum: Draft for consultation 2006* and the *Mathematics and Statistics Achievement Objectives*. I am particularly interested in investigating the teaching and learning statistical literacy and the demands that it will place on students and teachers.

I am especially interested in investigating the teaching and learning of statistical literacy in schools that are like my own. In such schools statistical literacy will be taught in classrooms where there is a wide diversity in the language and literacy skills of learners. I am interested in finding ways of how this diversity can be used to help students learn.

Many of the issues, about pedagogy, curriculum change, literacy and equality for students are shared by the teachers in this research. This research is in response to those concerns.

[1] ESOL – English for Speakers of Other Languages.

1.2 Research question

There is research available, both internationally and from New Zealand on the nature of statistics and statistical literacy. There also exists excellent New Zealand research into teacher professional development and curriculum development projects for the teaching of statistics and statistical investigations. Some investigation has been made into the teaching of statistical literacy in New Zealand. However, I do not believe that links between statistics education, statistical literacy and literacy have been fully explored in the research.

Therefore, the main research question addressed in this study is:

> How can we help students and teachers develop statistical literacy in the secondary mathematics classroom?

In answering this main research question the following questions may hopefully also be answered:

> What are teachers and students views about the nature of statistics and statistical literacy in the Mathematics [and Statistics] curriculum?
>
> What is needed to facilitate the development of statistical literacy with students and teachers in secondary mathematics classrooms?
>
> How can we assess statistical literacy with our students?
>
> How can using language learning principles help students and teachers to develop statistical literacy in secondary mathematics classrooms?
>
> How can using the 'principles of effective teaching for learners from diverse language and cultural backgrounds'[2] help students and

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[2] Taken from ESOL online and the DVD *Making Language and Learning Work 1: Integrating Language and Learning in Secondary Maths and Science*

teachers to develop statistical literacy in the secondary mathematics classroom?

What are the appropriate professional development strategies for teachers to use in this context?

1.3 Overview of the thesis

This opening chapter presents the research question for this inquiry. Chapter 2 reviews the literature on statistical literacy. The chapter begins with a description of statistics education and statistical literacy. The chapter then explores the links between statistical literacy, literacy and critical literacy. The next section attempts to link the teaching principles for statistical literacy to the teaching and learning principles of literacy by investigating possible frameworks and models for instruction. Finally the literature review explores the implications for the classroom and professional development for teachers. Chapter 3 describes the methodology used for collecting and analysing the data. Chapter 3 also outlines clearly the context of the study and how the research was planned and undertaken. The initial results and analysis from the first cycle of the research are presented in Chapter 4. The chapter documents the experiences of teachers and students in the teaching and learning of a unit of work on statistics and statistical literacy. The findings are discussed in Chapter 5. The limitations of the study, implications and recommendations for further research are discussed in Chapter 6.

2.1 Introduction

This chapter is a review of the literature about the notion of statistical literacy and its place in the secondary mathematics classroom. Many teachers and education researchers, both in New Zealand and internationally, consider statistical literacy to be an integral part of an effective school mathematics programme. However, there are a range of conceptualisations of statistical literacy and what statistical literacy means for secondary school mathematics teachers and students. Different experts have theorised about statistical literacy and different teachers, schools, states and nations have implemented programmes for developing statistical literacy into their curricula statements. The intention of this literature review is to explore some of these issues particularly in relation to the research questions posed.

Section 2.2 gives a brief history of statistics education both internationally and in New Zealand. Section 2.3 investigates the perceived differences between mathematics and statistics. In section 2.4 the development of mathematics and statistics education in New Zealand is examined. In section 2.5 an attempt is made to define what is meant by statistical literacy. Section 2.6 describes the theoretical models or frameworks for statistical literacy that are used by teachers and researchers to discuss statistical literacy in the mathematics classroom. Links between statistical literacy and literacy education are explored in section 2.7. Section 2.8 examines notions of literacy with respect to critical literacy, including the possibility of a critical statistical literacy. The implications for teachers and their classrooms in a statistical literacy classroom are considered in section 2.9. The place of teacher professional models, such as reflexive action, or action research in improving practitioners' [own] practice through evaluation and action are investigated. Section 2.10 concludes the Chapter by restating the focus of study.

2.2 Statistics education

> It has long been recognised that the subject of statistics has been badly taught and not well learned....
>
> (Stuart, 2005, p.1)

As teachers, we hope that we can help our students develop into statistically educated citizens. However, Stuart (2005) contends the reality may be somewhat different. It is therefore important to try and track the development of statistics education so that we can reach a greater understanding of why things may or may not be happening in our classrooms and how we might look for ways to foster statistical literacy and the ability to think statistically with our students.

2.2.1 International trends

There is a significant body of literature regarding statistics and the development of statistics education in schools both from New Zealand and from around the world. Watson (2006), focusing on the predominately English speaking countries of Australia, United Kingdom, New Zealand and the United States, documents the development of statistics education in schools. She describes the work of pioneers such as Radhakrishna Rao and Peter Holmes in the United Kingdom during the 1970's and 1980's who pushed for the inclusion of statistics into secondary school mathematics curricula. Holmes' (1986) framework for statistics instruction comprises five components - *data collection, data tabulation and representation, data reduction, probability* and *interpretation and inference* and was seen as the basis for a statistics curriculum. Watson (2006) also traces the development of statistics in the school curriculum back to initiatives in the United States, led by groups like the American Statistical Association [ASA] the Quantitative Literacy[3] movement and the subsequent National Council of Teachers of Mathematics [NCTM] principles and standards set out in 1989. Updated in 2000, the NCTM principles and standards classify statistics as *data analysis*

[3]Quantitative Literacy is a term used predominately in the United States instead of the term Numeracy. However there could be some room for misunderstanding as the aims of Quantitative Literacy are perhaps much broader than what could be considered the goals of say numeracy in the Ministry of Education's National Education Goals in New Zealand. The Quantitative Literacy projects of the NCTM and ASA advocated for a greater emphasis on statistics and probability, communicating and problem solving in real-life contexts.

and *probability*. The data analysis and probability content standards were to encourage instructional programmes that would enable all students to be able to; *formulate questions* that can be addressed with data and *collect, organize and display* relevant data to answer them, select and use appropriate statistical methods to *analyse* data, *develop and evaluate inferences and predictions*, and reason with *probability* (NCTM, 2000).

There appears to be widespread agreement about the nature of statistical inquiry and the requirements for statistics education around the world. This is evident in curricula, policy statements and curriculum analysis from countries such as Australia (Australian Education Council, 1991), New Zealand (Ministry of Education, 1992), China (Li, 2004), Italy (Ottaviani & Luchini, 2005) and the United States (NCTM, 2000). The experience of these countries appears similar. In each case statistical organisations and mathematics and statistics educators have got together to be advocates for change and have worked to develop school curricula (Barbieri & Giacché, 2006). However, as Watson (2006) points out, the official implementation of statistics into school curricula in countries like Australia, New Zealand, United Kingdom and United States only started in the early 1990's. Remarkably, this means that the adoption of statistics and probability in many state and national curricula around the world has occurred only in the last 20 years.

Despite statistics education's relative newness as a discipline there is ample statistics education research regarding statistical thinking and statistical literacy (Chance, 2002; Gal. 2002; Garfield & Gal, 1999; Graham, 2006; Schield, 2005b; Stuart, 2005; Utts, 2003, Watson, 1997; Watson & Callingham, 2005; Wild & Pfannkuch, 1999) and how statistics should be expressed in curriculum statements (Begg; 2005; Begg, Pfannkuch, Camden, Hughes, Noble & Wild, 2004; Holmes; 1986; NCTM, 2000).

New Zealand is well placed in the statistics education discourse. Overseas researchers (Watson cited in Begg et al., 2004), have commented on the strength of the New Zealand curriculum with respect to the teaching of statistics. Perhaps this perceived strength is because of the relatively early adoption of statistics into school curricula compared to other countries or maybe because statistics had been adopted into an official national school curriculum. Whatever the reason, a positive consequence of this situation is that New Zealand researchers are well represented in the research literature. In addition New Zealand researchers and educators are well represented in international organisations for promoting statistics education such as the International Association of Statistical Education [IASE].

2.2.2 The New Zealand situation

The need for statistically literate students in New Zealand schools is highlighted very early in the 1992 curriculum document, *Mathematics in the New Zealand Curriculum* [MiNZC] (Ministry of Education, 1992). The MiNZC states, in the general aims for mathematics education, that the curriculum must "...help students to achieve the mathematical and *statistical literacy* needed in a society which is technologically oriented and information rich" (Ministry of Education, 1992, p.8). While I would argue that the majority of New Zealand secondary mathematics teachers find this a perfectly reasonable goal to make in a mathematics curriculum document, I believe that there is still little evidence of (or guidance provided for) the effective teaching of statistical literacy.

The latest description of statistics education in New Zealand in the 2007 curriculum gives us a new definition of mathematics and statistics. The learning area statement is at pains to differentiate between statistics and mathematics. The New Zealand curriculum (Ministry of Education, 2007b) states that "these two disciplines are related but different ways of thinking and of solving problems" (Ministry of Education, 2007b, p. 26).

2.3 Mathematics and statistics debate

Both in New Zealand (Begg et al., 2004) and internationally (Gal & Garfield, 1997; Watson; 2006) there is debate amongst educationalists and curriculum developers on the nature of statistics and mathematics and best practice for instruction. In fact Begg et al. go further to describe a debate about whether statistics should be placed in the mathematics curriculum at all. However, whatever the position taken all researchers attempt to describe the differences between statistics and mathematics.

Many researchers (Begg et al., 2004; Gal & Garfield, 1997; Holmes, 1986; Watson, 2006) attempt to contrast the deterministic nature of mathematics, with its precision and exactness, against the stochastic nature of statistics, with its probability and variation. Begg et al. characterise the differences as mathematics being ‘concerned with reasoning with certainty’ while ‘statistics is concerned with reasoning with uncertainty’. Gal and Garfield distinguish between mathematics and statistics by arguing that statistics is a mathematical science but is not a branch of mathematics.

In the following sections I attempt to classify the differences and points of differentiation between mathematics and statistics described in statistics education research.

2.3.1 Difference as context

Researchers (Chance, 2002; delMas, 2002; Gal & Garfield, 1997) describe the difference between mathematics and statistics as being the importance of context or the "‘messiness’ or context-boundness of statistics" (Gal & Garfield, 1997, p6). To some extent I feel that this is overstated, as mathematics problems are similarly situated in context and can be just as messy. However, statistics does require all learners to put the numbers and data from statistical problems into context and any attempt to remove the context makes the activity meaningless. Stuart (2005) believes that statistical problem solving "requires the statistician to become involved in the context of the problem at all stages" (Stuart, 2005, p.12). This is a more compelling argument for me. Whereas we often seek to generalise mathematical problems by de-contextualising the situation, statistical problems stop having any real meaning outside of their context. Removing the "noise" of a problem to abstract it into a mathematically concise form may be one of the strengths of mathematical thinking. However, removing the context does not work in statistics because the solution lies in the context.

2.3.2 Difference as multiple solutions

Gal and Garfield (1997) also believe that one of the major differences between mathematics and statistics is that the "fundamental nature of many statistical problems is that they do not have a single mathematical solution" (Gal & Garfield, 1997, p6). Statistics problems can have multiple answers and often have no right or wrong answers (Gal & Garfield, 1997). The researchers state that students are then expected to use mathematical and statistical tools to give "judgments, inferences and opinions" (Gal & Garfield, 1997) about data and that an answer to a statistics problem may involve students constructing an argument and then defending their position. While I am attracted to this explanation because of its focus on the literacy capabilities and communication skills of students I still think that this is only part of any description of the differences between mathematics and statistics. Mathematical problems can often have a variety of solutions and mathematics can also demand that students make judgements and arguments.

2.3.3 Difference as statistical literacy

Graham (2006) suggests that the present location of statistics within mathematics teaching has "…created a very technique-based topic, with little emphasis on context or problem solving" (Graham, 2006, p221) because teachers teach students to solve statistical problems like they would solve mathematical problems. Similarly, Stuart (2005) argues that mathematical thinking has dominated statistical teaching in the classroom. Stuart (2005) believes that mathematical thinking "emphasises mathematical models, methods and procedures" (p.12) and that the application of these techniques takes on more importance than dealing with the initial problem or context.

Stuart (2005) gives an example of the limitation of mathematical thinking with the particular example of probability and distributions. He argues that traditional mathematical thinking assumes that probability theory is fundamental to statistics. However, Stuart (2005) believes that variation is the fundamental statistical concept and that probability theory is not essential in coming to an understanding of variation and elementary methods of statistical inference, rather probability serves as an excellent model for statistical variation. He describes how teachers often start with the mathematical model – probability – rather than addressing the statistical concept of variation. Stuart (2005) claims that teachers simplify the conceptually difficult probability theory to make it more palatable for students, removing the students even further from understanding the problem in the original context. Stuart (2005) does not deny the importance of mathematics and mathematical thinking in statistics but rather claims that it is not essential in coming to an understanding of elementary methods of statistical inference.

In a similar vein, Schield (2005a) characterises the differences between mathematics and statistics in terms of methods of reasoning. Schield characterises mathematics, probability and statistics as examples of deductive thinking where an argument is either true or false. He then argues that statistical literacy is an example of inductive (and some deductive) thinking. An explanation of inductive reasoning is reasoning that judges an argument on a continuum and that the stronger the argument the greater the chance that its conclusions are accepted as true. Schield (2005a) states that for students to be statistically literate students have to ask whether a claim *could be true* rather than if it *is true*. Schield has complicated the issue somewhat by differentiating between statistics [as mathematical models and processes] and statistical literacy [as statistical thinking and reasoning]. Statistical literacy will be discussed in much greater detail in section 2.5.

2.3.4 Difference as teaching methods

The conflicts between mathematics and statistics education may exist not because of differences in content but because of pedagogical differences. Mvududu (2005) argues that while the word ‘constructivism’ may not have been stated explicitly in many of the developments in statistics education, researchers have advocated many of the elements of constructivist teaching, like active learning, scaffolding learning, sharing power with students, and helping them solve problems in context. In my opinion this view of learning, while widely held by mathematics teachers, is still at odds with what actually goes on in the classrooms. Watson (2006) claims that “if mathematics was taught as it should be – for reasoning rather than mastery of algorithms - there would be little need for a distinction” (Watson, 2006, p.11) between statistics and mathematics.

2.3.5 Difference as language

Gal (2000) focuses on the difference between mathematics and statistics in terms of language stating that an understanding of the terminology of statistics is critical because so many everyday phrases adopt technical meanings in statistics. Gal and Garfield (1997) go further stating that communication is crucial because “most students will be ‘consumers’ of statistics rather than ‘producers” (p.4). The importance of language in the study of statistics is central to this thesis. While I agree with many of the characterisations of statistics education and the descriptions of the differences between mathematics and statistics, it is the significance of language that resonates most with my own experiences as a teacher. The importance of language will be discussed in greater detail in section 2.7 on literacy and language in the mathematics classroom. The following section briefly outlines the development of statistics education in the New Zealand context.

2.4 Mathematics and statistics education in New Zealand

The *Effective Pedagogy in Mathematics/Pāngarau Best Evidence Synthesis Iteration [BES]* (Anthony & Walshaw, 2007) states that “the current academic view in New Zealand is that the mathematics taught and learned in schools should provide a foundation for working, thinking and acting like mathematicians and statisticians” (Anthony & Walshaw, 2007, p7). The inclusion of acting like a statistician in their definition of what constitutes the teaching and learning of mathematics is significant. As outlined earlier in section 2.2.2, the development of the teaching and learning of statistics in New Zealand schools appears to have followed a similar path to other countries. Again, New Zealand’s place in the development of statistics education in schools is one of early adoption with Begg (2005) and Begg et al. (2004) both giving descriptions of the development of statistics education going back to very early beginnings in primary schools fifty years ago, through to the early 1970's and up to the curriculum reform in 1992.

2.4.1 The current mathematics curriculum and its review

The 1992 mathematics curriculum clearly outlines the requirements for the study of statistics in schools. The statistics strand in Mathematics in the New Zealand Curriculum (Ministry of Education, 1992) is divided into three groups of achievement objectives where students are expected to; develop the skills of collecting, organising, and analysing data under the theme *statistical investigations*, as well as interpret data under the theme *interpreting statistical reports* and finally deal with probability under the theme of *exploring probability* (Ministry of Education, 1992).

New Zealand is currently undertaking a review of all of the curriculum documents implemented in the 1990's. The most obvious change in *The New Zealand Curriculum* (Ministry of Education, 2007b) is the name change for the learning area from Mathematics to Mathematics and Statistics[4]. However, the accompanying *Mathematics and Statistics Achievement Objectives* (Ministry of Education, 2007c) remain remarkably unchanged. The Statistics strand with three renamed achievement objectives for statistics. However, I believe that these small changes in titles give much better descriptions to the three sets of achievement objectives with the use of *statistical investigation [thinking]*[5], *statistical literacy* and *probability.* The links and progression from the Mathematics in the New Zealand Curriculum (Ministry of Education, 1992) to *The New Zealand Curriculum* (Ministry of Education, 2007c) are shown in figure 1.

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[4] In light of the international debate about whether statistics should be placed in the mathematics curriculum or taught as a separate subject entirely it is interesting to see that the *New Zealand Curriculum Draft for Consultation 2006* (Ministry of Education, 2006a) recommends that they remain combined as a discipline but that mathematics be renamed to mathematics and statistics to differentiate between mathematical and statistical thinking

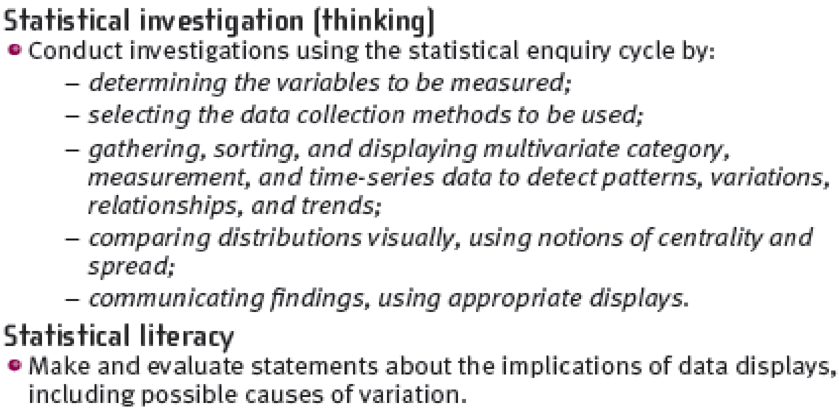
[5] It is of interest to see the dropping of the bracketed word [thinking] after statistical investigation from the draft document to the new curriculum in the achievement objective statistical investigation.

Figure 1 **Curriculum Development[6] - Brunning and Neill (2007)**

Existing curriculum 1992 	New curriculum 2007 
Statistical investigations	Statistical investigations
Interpreting statistical reports	Statistical literacy
Exploring probability	Probability

Other interesting features of the new curriculum can also be seen in the finer detail of the *Mathematics and Statistics Achievement Objectives* (Ministry of Education, 2006b). Statistical investigation is clearly set out with the features of a statistical enquiry cycle evident at all levels of the curriculum. For example, the statistics achievement objectives at level 4 and level 5 of the curriculum, which will be the level at which many of the students in this research would be working at, are shown in Figures 2 and 3. The achievement objective for statistical investigation [thinking] uses five bullet points to explain the statistical enquiry cycle. In contrast, statistical literacy is afforded a single sentence to describe features.

Figure 2 **Draft Level 4 Achievement Objectives**



Statistical investigation (thinking)

- Conduct investigations using the statistical enquiry cycle by:
  - *determining the variables to be measured;*
  - *selecting the data collection methods to be used;*
  - *gathering, sorting, and displaying multivariate category, measurement, and time-series data to detect patterns, variations, relationships, and trends;*
  - *comparing distributions visually, using notions of centrality and spread;*
  - *communicating findings, using appropriate displays.*

Statistical literacy

- Make and evaluate statements about the implications of data displays, including possible causes of variation.

(Ministry of Education, 2006b, p.21)

Figure 3 **Level 5 Achievement Objectives**

Statistical investigation

- Plan and conduct surveys and experiments using the statistical enquiry cycle:

[6] The table is taken from the presentation *Statistical shifts and the Curriculum* given by Deborah Brunning of Statistics New Zealand and Alex Neill of NZCER at NZAMT10 in Auckland, 25-28 September 2007.

- determining appropriate variables and measures
- considering sources of variation
- gathering and cleaning data
- using multiple displays, and re-categorising data to find patterns, variations, relationships, and trends in multivariate data sets
- comparing sample distributions visually, using measures of centre, spread, and proportion
- presenting a report of findings.

Statistical literacy

- Evaluate statistical investigations or probability activities undertaken by others, including data collection methods, choice of measures, and validity of findings.

(Ministry of Education, 2007c, p.22)

While the sections reproduced above are rather arbitrary and anecdotal, I believe they illustrate how the curriculum document is much more comfortable expressing the concept of statistical investigation than the concept of statistical literacy. Obviously the document is not a battle of text length. However, there is much more detail presented in the draft document for statistical investigation [thinking] than for statistical literacy. It will be interesting to see how teachers use these designations and definitions as they develop teaching and learning programmes for their students.

The draft curriculum (Ministry of Education, 2006a) and the accompanying draft achievement objectives (Ministry of Education, 2006b), and now the new curriculum (Ministry of Education, 2007c), are obviously important steps in the evolution of mathematics and statistics education in New Zealand.

2.4.2 1992 curriculum reform in New Zealand

Despite the setting of clear goals and objectives for statistics education in the Mathematics in the New Zealand Curriculum (Ministry of Education, 1992) the implementation of the statistics curriculum in New Zealand schools doe not appear unproblematic. Begg et al. (2004) describe how approaches and initiatives in New Zealand secondary schools were not fully implemented or failed to be adopted often due to teachers being trained in mathematics rather than statistics. Begg et al. echo similar observations made by overseas researchers (Garfield & Gal, 1999; Watson, 2006) who assert that probability and calculating statistics were often taught as a part of pure mathematics or arithmetic course of study and that the teaching of statistical investigations and statistical literacy were often skipped over or ignored.

With reference to senior secondary school reforms in New Zealand, Begg et al. (2004) how the introduction of a greater amount of teaching and learning of statistics was a challenge for many teachers. They refer specifically to the introduction of internally assessed project work in the Year 13 Mathematics with Statistics course and state that "…some teachers were not sympathetic to this and undermined the curriculum intention" (Begg et al., 2004, p.3). Watson (2006) believes that because statistics [7] is a relatively recent addition to the school curriculum schools and teachers believe that statistics cannot be as important as other, more traditional areas of the curriculum. As has been my experience in New Zealand schools, Watson states that it "is not at all unusual to find the units on data and chance to be placed in the timetable at the end of the academic year, to fill in time with activity when students and teachers are winding down, or to be deleted as unnecessary if more time is needed for other topics such as algebra or trigonometry" (Watson, 2006, p.8).

2.4.3 Evidence of current statistics education practice

Despite all of the difficulties, the teaching of statistics has become a core component of mathematics education in New Zealand. We have a recent indication of the attitudes of New Zealand teachers towards statistics in the curriculum from the responses to the draft curriculum such as *The New Zealand Curriculum Draft for Consultation 2006 Analysis of Long Submissions* (Watson et al, 2006). While there were some responses from teachers and educational groups that still questioned the need for an emphasis on statistics or queried the difference between statistical thinking and mathematical thinking, the majority of respondents valued the place and emphasis of statistics in the curriculum.

[7] I have used the term *statistics* where Watson (2006) uses the terms *data and chance.* As an Australian researcher/educator, Watson could be using the terms *data and chance* as is used to describe strands in Australian mathematics curriculum documents. The equivalent strand in MiNZC is *statistics.* However, the statistics strand in MiNZC is then broken down into *interpreting statistical reports, statistical investigations* and *exploring probability*. However, Watson may also be using the terms *data and chance* because the terms offer more to readers than the term *statistics* which can have multiple meanings such as the wider study of statistics or as summary statistics such as the mean or median.

We also have some indication of the success of schools and teachers in teaching the mathematics and statistics curriculum. In *Learning for Tomorrow's World: Programme for International Student Assessment (PISA) 2003* (Ministry of Education, 2005) we have an analysis of a large sample of New Zealand 15 year olds performance in the second cycle of PISA testing which had a special focus on mathematical literacy. PISA results compare results within and between 41 countries, the majority of who are in the Organisation for Economic Cooperation and Development [OECD]. The New Zealand student mean score in mathematics placed New Zealand within the group of second highest performing countries for each subject area, along with countries such as Australia, Canada and Japan.

In the 2003 PISA[8] study mathematical literacy is described using four scales – *quantity, uncertainty, shape and space* and *change and relationships*. New Zealand students showed stronger performance on the *uncertainty* scale than on the other three scales, whereas they showed the weakest performance on the *quantity* scale. The researchers state that the "relative performance of countries in the four mathematics content areas provides an insight into potential strengths and weaknesses of each country's intended curricula and the effectiveness with which these curricula are delivered" (Ministry of Education, 2005, p4).

Significantly, the PISA researchers also found that New Zealand had one of the widest distributions of achievement in mathematics or within-country variations for student performance in mathematics (Ministry of Education, 2005). The PISA researchers go on to assert "that educational programmes, schools and teachers may not be appropriately addressing the wide range of student knowledge and skills that exists within the New Zealand education system" (Ministry of Education, 2005, p4).

Although this is not a comment on the efficacy of statistics teaching but of wider mathematics teaching in New Zealand, it does give an indication of the

[8] PISA assesses the mathematical literacy of students using a test consisting of questions derived from four scales – quantity [Number], uncertainty [Statistics and Probability], shape and space [Geometry] and change and relationships [Algebra]. Interestingly the study gives an example on page 7 from the uncertainty scale that would be an excellent example of a statistical literacy task.

link between curriculum goals and what is actually going on in classrooms. There is evidence that there is a real strength in the curriculum policy and development of statistics education in New Zealand. This can be shown in international comparisons of student performance such as PISA. However, one interpretation of the PISA results is that, the strengths in curriculum policy and development are not necessarily matched in the pedagogical practices of all teachers.

2.4.4 Unpacking statistics

As mentioned in section 2.4.2 the statistics and statistics education discourse is a relatively recent one. There appears to be enough evidence that thinking and doing statistics is sufficiently different from thinking and doing mathematics for statistics to be treated differently in the classroom. It is clear that teachers need to unpack what is meant by statistics education and understand the implications of statistical thinking, probability and statistical literacy for teaching and learning in their classrooms.

2.5 Statistical literacy

Because the focus of this thesis is about developing statistical literacy in the secondary mathematics classroom it is important to determine what statistical literacy is defined as.

2.5.1 Definitions

> ’Statistical literacy’ is the ability to understand and critically evaluate statistical results that permeate our daily lives – coupled with the ability to appreciate the contributions that statistical thinking can make in public and private, professional and personal decisions.
>
> (Wallman, 1993, p.1)

We see in Wallman’s (1993) definition both a personal and a societal need for our students to develop statistical literacy skills. Similarly Gal (2002) defines statistical literacy as a basic principle for participation in society and the “key ability expected of citizens in information-laden societies” (Gal, 2002, p.1) where decision-making is based on critical skills from statistical literacy Likewise, Watson (2006) sees statistical literacy as the “meeting point of the chance and data curriculum and the everyday world, where encounters involve unrehearsed contexts and spontaneous decision-making based on the ability to apply statistical tools, general contextual knowledge, and critical literacy skills” (Watson, 2006, p.11)

Chick, Pfannkuch and Watson (2005) describe statistical literacy as ‘transnumerative thinking’ where students will be able to make sense of and use different representations of data to make sense of the world around them. Gal and Garfield (1997) see statistical literacy as the need for students to be able interpret results from studies and reports and to be able to “pose critical and reflective questions” about those reports because “most students are more likely to be consumers of data than researchers” (p.4) of statistics.

In New Zealand, Begg et al. (2004) have called for a greater emphasis to be placed on statistical literacy in the curriculum so that students can become active and critical citizens. As stated previously, the use of the term statistical literacy is much more explicit in the 2007 curriculum with the addition of statistical literacy achievement objectives (Ministry of Education, 2006b). The 2007 curriculum also goes to great lengths to delineate between mathematical thinking and statistical thinking.

Overseas researchers describe the promotion of statistical literacy in their countries. For example, Barbieri and Giacché (2006) in Italy and Araujo (2006) in Latin America describe the same tensions between mathematics curricula and the goals of statistical literacy that have characterised developments in other countries. Barbieri and Giacché state that Italian citizens are unfamiliar with the language and the concepts of statistics and that “they are not able to understand precisely the meaning of the figures measuring economic and social phenomena, even if the decisions of people, business and administrations are growingly based on statistics “ (Barbieri & Giacché, 2005, p.2)

All of the previous researchers share common themes for statistical literacy such as interpreting data in context and developing statistical citizenship in a data-rich world. However, there appears to be some conflict with researchers and educators about the definitions of, and distinctions between, statistical literacy, statistical reasoning, and statistical thinking in the discipline of statistics. Many researchers appear to use the phrases *statistical thinking*, *statistical reasoning* and *statistical literacy* interchangeably.

2.5.2 Statistical literacy, statistical reasoning and statistical thinking

For some researchers (Ben-Zvi & Garfield, 2004; Rumsey, 2002) statistical literacy involves understanding and using the basic language and tools of statistics. In these terms statistical literacy is a procedural literacy or what Rumsey calls *statistical competency*. This definition may be used to distinguish the understanding of statistical concepts from the numerical manipulation and graphing of data. However, with the increased use of technology there is much less need for “number crunching” (Garfield, 2002) and such a definition may be limiting. Rumsey does include thinking critically and making decisions in a much broader definition of statistical literacy. However, for the purpose of exploring and understanding the links between statistical literacy, reasoning and thinking Rumsey’s simpler statistical competency will be used as an initial definition for statistical literacy.

In comparison, statistical reasoning may be defined as the way people reason with statistical ideas to make sense of statistical information (Garfield & Gal, 1999). Ben-Zvi and Garfield (2004) describe statistical reasoning as interpretation of data and its different representations. Garfield (2002) describes a five level hierarchy for statistical reasoning that ranges from idiosyncratic reasoning, where students have little or no understanding of words, symbols and concepts, through to integrated process reasoning where students have a complete understanding of a statistical process. Understanding and using statistical language is seen as significant.

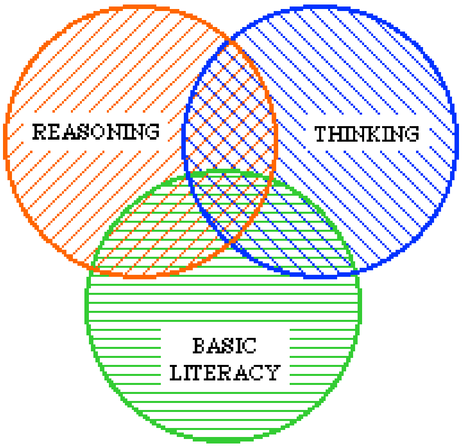
Interestingly, Garfield suggests that critiquing media reports may be one way to assess statistical reasoning.

Both Ben-Zvi and Garfield (2004) and Chance (2002) describe statistical thinking as an understanding of why and how statistical investigations are conducted. This includes recognising how, when, and why inferences can be made, and using the context to plan and evaluate and to draw conclusions. Context is core to Chance's definition of statistical thinking.

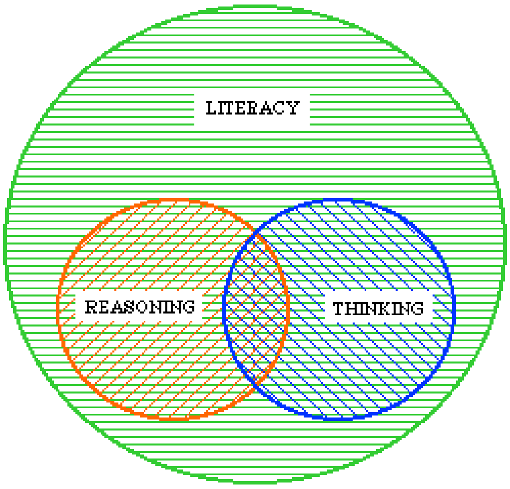
DelMas (2002) discusses the competing goals of statistical literacy, reasoning and thinking in statistics instruction. He succinctly encapsulates the conflict by presenting two models. In the first model of instruction, each domain [statistical literacy, statistical reasoning, and statistical thinking] is independent of the other two, but with some overlap. In the second model statistical literacy is the all-encompassing goal of instruction and statistical reasoning and thinking no longer have independent content. The two models are represented as Venn Diagrams in Figure 4.

DelMas (2002) characterises statistical literacy in the first model as the "development of basic skills and knowledge" (Section 4, ¶ 3) that are needed to develop statistical reasoning and thinking. In the second model there are no parts of the domains separate from statistical literacy. In this model statistical reasoning and statistical thinking become "sub-goals within the development of the statistically competent citizen" (delMas, 2002, Section 4, ¶ 4).

Figure 4 **delMas' perspectives on statistical literacy**



Independent domains with some overlap



Reasoning and thinking within literacy

(delMas, 2002)

In both of delMas' (2002) models statistical literacy can be seen as the foundation [A stretch perhaps in the first diagram with overlapping domains, though literacy is at the bottom]. In the 'reasoning and thinking within literacy' diagram statistical literacy is also presented as the goal of instruction. However, delMas then proceeds to question his own models when he points out that in advanced courses in statistics, "it is not difficult to imagine statistical thinking as the overall goal that encompasses and is supported by a foundation in statistical literacy and reasoning" (delMas, 2002, Section 4, ¶ 5).

The interrelatedness of statistical literacy, statistical reasoning, and statistical thinking does potentially make it difficult for teachers to design lessons or assessments that would meet all the competing goals. DelMas (2002) makes a final attempt to describe the features of statistical literacy, statistical reasoning, and statistical thinking by focusing not on the context or content of problems but what teachers ask students to do with the context or content. DelMas outlines in Figure 5 assessment questions that are asked in tasks for statistical literacy, reasoning and thinking that would involve students being in "one domain more so than in another" (delMas, 2002, Section 5, ¶ 2).

Figure 5 delMas' three instructional domains

BASIC LITERACY	REASONING	THINKING
Identify Describe Rephrase Translate Interpret Read	Why? How? Explain (The Process)	Apply Critique Evaluate Generalize

(delMas, 2002)

Again it appears here that delMas (2002) is attempting to limit statistical literacy to a procedural literacy. Statistical reasoning appears to be the ‘doing’ of statistics and statistical thinking the ‘questioning’. While this may be attractive as a description we must contrast the attempts by delMas and Rumsey (2002) to characterise statistical literacy as statistical, graphical or technical competency with researchers and educators (Gal, 2002, Schield, 2005a; Watson, 2006) who characterise statistical literacy as a much wider analytical and critical literacy. In this definition statistical literacy focuses on understanding what is being presented, asking good questions and then evaluating arguments, As Schield asserts; “statistical literacy is more about questions than answers” (Schield, 2005a, p.6)

2.5.3 My stance on statistical literacy

It is clear that there is some debate about the nature of statistical literacy and that there are overlaps in definitions. However, I see part of the conflict as another illustration of the wider tension in education between traditional behaviourist or developmental perspectives [with phrases like basic skills and knowledge] and constructivist or emergent perspectives where students are asked to become critical and analytical.

For this thesis, I have chosen to use a definition of statistical literacy in the spirit of Schield (2005a) that is about asking good questions. It is the much wider definitions of statistical literacy, such as the critical literacy described by Gal (2002) and Schield or delMas’ (2002) model of statistical reasoning and thinking as part of a wider statistical literacy, rather than Rumsey's (2002) statistical competency. I have also chosen to use the term statistical literacy instead of statistical reasoning or statistical thinking because much of the literature focused on the areas of statistical thinking and reasoning is about students doing statistics or completing investigations rather than responding to the statistics of others. This positioning may create a certain amount of difficulty when talking to other teachers and when designing lessons and unit plans and schemes of work.

There are further challenges in using the term *statistical literacy*. Statistical literacy situates the discussion in *literacy*. For many secondary mathematics teachers this relates to the work undertaken in New Zealand secondary schools to raise literacy levels and all the teacher experiences and attitudes associated with such interventions. For some [mathematics] teachers the term statistical literacy also alludes to a statistical literacy as one of the many *multiliteracies* needed by students. For others statistical literacy leads to conceptions of a *critical* literacy where students bring critical thinking skills to analyse and evaluate the work of others. We can see here that there are difficulties in using relatively new terms like statistical literacy without unpacking or declaring meanings.

2.6 Statistical literacy frameworks

Despite the challenges of the terminology it is generally accepted that statistical literacy is an important notion in statistics education. In the following section I will attempt to describe features of statistical literacy as presented by researchers. I will describe two frameworks or models that attempt to represent the features of statistical literacy and one framework that attempts to describe statistical thinking. The first framework is from Gal's (2002) research into the understanding of statistics by adults. The second model is the Statistical Literacy construct from Watson and Callingham (2005). Finally I will look at the work of Wild and Pfannkuch (1999) who have developed their framework for statistical thinking in empirical enquiry.

2.6.1 The components of statistical literacy

Gal (2002) suggests there are two components to statistical literacy in his research of adults' statistical practices. The components of statistical literacy are:

a) the ability to *interpret* and *evaluate critically* statistical information in a variety of contexts and when relevant.
b) the ability to *discuss* or *communicate* this understanding in a fashion that can have an impact on decision-making.

(Gal, 2002, p.2-3)

According to Gal (2002) there are five interrelated knowledge bases that must be used to exhibit these components of statistical literacy

a) mathematical knowledge
b) statistical knowledge
c) knowledge of the context
d) literacy skills
e) and critical questions

(Gal, 2002, p.4)

Gal (2002) also notes the need for dispositions or associated attitudes and beliefs that would motivate citizens to be critical thinkers with statistics. Also significant is that Gal separates literacy and being critical in his model. Both of these issues will be discussed in greater detail later in this section and in sections 2.7 and 2.8.

2.6.2 A statistical literacy construct

The Statistical Literacy construct from Watson and Callingham (2005) builds on previous work by Watson (1997) where she uses the SOLO taxonomy of Biggs and Collis (1982) from developmental psychology to categorise statistical thinking into a three tier hierarchy. Here again we have statistical thinking as inseparable from statistical literacy. In the first tier of Watson's model students develop an understanding of the basic statistical and probability terms. In the second tier students are developing an understanding of statistical terms and concepts in context. At the most sophisticated level students are developing a questioning attitude and using critical thinking.

Subsequently, Watson and Callingham (2005) have developed this three tiered view into their Statistical Literacy construct. Watson and Callingham's model is a six level hierarchy that represents increasingly sophisticated thinking starting from idiosyncratic through to critical mathematical. At the Idiosyncratic (Level 1) and Informal (Level 2) levels students are only merely interacting with the language and meanings of statistical terms. For the Inconsistent (Level 3) and Consistent Non-critical (Level 4) levels of the construct students are beginning to engage with the context and uncover the statistics embedded in the context. In the last two levels of the classification, Critical (Level 5) and Critical Mathematical (Level 6), students are able to be critical and challenge claims made in statistical reports and data. The levels of the Watson and Callingham Statistical Literacy construct are shown in Figure 6.

Interestingly Watson and Callingham (2005) felt that traditional text book questions could fulfil the requirements of levels 1 and 2 but that the same types of questions were unlikely to fulfil the need of 'providing motivating contexts to challenge students' critical thinking' and that teachers would have to seek out contexts that engaged students in the media.

Figure 6 **A statistical literacy construct - Watson and Callingham**

6 **Critical Mathematical**	Critical, questioning engagement with context, using proportional reasoning particularly in media or chance contexts, showing appreciation of the need for uncertainty in making predictions, and interpreting subtle aspects of language.
5 **Critical**	Critical, questioning engagement in familiar and unfamiliar contexts that do not involve proportional reasoning, but which do involve appropriate use of terminology, qualitative interpretation of chance, and appreciation of variation.
4 **Consistent Non-critical**	Appropriate but non-critical engagement with context, multiple aspects of terminology usage, appreciation of variation in chance settings only, and statistical skills associated with the mean, simple probabilities, and graph characteristics.
3 **Inconsistent**	Selective engagement with context, often in supportive formats, appropriate recognition of conclusions but without justification, and qualitative rather than quantitative use of statistical ideas.
2 **Informal**	Only colloquial or informal engagement with context often reflecting intuitive non-statistical beliefs, single elements of complex terminology and settings, and basic one-step straightforward table, graph, and chance calculations.
1 **Idiosyncratic**	Idiosyncratic engagement with context, tautological use of terminology, and basic mathematical skills associated with one-to-one counting and reading cell values in tables.

(Watson & Callingham, 2005, p117)

The model had been proposed as the researchers felt that while statistical literacy was a part of the school curriculum, “very little research has been carried out to document the progress made by students as they progress through …their schooling in developing both statistical techniques and critical evaluation skills” (Watson & Callingham, 2005, p116). There was an attempt to understand how development in statistical literacy was related to the development of statistical concepts in students. The framework was from an educational or psychological background. A real strength of the Watson and Callingham (2005) study is that they have trialled their statistical literacy scale with a large number of Australian students. This has enabled them to attempt to determine how and when instruction for statistical literacy could take place and how instruction can be scaffolded to help students progress.

Watson (2003) states that “...Level 6 (of the statistical literacy construct) is the goal by the time students leave school but without an appreciation of the preceding levels of likely progression, it is not possible to plan experiences that will assist students to the higher levels of understanding" (p. 3). Watson does not attempt to align year levels with the levels of development observed, however she does observe that "by the end of compulsory schooling[9], many students are not performing at the highest levels described above" (p. 3). This has major implications for this research study. The students involved are all in Years 9 and 10. If Watson is correct it may too difficult a task to achieve any level of statistical literacy with these students.

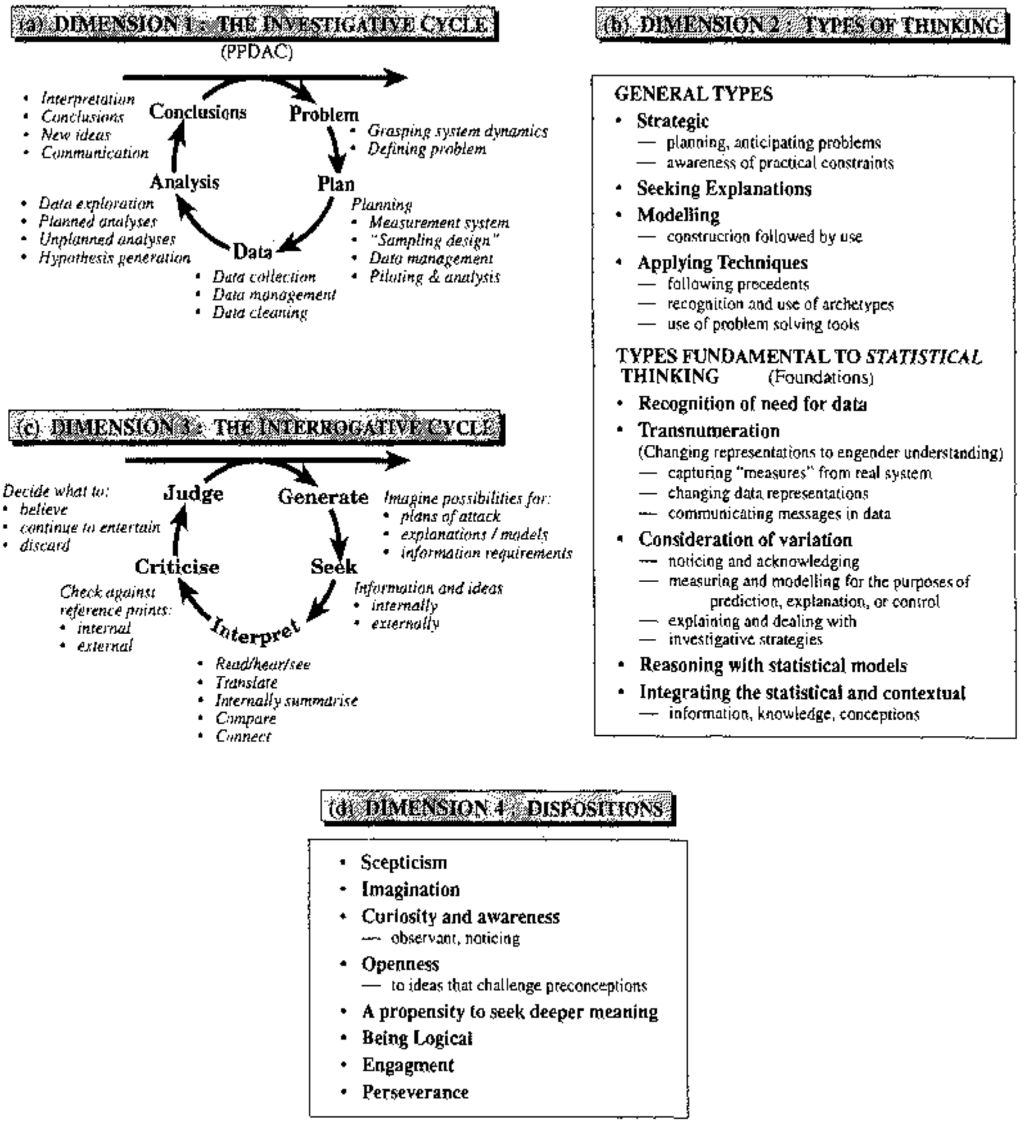
There are some obvious differences between Gal's (2002) approach and that taken by Watson and Callingham (2005). Gal presents a full definition of statistical literacy along with the necessary components that are needed. However, Watson and Callingham differentiate between hierarchical levels of statistical literacy. As mentioned earlier, the different approaches can be understood by the contexts of their studies into adults and students respectively. Regardless, the essence of both Gal's and Watson and Callingham's descriptions are very similar. Both emphasise a need for statistical knowledge and skills, the ability to communicate ideas, the centrality of context, and the need to be critical.

2.6.3 A framework for statistical thinking in empirical enquiry

Alternatively, Wild and Pfannkuch (1999) have developed a framework for statistical thinking called the framework for statistical thinking in empirical enquiry. They have identified four dimensions: an investigative cycle, types of thinking, an interrogative cycle, and dispositions [see Figure 7].

[9] For Watson in Australia this is Grade 10 equivalent to Year 11 in New Zealand.

Figure 7 Statistical thinking in empirical enquiry – Wild and Pfannkuch



(Wild & Pfannkuch, 1999, p.226)

The investigative cycle or PPDAC cycle (problem, plan, data, analysis and conclusion) describes the process of statistical investigation. Wild and Pfannkuch's second dimension states that there are five fundamental types of statistical thinking: recognition of the need for data, transnumeration (or using different representations of data to give better understanding), understanding variation, using statistical models and integrating the statistical with the contextual (Wild & Pfannkuch, 1999). The interrogative cycles (generate, seek, interpret, criticise, and judge) describes the thinking process that statisticians use when dealing with the problem and the data. Finally, Wild and Pfannkuch describe the dispositions that statisticians require for statistical problem solving. Wild and Pfannkuch's dimensions are non-hierarchical. However, the investigative cycle and the interrogative cycle are sequential.

We get a good description of what is needed by students to become statistical literate in the dispositions. Wild and Pfannkuch's (1999) dispositions are *scepticism, imagination, curiosity, awareness, openness, propensity to seek deeper meaning, being logical, being engaged* and *persevering*. In scepticism Wild and Pfannkuch see the need to 'adopt a critical eye'. Some of the statisticians that Wild and Pfannkuch researched believed that the dispositions could not be taught but Wild and Pfannkuch are more positive about this. They describe how the investigative cycle and the interrogative cycle for example can be used as thinking tools to prompt students to address certain issues. Both Gal (2002), with his attitudes and beliefs, and Watson and Callingham (2005) describe a need for similar dispositions in their models.

While the Watson and Callingham (2005) framework comes out of the work of statistics educators working in classrooms with students, the Wild and Pfannkuch (1999) framework comes from the researchers researching from the statistician's viewpoint and looking at what statisticians believe they do. Wild and Pfannkuch do not attempt to describe the progression or development in statistical literacy or the development of statistical concepts in students but rather outline what statisticians actually do. The focus is on describing a much wider framework for statistical thinking. I can see some difficulties for teachers in using the framework to help students learn as while desirable outcomes are outlined no pathway or progression is described to follow. This was clearly not the intention of the researchers. Wild and Pfannkuch do not see statistical thinking or statistical literacy as separate entities but rather that there is "holistic thinking informed by statistical elements" (Wild & Pfannkuch, 1999, p.244).

These three frameworks are by no means the only frameworks available for describing statistical thinking or statistical literacy. Reading (2002) suggests a ‘profile for statistical understanding’ based on the SOLO taxonomy across five areas of statistics: data collection; data tabulation and representation; data reduction; probability; and interpretation and inference. The Reading (2002) framework is again from an educator’s perspective as is informed by studying what students were doing in Australian classrooms. The framework does not specifically mention statistical literacy and as it is similar to the hierarchical framework of Watson and Callingham (2005) that I have not expanded on it here.

2.6.3 Being critical

In both the Watson and Callingham (2005) and Gal (2002) descriptions of statistical literacy and Wild and Pfannkuch’s (1999) framework for statistical thinking there are clear references to ‘being critical’. Being critical also appears in the statistics literacy achievement objectives of the New Zealand curriculum. In the draft *Mathematics and Statistics Achievement Objectives* (Ministry of Education, 2006b) students at Level 6[10] are asked to ‘critically evaluate statistically based information’ as part of the statistical literacy objectives. While the word ‘critically’ is no longer present in the final version of the *Mathematics and Statistics Achievement Objectives* (Ministry of Education, 2007c), critical thinking and critical literacies are present across the statements for key competencies, values and descriptions of learning areas in the new curriculum..

Gal (2005) has further explored critical literacy, where statistical literacy [or probability literacy or computer literacy] is more than acquiring basic skills. Gal broadens the definition to where statistical literacy is a much wider concept of critical analysis and is linked closely to metacognition. Similarly, Watson (2006) makes direct links from statistical literacy to literacy by

[10] Interestingly, in the draft Mathematics and Statistics Achievement Objectives (Ministry of Education, 2006b) for statistical literacy, students at Level 5 are asked to only ‘evaluate the statistical processes of others’. It is not until Level 6 and beyond that students are asked to “critically evaluate the statistical processes of others’. Perhaps the curriculum developers have adopted Watson’s (2003) view that students are not ready to be fully statistically literate until potentially their last year of mathematics study.

discussing the multiliteracies pedagogy of Kalantzis and Cope (1999). Statistical literacy is then an opportunity to call on all the research and good practice available in the field literacy, rather than literacy being a problem that stops students doing statistics.

As a teacher of ESOL students or students who have English as another language [EAL] I have been exposed to some of the research around language learning and language acquisition. While there is ample research concerned with notions of critical literacy (Kalantzis & Cope, 1999; Knobel & Healy, 1998; Pennycook, 2001; Wright & Lather, 2006) research linking literacy, language and statistics is harder to find. Some researchers such as Thornton and Hogan (2001) have attempted to describe mathematics and mathematics teaching as a critical mathematics literacy that works to empower students to become critical citizens in modern society. I believe that much of the language and linguistics research sits comfortably with the definitions of statistical literacy given by statistics educators. In the next section I will to investigate literacy and language in the classroom before returning to this notion of critical literacy.

2.7 Literacy and language in the mathematics classroom

"Language plays a central role."

(Anthony & Walshaw, 2007)

The centrality of language in the teaching and learning of mathematics and statistics is clearly stated in research and policy. The importance of language has long been signalled in New Zealand curriculum documents. The interpretation and communication of mathematical ideas is present throughout the Mathematical Processes strand of the MiNZC (Ministry of Education, 1992). I would suggest that while the curriculum explicitly links statistical and literacy skills the situation at school level is very different. Many teachers, who are good at manipulating symbols in traditional mathematics, struggle with the teaching of the reading, interpreting and writing skills demanded by the curriculum. It is still common to hear secondary mathematics teachers bemoan assessment questions and problems that are presented in context as unfair on students. Similarly, many teachers share a belief that the lack of literacy skills in their students is holding many a good mathematician back.

The importance of literacy in statistical literacy is clearly stated in research. One of the five inter-related knowledge bases in Gal's (2002) model of statistical literacy is literacy. Gal states that unless a student has good comprehension skills there is no chance of students understanding statistical reports, graphical representations or data. Further, students can have relatively high levels of numerical or statistical skill, but then be held back by written work that is unexpectedly poor.

2.7.1 Language demands in the mathematics classroom

Teachers and researchers have long identified these concerns with the wider literacy levels of students. Responses to the draft curriculum questioned whether average students have the mature language skills and training to be able to express the ideas of the mathematics curriculum (Watson et al., 2006). Others queried a possible mismatch between the level of logic and communication needed in statistics and the corresponding levels of students' English. Meaney and Flett (2006) suggest that New Zealand students entering high school are "likely to have difficulty extracting relevant information from material …" (p.10).

Many researchers (Huferd-Ackles, Fuson & Sherin, 2004; Kalantzis & Cope, 1999; Moschkovich, 2002; Nation, 1989) in the language learning and language acquisition fields express the view that the learning of English and content should be simultaneous. Some researchers (Doerr & Tinto, 2000; Turner, Dominguez, Maldonado & Empson, 2005) go further to say that a language focus in a content classroom is beneficial for all learners.

Turner et al. (2005) describe an after-school mathematics programme with bilingual students in the United States where students can 'incrementally gain access' to mathematical discourse practices when given repeated opportunities to participate fully in the mathematics classroom. They state that teachers should provide access to multiple resources and representations and give students models of using mathematical language and thinking. Again with reference to mathematics classrooms in the United States, Khisty and Chval (2002) believe that students can gain control of the mathematical discourse even when there is a mismatch between the language proficiency of the student, class and teacher. Khisty and Chval restate the need for students to have repeated opportunities to participate in mathematical discussion and argue that teachers are critical in providing the right climate.

While some acknowledge using academic mathematical language is a difficulty for all students -“helping students to articulate mathematical thinking can be a challenge even in monolingual classrooms” (Turner et al., 2005, p.8) - the focus of all the research highlighted is about English language learners in mainstream classrooms. In the research it is noted that learners have the challenge of not only learning mathematical language but academic language, conversational language and the mathematics as well. Despite these challenges many of the researchers, like Moschkovich (2002), believe that linguistic diversity is a resource in the mathematics classroom.

Central to all of these researchers is their belief that understanding the language is vital to making sense of the mathematical tasks and that language learning and mathematical learning are part of the same process. In all of this research it is stated that the teacher is the key to the success of learning in the classroom.

In the New Zealand context there are a number of teachers and researchers investigating the place of language in the mathematics classroom (Latu, 2005; Meaney & Flett, 2006; Woodward & Irwin, 2005). While some of the research has focused on language in mathematics in general, the majority of the research focuses on particular groups such as English language learners. Some of this research has also been disseminated to the wider teaching profession through initiatives and professional development like the Learning through Language programme in the 1990’s and the work of ESOL online.

Irwin and Woodward (2005) analysed the discourse in classrooms involved in the Numeracy Development Project [NDP]. The researchers were working in New Zealand primary and intermediate classrooms where the teachers had adopted the NDP pedagogy of questioning and listening. Irwin and Woodward describe how teachers who adopt the NDP pedagogy develop skills in asking questions about student thinking and listening and state that "students should also adopt some aspects of the same discourse" (Irwin & Woodward, 2005, p.69). Irwin and Woodward recommend that more emphasis be placed "on the use of the mathematics register, both terms and the discourse of premise and consequence, rather than colloquial terms and conversational conventions" (Irwin & Woodward, 2005, p.73). Irwin and Woodward see this as potentially being in conflict with the curriculum statement, Mathematics in the New Zealand Curriculum (Ministry of Education, 1992) that instructs teachers to use everyday language with their students before using mathematical language. Irwin and Woodward believe that the issue is even more important for students that have emerging or limited proficiency in English. This research was done in the context of Numeracy Development Project.

Latu (2005) investigates the language issues for Pasifika students in senior secondary mathematics classrooms. Latu believes that if students are going to solve language rich mathematics tasks "students need to be strong in both general and mathematical language" (Latu, 2005, p.489) and that it does not necessarily matter in what language that strength lays - either English or their first language. Latu reminds teachers that code-switching is an important tool for students to gain understanding. Code-switching is when an EAL[11] student or teacher switches between their first language and English to find meaning or express ideas. However, he cautions that if students have not learnt mathematics in their home or first language students may not have access to the mathematical discourse in their first language. Latu also notes that some mathematical vocabulary and concepts may exist or may be emerging in the student's first language. Latu does not specifically mention statistical concepts here. However, he does offer the example of Tongan

[11] Latu prefers to use EAL – students for whom English is an Additional Language - rather than ESOL.

teachers finding it “difficult to distinguish between the meanings of non-equivalent terms such as ‘very likely’, ‘probable’ and almost certain’ when expressed through the Tongan language” (Latu, 2005, p.484)

In this section I have attempted to show that there is a need for mathematics teachers and researchers to address literacy and language in their classrooms. An understanding of potential frameworks for teaching and learning or pedagogical principles that can be applied in the classroom to affect change will be discussed in section 2.8.

2.8 Critical literacy and the mathematics classroom

My understanding of critical literacy comes largely from my study into language learners in the mathematics classroom. It is taken from the work of researchers such as Kalantzis and Cope (1999) and Knobel and Healy (1998) who encouraged teachers to not just focus on language acquisition but also to encourage readers to question texts. The critical literacy research also characterises a much wider definition of literacy and a much wider definition of a text. This broader definition allows us to include statistical literacy and the statistical practices of our students into literacy practices. In this critical discourse we can then be comfortable with Schield’s (2005b) definition of statistical literacy where “statistical literacy should be viewed as is critical thinking about everyday arguments in which statistics are used as evidence” (p.2).

2.8.1 Descriptions of critical literacy

Researchers (Kalantzis & Cope, 1999; Knobel & Healy, 1998; Pennycook, 2001) assert that literate practices are situated where the students are. They show the literacies to be ‘multiple, dynamic and changing’ (Kalantzis & Cope, 1999). They state that the best place to learn language can be in a content classroom where the student has a need or desire to learn. Moschkovich (2002) also takes a situated or socio-cultural perspective of learning in describing language learners’ experiences in mathematics classrooms. Moschkovich asserts that aiding English language learner’s participation in mathematical discussion and problem solving is achieved by giving students repeated opportunities to communicate in real mathematics and problem solving roles "…and that these multiple meanings for representations and inscriptions are negotiated through conversations" (Moschkovich, 2002, p.197). There are links here to Watson (2006) who states that "context is a very significant component of statistical literacy" (p.249).

Pennycook (2001) states that classrooms are 'situated in political and ideological worlds' and that classrooms are the interactional spheres for power relations of both the societal and local or classroom contexts. In other words, pedagogy is both political and ideological in nature, and one cannot deny the reproduction of social and cultural conditions taking place in schools. This is clearly a challenge to teachers to address the issue of language in their classrooms and to be accountable for whether or not their classroom is a classroom where social and cultural inequalities are reproduced.

Just as I have discussed models and frameworks for the teaching and learning of statistics and statistical literacy I would like to explore a selection of models and frameworks used by teachers and researchers in literacy and language learning. I would also like to explore frameworks used by teachers and researchers focused on literacy practices in mathematics classrooms. I will then look for similarities and links between statistical literacy frameworks and the critical literacy frameworks and also for points of difference.

2.8.2 Critical literacy frameworks

In the same way we have the Statistical Literacy scale of Watson and Callingham (2005) and the framework for statistical thinking in empirical enquiry of Wild and Pfannkuch (1999) we have well established models for discussing critical literacy in the classroom. All of the critical literacy frameworks I describe come from a socio-cultural or socio-linguistic perspective. I believe that this is consistent with the constructivist or social-constructivist stance that I take when investigating statistics and statistical literacy in the classroom.

Australians Freebody and Luke (1990) developed a four-part paradigm for reading that describes the different levels of a critical literacy. The framework is student or learner focused. The Freebody and Luke four resources model for reading is shown in Figure 8.

Freebody and Luke's (1990) literacy framework suggests that there are several dimensions or aspects to learning, including a critical/analytical dimension that students must adopt. The authors emphasise that none of the dimensions of literacy has any priority over the others or that the model exists as a hierarchy. Freebody and Luke state that all dimensions of the framework need to be addressed in "an integrated view of literate practice and literacy pedagogy" (Freebody & Luke, 1990, p.11).

Figure 8 The four resources model – Freebody and Luke

- Code-breaker (How do I crack this?)
- Text-participant (What does this mean to me?)
- Text-user (What do I do with this text?)
- Text-analyst (What does this do to me?)

(Freebody & Luke, 1990)

Alternatively, we have Kalantzis and Cope's (1999) multiliteracies pedagogy which is designed to recognise the diversity of language use and the increasingly 'multimodality of communication'. In this multiliteracies pedagogy we can see statistical literacy as one such literacy. The Kalantzis and Cope model of instruction is shown in figure 9.

Figure 9 Multiliteracies pedagogy - Kalantzis and Cope

- Situated practice (Immersion in experience – starting from students experiences and moving to new experiences)
- Overt Instruction (Explicit teaching)
- Critical framing (Locating the purpose)

- Transformed practice (Real world meanings, communication in practice)

(Kalantzis & Cope, 1999)

Kalantzis and Cope's (1999) model is teaching focused and gives objectives for instruction that would enable students to become critically literate. In adopting a critical literacy framework Kalantzis and Cope start from a position where teachers build on and value home [mathematical] literacy practices. Kalantzis and Cope believe that teachers cannot value and respect what students bring to school if the only knowledge that teachers have of students is what they see in the classroom.

Overt instruction or explicit teaching in Kalantzis and Cope's (1999) multiliteracies pedagogy has been alternatively described by Gee (1996) as letting students into "the rules of the game" (p. 136). The researchers state that once the students understand the rules of the discourse they are able to fully participate in the learning.

Both the Freebody and Luke (1990) and the Kalantzis and Cope (1999) models offer dimensions beyond acquiring skills and knowledge that include being critical, analytical or ultimately transformational for the learner.

2.8.3 Critical mathematical frameworks

Other researchers, (Frankenstein, 1998; Skovsmose, 2005) have attempted to describe a specifically critical mathematical framework. Frankenstein is openly political with her attempt to introduce mathematics as a tool for interpreting and challenging inequities in society. Her research was based around making mathematics more accessible and applicable to students by developing programmes for learning that are set in the context of real-life, meaningful experiences. Frankenstein's research participants were primarily working-class adults who did not receive quality mathematics instruction when they were in high school and who were discouraged from continuing their mathematics studies.

Frankenstein (1998) has developed a framework for discussing the ideas of critical literacy and mathematics. Students examine data and questions through the four goals of Frankenstein's criticalmathematical literacy curriculum shown in Figure 10 below.

Figure 10 Frankenstein's criticalmathematical literacy curriculum

1. Understanding the mathematics.
2. Understanding the mathematics of political knowledge.
3. Understanding the politics of mathematical knowledge.
4. Understanding the politics of knowledge.

(Frankenstein, 1998)

Similarly, Skovsmose (2005), whose ideas were influenced by his work with mathematics educators in post-apartheid South Africa, believes that if mathematics education "…can be organised in such a way that it challenges undemocratic features in society, we can call it critical mathematical education" (Skovsmose, 2005, p.208). Just as Freebody and Luke (1990) and Kalantzis and Cope (1999) expressed in their frameworks, Skovsmose and Frankenstein (1998) see mathematics as more than acquiring a set of well defined competencies.

2.8.4 A critical statistical literacy

I believe that these frameworks are a perfect starting point for examining a possible critical literacy pedagogy for statistics and statistical literacy that can link statistics teaching with the real world. I wonder whether the adoption of such a framework can also begin the process of understanding and resolving issues such as the (in)equity in distributing the benefits of mathematics and statistics to all.

A critical statistical literacy would involve having a sound knowledge and understanding of a significant part of school mathematics and statistics. This is like the *code breaker* from Freebody and Luke's (1990) framework or *understanding the mathematics* as in Frankenstein (1998) and could be achieved by the *overt instruction* of Kalantzis and Cope (1999). It can be argued that many teachers have often only focused on this component of the framework. Despite curriculum changes, much of the secondary mathematics programme is still skill-based learning largely removed from any real world context (Begg, 2005).

The *text participant* in Freebody and Luke's (1990) framework would involve students being able to confidently use the statistical skills to solve problems in context. Mathematics teachers have responded to this by attempting to contextualise school statistics by using problems and contexts that appear to be relevant to the students. However, despite teachers' best efforts many of these 'real world problems' are contrived and the real parts are removed so as not to completely obscure the primary purpose of teaching school statistics. We do not have to look far to find examples of this in popular textbooks used in secondary schools.

The next important skill is applying statistical knowledge independently to pose and solve problems in a wide variety of contexts. This involves finding out any missing facts or acquiring any skills needed in the process and in evaluating solutions critically like in the *text user* of Freebody and Luke's (1990) framework or Frankenstein's (1998) *understanding the mathematics of political knowledge* and *understanding the politics of mathematical knowledge*. It would seem that if students are to learn to use mathematics outside the mathematics classroom then that is where they need to experience using mathematics. This is quite challenging for secondary mathematics teachers who control the teaching of statistics in secondary schools. However, Thornton and Hogan (2001) argue that adopting such features of a critical mathematical literacy framework would enable students to more fully participate in society by investigating real issues of interest.

Finally, adopting such a critical pedagogy would require students to interpret, evaluate, and critique the statistics placed in a social and political setting [e.g. from advertisements and media reports to government decision-making and the distribution of the resources in society]. This can be seen like the *text analyst* in Freebody and Luke's (1990) framework, Kalantzis and Cope's (1999) *transformed practice* or Frankenstein's (1998) *understanding the* *politics of knowledge*. In this setting statistics cannot be removed from the culture just like language cannot be removed from the culture and therefore statistics becomes not only a tool for critique but also an object of critique.

2.8.5 Equity issues and critical literacy

Knobel and Healy (1998) believe that teachers should be very clear about why they are doing critical literacy in their classrooms. Knobel and Healy challenge that if teachers are going to embark on a critical literacy journey they will have to pay attention to all four corners of the critical literacy framework. A critical (statistical) literacy is not possible where the teachers themselves are aware of all practices yet where the teachers only teach students become 'code breakers'. I believe the particular challenge in adopting a critical literacy pedagogy in the classroom is in implementing the dimension that Freebody and Luke's (1990) call '*the text analyst'* or what Kalantzis and Cope (1999) refer to as *transformed practice* into mathematics and statistics teaching.

If teachers continue to focus on just 'doing' statistics and not 'thinking' statistics and do not address the different literacies required for success in the 21st century, then not being statistically literate will become another equity issue in the classroom and society. I believe that this inequity will be even more pronounced in classrooms where there are a greater number of students with low literacy levels. However, after some years of literacy interventions in secondary schools New Zealand mathematics teachers are becoming more comfortable with the world of literacy and are prepared to, in the language of Kalantzis and Cope (1999), use situated practice and overt instruction and even critical framing to provide a more holistic learning environment. Both Kalantzis and Cope and Freebody and Luke (1990) state that there may be little value in making these changes if we never include the analysis and evaluation of the *text analyst* or *transformed practice'.* However, adopting such a stance could be very difficult for teachers in the classroom. To do so could see much greater control going to the students to decide what is studied in the classroom. I am unsure how mathematics teachers will respond to such challenges and criticism from students that their teaching may be reproducing inequalities.

2.8.6 Links between critical literacy and statistical literacy

There are links between the models of statistical literacy and critical literacy. Gal's (2002) definition of statistical literacy, with the knowledge bases of mathematical knowledge, statistical knowledge, literacy skills, knowledge of context and critical questioning, is consistent with the concepts of critical literacy. Critical mathematical is the final goal in Watson and Callingham's (2005) statistical literacy construct. Watson (2006) makes the direct connection between statistical thinking and literacy using Freebody and Luke's (1990) critical literacy model. Watson calls for students to be challenged to not only to develop mathematical skills but to develop critical literacy skills, where students will not only have to be able to communicate mathematically but to also be able to communicate meaning in the contexts given and link findings to everyday experience (Watson, 2006, p.287).

The themes of critical literacy have implications for teaching. In the next section I will explore the possibilities of affecting change in teacher practice and what possible protocols and procedures that could be adopted to make that change

2.9 Implications for classroom practice

Research in New Zealand and overseas has consistently acknowledged the importance of the teacher in student learning. The *Quality Teaching for Diverse Students in Schooling: Best Evidence Synthesis* (Alton-Lee, 2003) state "that both the subject matter knowledge and pedagogical knowledge of teachers are critical to their effectiveness" (Alton-Lee, 2003, p.10). The *Effective Pedagogy in Mathematics/Pāngarau Best Evidence Synthesis Iteration* (Anthony & Walshaw, 2007) quote the NCTM which state that "[e]ffective mathematics teaching requires understanding what students know and need to learn and then challenging and supporting them to learn it well" (Anthony & Walshaw, 2007, p.7).

2.9.1 New Zealand classrooms

New Zealand secondary mathematics teachers appear well placed in terms of subject knowledge as an aspect of an effective teacher. Anthony and Walshaw (2007) report that a 2001 census of New Zealand secondary schools teachers found that "the proportion of teachers with a third year university or postgraduate qualification in a given subject area to be higher for mathematics than for any other curriculum area" (p.128). However, Begg et al. (2004) point out that "teachers vary considerably in their statistical knowledge, their mathematical knowledge, and in their confidence and experience in teaching statistics" (p.18) and that this variation has not been considered when planning curriculum implementation. In addition to the teachers' knowledge and teaching experience, Begg et al. outline other aspects that influence teaching such as age, position, tradition and expectations and that these beliefs may make something like an investigative approach as wholly inappropriate for some teachers.

These views are not restricted to just researchers. In response to proposed changes to NCEA Achievement Standards, compiled by mathematics advisor Louise Addison, teachers from the Southern Cluster of the Auckland Mathematics Association expressed concerns about changes to statistics assessments. Teachers felt that a lot of training, ongoing professional development and resources would be required before teachers could feel confident about students being able to do the 'new' work in statistics. Some teachers still remain sceptical of any changes and even claimed that the changes were a complete new way of looking at statistics (Addison, personal communication, June 2007).

2.9.2 Teacher professional development

> Given the magnitude of teacher and classroom effect, and our diverse student population, the project of seeking to improve policy and practice through synthesising the evidence-base for quality teaching for diverse students, and developing access to, and use of,

> this knowledge, is a pressing one for New Zealand education.
>
> (Alton-Lee, 2003, p.3)

> …change is a long process that may start with rearranging seats.
>
> (Auerbach, 1995, p.30)

As stated by Alton-Lee, quality professional development based on the best evidence available is an urgent need for all teachers. However, as Auerbach alludes the actual process may be a long and tortuous one.

Some New Zealand researchers have attempted to work with teachers to implement change. Merriman (2006) has undertaken research into statistical literacy in New Zealand by using media reports in the classroom. Merriman's analysis uses Watson and Callingham's (2003) hierarchy to examine Year 10 student's responses. She found a positive linear correlation between English ability and ability in statistical literacy. Merriman goes on to assert that "when students are supported in their discussions in the classroom and encouraged to be open, with a healthy dose of scepticism, along with a persistence of effort, then they will begin to make inroads into interpreting statistical information" (Merriman, 2006, p. 4). However, Merriman does not discuss how students are to be supported in their learning

Pfannkuch and Horring (2005) describe an ongoing project to help teachers change their practice in the teaching and learning of statistics. The motivation for change was a response to assessment and curriculum changes. In this study, the researchers plainly state that any "curriculum development necessitates professional development and resource development" (Pfannkuch & Horring, 2005, p.205). It will be interesting to see if this voice of reason will be heard in New Zealand's current curriculum implementation.

In the professional development model employed in the Pfannkuch and Horring (2005) project, teachers participate actively in the change process from inception to implementation. Pfannkuch & Horring describe this as a method of curriculum development where the "teachers must become fully conversant with the theory to participate in the research process" (p.205). For Pfannkuch and Horring the teachers are central to the process, and the changes draw on their own experience.

There are other excellent examples of research in New Zealand into mathematics and statistics instruction where the research study authors have endeavoured to describe good practice for teacher professional development. Kensington-Miller (2004) describes a long term study of the professional development of mathematics teachers in several low socio-economic secondary schools in Auckland. She describes a range of strategies trialled to change the practice of teachers. In this study the interventions are not linked to any single goal of the mathematics curriculum such as statistics. Like Pfannkuch and Horring (2005), Kensington-Miller describes how change can occur with proper allocation of resources and support of teachers.

Kensington-Miller (2004) describes four different strategies trialled to change the practice of teachers from a predominately transmission style of teaching and classroom control to a more constructivist approach to teaching. The strategies involved meetings with teachers, peer mentoring, one-to-one mentoring and reading literature. A key finding was that all the teachers involved believed in the importance of ongoing professional development. However, the efficacy of the intervention was questioned as to whether it produced any real or long term changes to teaching. Kensington-Miller describes "the enormity of implementing professional development and the problems associated" (p. 326) but does not stop from suggesting that the difficulties should be addressed and that progress can be made when greater support can be given to teachers.

The importance of the teacher is also a central theme in Anthony and Walshaw's (2007) *Best Evidence Synthesis.* They cite Muijs and Reynolds (2001) who emphasise: "All the evidence that has been generated in the school effectiveness research community shows that classrooms are far more important than schools in determining how children perform at school" (Anthony & Walshaw, 2007, p.4). Anthony and Walshaw go on to state that "quality teaching is not simply a matter of 'knowing your subject' or 'being born a teacher" (p.4) and that there is a need for quality professional development in secondary schools to make sure that good practice occurs in as many classrooms as possible.

2.9.3 Other models for teacher professional development

With the importance of the teacher in the learning process established it is necessary to look at possible models for how teachers actually change. One such model from Kazemi and Franke (2004) focuses on teachers investigating the thinking processes of students.

In their research study Kazemi and Franke (2004) document key changes or shifts that occurred for teachers during the course of a year of monthly workgroups. Their research uses Cognitively Guided Instruction (CGI), a research and professional development programme that a number of researchers (Carpenter & Fennema, 1992; Carpenter, Fennema, Franke, Levi, & Empson, 1999) have used in different educational research settings. In their work with teachers, Kazemi and Franke found that the most powerful change occurred when their research teachers were engaged in investigations into students' thinking. Kazemi and Franke describe a framework of five levels that they used in the observations of teachers engaging with students' mathematical thinking. The Kazemi and Franke hierarchy shows differing degrees of pedagogical aptitude in juggling instructional approaches, teaching principles, and students' contributions. The Kazemi and Franke approach fits with the constructivist viewpoint described by Mvududu (2005) where "statistics instructors need to (a) study how students think about the particular statistics topics they teach and (b) work to understand their students' thinking at a level deeper than everyday communication." (p.54)

At Level 1 on Kazemi and Franke's (2004) scale the teacher does not believe that the students in his or her classroom can solve the problems unless they have been taught how and does not provide opportunities for solving problems or bother to ask the students how they solved problems. At level 2 the teacher begins to view students as bringing mathematical knowledge to learning situations and talks about the value of a variety of solutions. By level 3 of the Kazemi and Franke model the teacher is able to provide a variety of different problems for students to solve and is able to then give students opportunities to discuss their solutions because they want to listen to students talking about their thinking. Teachers operating at Level 4A of the Kazemi and Franke hierarchy believe that students' mathematical thinking should determine the evolution of the curriculum and the ways in which the teacher individually interacts with students. Kazemi and Franke finally describe Level 4B where the teacher can describe in detail individual students' thinking. These teachers create opportunities to build in students' mathematical thinking and use "what he or she learns about individual students' mathematical thinking to drive instruction" (Franke & Kazemi., 2001, p. 662).

Researchers (Fennema et al., 1996; Franke & Kazemi, 2001) have shown that movement through the levels requires a supportive community who will pose questions about students' thinking for teachers to reflect upon and where after awhile the teachers begin to initiate this questioning themselves and it becomes part of their own pedagogical practice. Teachers in the Kazemi and Franke (2004) research, who engaged in reflection-in-action, were able to change their teaching in ways that were both sustainable and self-generative which led to an enhancement in the quality of mathematical interactions.

2.9.4 Models for professional development in New Zealand

Researchers in New Zealand have also been attempting to get mathematics teachers to be more responsive to their students by focusing on their thinking. I am particularly interested in research carried out by Woodward and Irwin (2005) because of its links and similarities to my own context. In the Woodward and Irwin study they report about how opportunities for students to explain and justify solutions were given. The context for the study was two classes of primary school classes involved in the Numeracy Project where the majority of students were Pasifika. The researchers describe how a teacher involved in this study made a significant contribution to students' mathematical development by listening attentively to her students' queries and explanations. In a description comparable to Kazemi and Franke's (2004) CGI higher level operation, the teacher asked them to justify their answers and held back with her own explanations.

Woodward and Irwin (2005) focus on the discourse practices of the mathematics classroom. They cite the Khisty and Chval (2002) research quoted earlier in this literature review that argues that students need to have repeated opportunities to participate in mathematical discussion. Khisty and Chval's method, of using the correct mathematical terms with students rather than avoiding the academic vocabulary, is suggested by Woodward and Irwin as a way in which teachers can improve the academic achievement of ESOL students where they provide a climate for this to happen in the classroom.

While the Woodward and Irwin (2005) research focused on language, statistics just happened to be the topic that the teachers were teaching when researched. There is other research available in New Zealand that focuses on statistics teaching and learning in secondary schools. Pfannkuch and Horring (2005) investigated the professional development of teachers by focusing on a specific goal of the statistics curriculum. Their research explored the use of statistical investigations to teach statistics with Year 11 students. Pfannkuch and Horring outline a methodology for research that has the teacher and researcher at the centre. To use their paradigm for changing practice there would be a need to understand the notion of statistical literacy in the current situation with respect to current teaching and learning. Secondly, the researcher and teacher collaborate by "envisioning how the current situation might be changed" (Pfannkuch & Horring, 2005, p.205) and by designing and trialling a unit of work that the teachers believe could enhance students' statistical literacy. Thirdly, the researcher and teachers evaluate the process of trialling and implementing changes in teaching, learning, and assessment. Finally, in Pfannkuch and Horring's process the researcher takes the knowledge gained through the curriculum development activity to “ultimately abstract a theoretical base for the development of statistical literacy in instruction” (p.205).

Finally, from the area of language and learning for ESOL and language learners we have another model for professional development. In a series of DVD’s produced for the Ministry of Education we see how teachers can effectively integrate content teaching and language learning. The *Making Language and Learning Work 1: Integrating Language and Learning in Secondary Maths and Science* DVD (Ministry of Education, 2007a) features science and mathematics teachers exemplifying good practice. The professional development model also includes support and facilitation from school advisors and from notes on the internet. The basis for the programme is seven principles that underpin the integration of content and language learning. The principles are outlined in Figure 11.

A combination of these research methods and principles would I believe form the basis of a good intervention for changing practice in the mathematics classroom. All the approaches highlighted are steeped in the research. However, Pfannkuch and Horring’s (2005) model for implementation and the Ministry of Education’s principles appeal most as possible methods for research because of their closeness to the context of this study. Although the two approaches do not explicitly mention critical literacy or statistical literacy both the Pfannkuch and Horring’s model for implementation and the Ministry of Education’s ESOL and language learners’ principles for teaching appear to be situated in a similar discourse.

Figure 11 Principles from "Making language and learning work 1"

Principle 1:	Know your learners - their language background, their language proficiency, their experiential background.
Principle 2:	Identify the learning outcomes including the language demands of the teaching and learning.
Principle 3:	Maintain and make explicit the same learning outcomes for all the learners.
Principle 4:	Begin with context embedded tasks which make the abstract concrete.
Principle 5:	Provide multiple opportunities for authentic language use with a focus on students using academic language.
Principle 6:	Ensure a balance between receptive and productive language.
Principle 7:	Include opportunities for monitoring and self-evaluation.

(Ministry of Education, 2007a)

The merits of the approaches will be discussed further in Chapter 3 when considering methodology.

2.10 Conclusions and focus for study

There appears to be a commonly held definition of statistical literacy that consists of students being able to understand and critically evaluate the statistics in the context of the world around them. However, there may be a match/mismatch between the stance taken by the curriculum towards statistical literacy and what teachers understand of statistical literacy.

There are models and frameworks available for statistics teachers to use to discuss statistical literacy. Some of the frameworks have emerged from mathematics and statistics educators while others have come from statisticians. The frameworks describe how students' statistical thinking or statistical literacy can be effectively analysed. Similarly, there are good models available on how statistical literacy can be developed and assessed. There also appears to be particular ways of teaching that can elicit the specific types of thinking identified in the statistical literacy frameworks. However, as stated by Anthony and Walshaw (2007) there is limited research about effective teaching of mathematics in New Zealand secondary schools. I believe that there is even less research into the effective teaching of statistical literacy. The *Effective Pedagogy in Mathematics/Pāngarau Best Evidence Synthesis Iteration [BES]* also states that there is only a small amount of reported research that focuses on quality teaching for Pasifika students.

There appears to be very strong links between researchers working with statistical literacy and those researchers focused on literacy. However, despite a significant intersection between the goals of statistical literacy and [critical] literacy there does not appear to be research about how secondary mathematics teachers could integrate statistical literacy and language in the classroom. Statistics focused researchers like Gal (2002; 2005) and Watson (2006) concentrate on the statistics while language focused researchers like Kalantzis and Cope (1999), Khisty and Chval (2002) and Moschkovich (2002) focus on the language especially for language learners and ESOL students. It is my conviction that both these groups need to come closer together if practical help is to be given to teachers working in classrooms.

There are good teacher professional models for improving practice that could be adopted to improve the teaching of statistical literacy. Kazemi and Franke (2004) research provides a model where teachers engage in investigations into students' thinking. The New Zealand research of researchers such as Kensington-Miller (2004) and Pfannkuch and Horring (2005) signal ways that teachers can work effectively together to change practice. However, there does not appear to be much research that describes how the development of statistical literacy can be supported. An example is the *Making Language and Learning Work 1: Integrating Language and Learning in Secondary Maths and Science* DVD (Ministry of Education, 2007a) which gives teachers ways that they can effectively integrate content teaching and language learning. It is hoped that these initiatives can be used to help teachers make the links between the language and statistics that I see as so important.

In all of these approaches the teacher is central to effective teaching and learning of statistics and statistical literacy. Here I will restate the position of the *Effective Pedagogy in Mathematics/Pāngarau Best Evidence Synthesis Iteration* (Anthony & Walshaw, 2007) which strongly asserts that it is teacher's pedagogical knowledge and expertise that helps students learn. Anthony and Walshaw stress that "the teacher's expertise is also related to the role he or she assumes as earnest listener and co-learner" (p.77).

3.1 Introduction

In this chapter I wish to discuss the methodological issues of this research study. In section 3.2 there is a description of the action research process chosen. In section 3.3, issues of trustworthiness are investigated. In section 3.4, there is a description of and justification for the qualitative data collection procedures selected for research in such a setting. Issues around data analysis are examined in section 3.5. In section 3.6 I attempt to give an outline of my own philosophical standpoint and how that informs and influences the research. Finally, in section 3.7 there is a description of the methodology in practice. There is an in-depth description of the participants involved, the context and structure of the research and a description of the practicalities of the data collection techniques used in this qualitative practitioner enquiry.

3.2 Action research

This research project is concerned with improving the teaching and learning of statistical literacy with three teachers in three classrooms of Year 9 and 10 students. There is no intention by the teachers involved in this research to leave the current situation undisturbed. Many researchers (Burns, 1994; Cohen, Manion & Morrison, 2000; Doerr & Tinto, 2000; Kemmis & McTaggart, 1988; Murray & Lawrence, 2000) state that action research is a suitable approach for studying such a context. Therefore, an action research model has been chosen as appropriate for this project

Action research is, above all, a method for simultaneously doing what the name says - action and research. The benefits of action research are that it is a process where change and understanding can be pursued at the same time (Kemmis & McTaggart, 1988) and because it can be done by a group of people to improve their practice (Cohen et al., 2000). Burns (1994) states that:

> Action-research is a total process in which a '*problem situation' is diagnosed, remedial action planned and implemented, and its effect monitored,…* It is both an approach to problem solving and a problem-solving process.
>
> (Burns, 1994, p.294)

Unlike more positivistic or experimental research models, action research is focused on practice. Action research is a methodological approach that is more about guiding practitioners towards 'practical next steps' (Doerr & Tinto, 2000) than generating theories of learning. Action research is adaptive, tentative and evolutionary (Burns, 1994).

As with all research in education there are different interpretations and definitions of action research. Action research is alternatively called reflective enquiry, reflective practice, critical reflection, participatory practitioner research, emancipatory research, practitioner-based enquiry or collaborative action research. Each interpretation of the action research process places the researcher in the research epistemology and methodology discourse. It is hoped that the following sections enable readers to locate the methodology of this research.

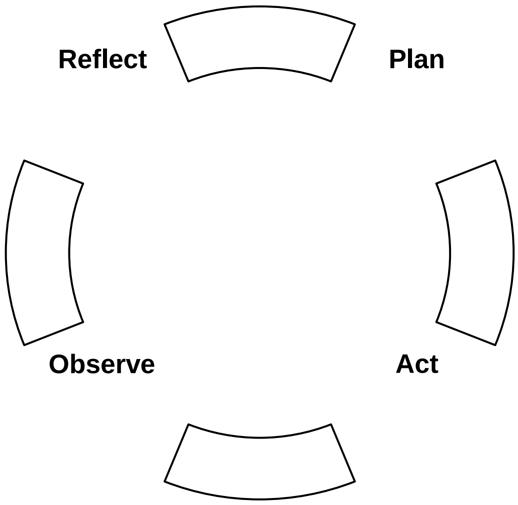
3.2.1 Key components of action research

Action research is usually described as cyclic; with action and critical reflection taking place in turn (Burns, 1994; Hughes & Seymour-Rolls, 2000). In the planning phase the teacher or teachers develop a plan of critically informed action to improve their current practice. Another advantage of action research is that the plan can be flexible to allow adaptation for unforeseen effects or constraints (Kemmis & McTaggart, 1988).

Action research can be effective because it adapts to the situation (Cohen et al., 2000). Action research operates in a reflective spiral or cycle. Kemmis and McTaggart (1988) describe a cycle of plan, act, observe and reflect shown in Figure 12 below. Each turn of the cycle integrates theory and practice, understanding and action, and informs the next turn (Hughes &

Seymour-Rolls, 2000) to produce a spiral effect. An action research spiral implies that action and knowledge development must occur otherwise it cannot be considered a successful action research project (Hatten, Knapp & Salonga, 2000). The results of an action research project can contribute to the development of theories about a given situation or setting. Outcomes can provide the practitioner with a justification for the methodologies used (Hatten et al., 2000).

Figure 12 Action research cycle



As stated in section 2.2, there are options within the action research paradigm. In a problem focused action research project the researcher and practitioner/s come together in order to identify potential problems, underlying causes and possible solutions or interventions and the researcher encourages participation and self-reflection of the practitioner/s (Kemmis & McTaggart, 1988). However, I desire a more emancipatory, collaborative (Doerr & Pinto, 2000), critical theory (Bucci, 2002) or critical (Skovsmose & Borba, 2004) type of action research which involves all participants working together equally with no hierarchy existing between the researcher and practitioner.

Some theorists would argue that action research paradigms are only interested in understanding a particular situation whereas an emancipatory or critical paradigm looks to question or transform it (Cohen et al., 2000). In a critical emancipatory research paradigm researchers are reacting to a "dominant construction of reality that perpetuates inequality" (Bucci, 2002, p.76) and researchers are ‘researching possibilities’ (Skovsmose & Borba, 2004, p.223) to make transformations in the classroom.

It is an intention of this research to go beyond just trialing different ways of teaching of statistics in the classroom and to look at how teaching and learning of statistics can be transformed. In such a setting the research hopes to be more than just quality assurance of the teaching of a curriculum topic.

3.2.2 Benefits of action research

There is some evidence for the wider benefits to teachers undertaking such action research. Kemmis and McTaggart (1988) maintain that emancipatory action research facilitates reflective discussion between practitioners and that the discussion allows participants to identify underlying problems and assumptions with the area of concern. Action research can involves all participants acting equally with no hierarchy existing between the researcher and practitioner, such as Doerr and Tinto’s (2000) collaborative action research where the teacher is central to the whole process and takes a full part in posing questions, collecting data and drawing conclusions. The researcher aims to decrease the distance between the actual problems identified by the practitioner and the theory used to explain and resolve the problems. Adopting this type of emancipatory action research assists the researcher to become a collaborative member of the group and less of a researcher (Kemmis & McTaggart, 1988, p.12).

Hatten et al. (2000) state that one of the benefits of an action research project undertaken by a group of teachers is that it is not essential that all participants have a well developed level of professional knowledge around the topic of study as long as some members need to have this for the group to function. Importantly, Hatten et al. emphasise that all members bring their own knowledge developed from their personal experiences to the action research process.

Differing levels of knowledge in the group members dictate the nature of the negotiation process which occurs in the development of the plan of action.

There are advantages associated with such a negotiation. Skovsmose and Borba (2004) state that the very fact that the researcher is exploring possibilities with others in a collaborative research project means that the researcher can not do research on someone but must research with someone. However, the collaborative nature of the action research may also mean that setting and achieving researcher set outcomes is not possible. This has been described as the 'chaos of practice' (McCormack, Illman, Culling, Ryan & O'Neill, 2002). In such a 'chaos of practice' the description of clearly defined research phases is replaced with a description of a much wider journey from problem to outcome.

Ultimately, researchers hope that the action research process can benefit the teachers involved beyond the boundaries of a short research project. As Van Zoest (2006) states; "there is no question that engaging in inquiry about teaching and learning mathematics is an important form of professional development that enhances teachers' knowledge, skill and understanding" (xvii). Van Zoest goes further to state that for teachers "…engaging in self-critical systematic inquiry is transformative and professionally life-changing" (xvii).

3.3 Trustworthiness

Whatever the form the research takes, trustworthiness is always an issue in research. Trustworthiness is often described in terms of validity and reliability in research. However, there are a large number of meanings and definitions given for validity and reliability in educational research literature. Two commonly used descriptions of validity are internal validity and external validity. Internal validity can be seen as the ability of the data gathered to support the claims made by the research (Cohen et al., 2000) whereas external validity can be expressed as the ability of the results of research to be generalised to the wider population.

The terms reliability, external and internal validity may all be problematic in the context of qualitative emancipatory action research. Achieving a notion of internal validity may be possible because multiple pieces of evidence from multiple sources can be used to uncover findings. In action research the researcher also has the opportunity for prolonged engagement in the research situation. However, researchers must use the designated data gathering tools systematically and properly in collecting the evidence (Burns, 1994).

External validity and reliability may be more difficult outcomes to achieve or explain in this study. Because an action research process has been used there may be no way that the findings of this study can be generalised beyond the school situation. However, it is hoped that reliability can be addressed by ensuring that the procedures used are well documented and can be repeated (Cohen et al., 2000). It is also hoped that giving a detailed description of the research and the showing an understanding of my role as researcher/ participant will help provide validity and reliability. Likewise, I will attempt to show how any inferences made from the data collected have been affected by the theoretical perspectives that I have taken in this thesis.

3.3.1 Validity

To achieve this openness and awareness in the research I have looked to researchers who have attempted to describe validity in an action research setting. Anderson, Herr and Nihlen (1994) have suggested five different criteria that can be used to assess validity in action research; democratic validity, outcome validity, process validity, catalytic validity and dialogic validity.

Democratic validity is when stakeholders in the research have participated in the research and are part of the intervention planning, data collection and analysis. This is central to this research project. According to Skovsmose and Borba (2000) the quality of any participatory research can be assessed in terms of the co-operation between participants and I believe that the selection of an emancipatory action research paradigm works to facilitate this.

Outcome validity is where there has been a successful resolution of the research problem. Process validity is where an appropriate theoretical and methodological approach has been taken in the research. This has been addressed in part by the previous research that I have done into statistics, statistical literacy and language learning. The selection of an action research approach has been a considered one. Process validity may therefore be achieved because the researchers are using appropriate measures for the concepts being studied. Interviews, classroom observations and the collection of artefacts all seem suitable data collection methods for a study investigating statistical literacy and the use of language learning principles in the secondary mathematics classroom.

Catalytic validity is about the force for change that the research creates. Again, by adopting an emancipatory action research model it is hoped that the research will start an ongoing process of change in the teaching of statistical literacy as further cycles of action research are undertaken. Beyond this the emancipatory action research model also seeks to empower the participants not only to change teaching practices but to also facilitate wider collaboration between teachers.

Finally, dialogic validity can be addressed by sharing the research findings, initially by a participant debriefing and leading to wider dissemination of findings. The first and most important use of the research is that it informs the future teaching and learning of statistics in the school. However, information may also be presented in future teacher professional development sessions or submitted to a journal. When completed, this thesis and a summary of this thesis will be made available in my school for teachers, students and their parents to read if they wish. Other ways in which the information may be used will be subject to a process of consultation with participants. There are some issues here about the status and prominence that this affords me over the other participants of the research. I have discussed this further in the section ethical considerations.

3.4 Data collection

The action research cycle resonated with the teacher participants in this research because of the similarities between action research and the PPDAC statistical investigation cycle of Wild and Pfannkuch (1999). However, the reflection, plan, action, observation and reflection of the action research cycle uses data collection methods that are very different to the statistical methods used in the classroom.

For teachers researching their own practices and where the teachers take the place of 'participant observer' (Cohen et al., 2000; Hatch & Shiu, 1998) there is a basic need to produce a record such as interview notes, video, transcripts, anecdotes, and journals to provide data. Similarly, qualitative research concentrates on the words and observations found in these records to express reality and attempts to describe people in natural situations.

Because it is not in the spirit of action-research for the principal researcher to be overly prescriptive or definitive (Cohen et al., 2000; Hughes & Seymour-Rolls, 2000), it must be emphasized that the data collection methods described were revised collaboratively as participants began focusing their attention on the questions identified. This idea is again central to the descriptions of data collection methods throughout this chapter.

3.4.1 Interviews

Interviews are an important part of an action research project as they provide an opportunity for the researcher to investigate ideas and beliefs of teachers further and to gather data which may not have been obtained by other methods such as observation or survey (Cohen et al., 2000).

Where group interviews are used, the principal researcher can direct the interaction and inquiry in an unstructured manner (Denzin & Lincoln, 1994). One technique described is to order questions from the more general to the more specific, with questions of greater importance asked early. Denzin and

Lincoln believe that this interview approach (from general to specific) is one way of engaging the interest of participants quickly.

In documenting action research the interviews can take place during various parts of the cycle from the initial planning phase to the reflection phase of the action research. Action researchers state that reflection in interviews can aid in the group reconstruction of the meaning of the situation and provide help with the next cycle of planning for action. These steps are carried out in a more careful, systematic and rigorous way than that which usually occurs in daily practice (Kemmis & McTaggart, 1988; Zuber-Skerritt, 1992)

Researchers also state there are interviewer attributes that may contribute to successful interviews. Glesne and Peshkin (1992) feel that a good interviewer is anticipatory; alert to establishing rapport; naive; analytic; paradoxically bilateral (dominant but also submissive); nonreactive; nondirective and patiently probing. Glesne and Peshkin also describe time management as another essential skill of the interviewer, in particular, noting when a topic has been exhausted and further discussion will yield little new information.

Glesne and Peshkin (1992) suggest that interviewing more than one person at a time sometimes proves very useful; and that some young people may need company to be emboldened to talk, and some topics are better discussed by a small group of people who know each other.

There are some specific issues with regards to interviews in the school context. The *interpersonal conditions* (Murray & Lawrence, 2000) of the classroom and department may be compromised by the privileged position the researcher holds and may be a source of bias and contamination of data. Trust and respect are also key issues in the research, especially with Pasifika research participants (Anae, Coxon, Mara, Wendt-Samu & Finau, 2001). Finally, language is also an issue as participants in the research have English as a second language.

Data can be collected using video and note taking. Glesne and Peshkin (1992) state that note taking should not interfere with the discussion and that notes should be complete and useable in the event the video is not working. Roschelle (2000) states that videoing allows multiple opportunities to observe an event.

3.4.2 Classroom Observations

Classroom observations can be used in research to get a picture of what is occurring in the classroom as lessons and strategies are trialled. The observations enable there to be a clearer understanding of trends and patterns over time (Cohen et al., 2000). Another benefit of the observations being over an extended period of time is that there will be less of a chance of those selective observations being purely anecdotal and that "thick descriptions" (Cohen et al., 2000, p.311) of the situation are possible.

The observations can be unstructured. In unstructured observations the situation is observed before decisions are made about directions for research. However, in this case the research questions will mean that the observations are more structured and selective. Trustworthiness can be increased by the use of a combination of observation techniques such as video and observation notes and logs. The observations can also be shared with the other teacher participants to get a wider picture of events or an explanation of particular events (Roschelle, 2000).

3.4.3 Artefacts

Teacher generated and student generated artefacts can also play a part in the research. Student artefacts can take the form of assignments, tests, work from exercise books and journals while teacher artefacts can be lesson plans, notes and teacher generated materials (Hendricks, 2006). Artefacts can be original documents, facsimiles or even photographs of items.

The collection of artefacts gives the teacher participants materials to focus on when discussing what happened in the study in follow-up interviews. At the same time, using materials from students "...can help determine the effectiveness of an intervention continuously throughout the study" (Hendricks, 2006, p.74). This is particularly useful to this study because it allows the teachers to alter and refine the intervention during the unit of work.

3.4.4 Triangulation

All of the aforementioned data collection methods have been chosen to give the research a chance to describe the complexity of the situation. This process is sometimes characterised as triangulation. This research has embraced an action research paradigm. Therefore, no attempt has been made to triangulate the research by choosing alternative theoretical standpoints or methodologies. However, triangulation has been attempted through the collection and analysis of multiple forms of data (Cohen et al., 2000; Hendricks, 2006).

The data collection methods of student interview, teacher interview and observation will hopefully allow for data from various perspectives. However, there are obvious limitations to this approach. Much of the theorising has been done by me as the principle researcher. Likewise, the majority of the analysis will be completed by me. Therefore, triangulation is not used as the sole provider of reliability and validity in this research but may work towards satisfying some of the democratic validity and process validity concerns described by Anderson et al. (1994).

3.5 Data Analysis

As already alluded to, action research can involve using multiple sources and techniques in the data gathering process (Cohen et al., 2000). Tools to collect data can include interviews, documentation review, observation, and even the collection of physical artefacts. The selection of appropriate data collection methods can help towards ensuring validity for the study. However, another important part of the action research process is the analysis and evaluation of the data.

A feature of action research is that the analysis phase can begin concurrently with the data collection (Cohen et al., 2000). A real strength of an emancipatory action research model is that much of the data analysis is collaborative. Working together not only enables the teachers involved to generate knowledge about their setting but also makes it possible for the action research to become educational for the teachers involved.

With action research the data can be analysed using an open ended approach. In such an open ended approach the data can be analysed with respect to the questions and the theories posed by the researcher as well as theories of what is occurring that can come out of the data itself. This is a *grounded theory* approach (Cohen et al., 2000) where the analysis of the data comes from looking at the data. Again, with emancipatory action research there is a possibility that theories can come from any of the participants. The discussion between teachers is therefore very important and can go a long way to ensuring process validity.

Grounded theory data analysis can be done by a comparison to a number of factors. This is called a constant comparative approach (Cohen et al., 2000). The data can be analysed by comparing between the differing views of participants, between lessons, comparisons of change over time for teachers and students in terms of practice, knowledge and achievement and comparisons between data and the theories.

A constant comparison approach to data analysis looks to discover key and recurrent themes that may emerge from the data (Cohen et al., 2000). The themes can then be used to find, classify and compare incidents the data so a clear account can be given of the research.

The analysis and evaluation of the data must be concerned with trustworthiness. By using a grounded theory approach it is hoped that the 'real story' can emerge from the research. However, these theories and themes are already present in my own investigations. It has to be acknowledged that this thesis remains my telling of the situation and that my story is not the whole story.

The analysis of the different data collection strategies also has implications for the research. The information collected from meetings, interviews and discussion is raw data. The principal researchers' task is to prepare a statement regarding the collected data. The first step is to transcribe the entire interview. This will provide a complete record of the discussion and will facilitate analysis of the data. However, the next critical step is the analysis of the content. The aim of this analysis is to look for trends and patterns that reappear within either a single events or in multiple events in the data. The emphasis or intensity of the respondents' comments should be considered.

3.6 My place in the research

> …we are each always already positioned and yet have agency to (re)position ourselves in the theory, practice and discourse of educational research.
>
> (Wright & Lather, 2006, p7)

I too am positioned in the discourse of educational research. In this research I focus on the experiences of teachers and students in three mathematics classes in a high school mathematics department. The goals of the teachers involved in this study were to make changes to their classroom practice towards more effective teaching of statistics and statistical literacy at the Year 9 and 10 levels.

In the review of the literature in Chapter 2, I attempted to describe how these goals could be met inside a statistics education discourse. However, the school is a low decile, co-educational secondary school in Auckland and the school population is culturally and linguistically diverse. Therefore, I have attempted to discuss ways of achieving the set goals in terms of literacy theory and practice. I have also attempted to describe a critical discourse, with strong links to critical literacy theories from a language acquisition background (Kalantzis & Cope, 1999; Freebody & Luke, 1990; Knobel & Healy, 1998) and more tentative links to a critical mathematical literacy (Frankenstein, 1998; Skovsmose & Borba, 2000). Finally, I have investigated possible pedagogical approaches and principles that could be adopted by teachers to develop statistical literacy with students (Kazemi & Franke, 2004; Ministry of Education, 2007a).

Ultimately the research is affected by my core beliefs about education. My reason for undertaking this research, and the reason why I believe the other teachers participated in the research, is the belief that education is fundamentally about relationships between teachers and learners. This research hopes to investigate aspects of those relationships.

In contrast to a naturalistic perspective, I am also a mathematics teacher who has been trained in the scientific method. Mathematics is often described as being situated in a realist, positivist paradigm. Therefore, for a group of mathematics teachers undertaking research in the mathematics classroom research could become a process where a hypothesis is adopted around statistical literacy, the hypothesis is tested against predominately quantitative data collected and conclusions drawn. In fact the statistical enquiry cycle of Wild and Pfannkuch (1999) described in this thesis is a case in point. The statistical enquiry cycle was a much more recognisable process for us as mathematics teachers than the qualitative action research approach that was used. It took some effort to resist adopting some statistical procedure to test the efficacy of interventions with control groups and random selection. All of this could be achieved without developing or nurturing any of the relationships in the classroom.

However, ontologically it is my belief that knowledge gained from research in the classroom is dependent on the context, the participants and that the process is what Cohen et al. describe as “personal, subjective and unique” (Cohen et al., 2000, p.6). Therefore, adopting a positivist, scientific, or even a solely quantitative research paradigm or methodology such as those used in the study of mathematics and science does not fit with my notion of research in the classroom. Epistemologically I see any knowledge gained is constructed personally and in interactions with others. I am not interested in a study where the object of study is independent of the researchers or where knowledge is discovered and verified through measurements and observation from afar.

I believe that the nature of research questions suggest an in-depth study of the situation. Any attempts to use a scientific research paradigm, such as having control classes excluded from any intervention to quantify progress, were quickly rejected on both ethical and philosophical grounds. Since the teachers involved are undertaking this project to improve the situation the idea of excluding students from any possible benefits seems unethical regardless of whether any benefits could be shown or not.

Implicit in an action research methodology is the notion of a cycle of problem definition, data collection, analysis and planning, monitored action, reflection leading to a phase of redefinition that restarts the cycle (Burns, 1994). Such a cycle is suited to the exploratory nature of this project and its essential open-endedness. The adoption of an action research framework is also in keeping with a desire to enhance teacher professionalism by according the teachers the role of reflective and collaborative generators of their own professional knowledge.

3.7 Research design and method for this thesis

The following sections outline the particular setting of this research and its participants. There is an explanation of the data collection methods chosen and how they operated in the research context.

3.7.1 Focus of this thesis

The focus of this research is developing statistical literacy in the secondary mathematics classrooms within an action research cycle. The main research question adopted by the teachers in this research project was:

> How can we help students and teachers develop statistical literacy in the secondary mathematics classroom?

This main research question created other supplementary questions that we, the teachers, also felt were necessary to consider. The supplementary questions include;

What are teachers and students views about the nature of statistics and statistical literacy in the Mathematics [and Statistics] curriculum?

What is needed to facilitate the development of statistical literacy with students and teachers in secondary mathematics classrooms?

How can we assess statistical literacy with our students?

How can using language learning principles help students and teachers to develop statistical literacy in secondary mathematics classrooms?

How can using the 'principles of effective teaching for learners from diverse language and cultural backgrounds'[12] help students and teachers to develop statistical literacy in the secondary mathematics classroom?

What are the appropriate professional development strategies for teachers to use in this context?

As mentioned earlier, the research questions have an influence over the research design and methods of data collection. The study explores both teachers' and students' views about the nature of statistics and statistical literacy. The research hopes to find ways to facilitate the development of statistical literacy with students and teachers in secondary mathematics classrooms and will signal possible professional development strategies for teachers to use in similar contexts. Therefore, an understanding of both the students and teachers in the research is needed.

3.7.2 Participants

The participants are the key to success in this research. This action research project involves self-selecting teachers. I am describing myself as the

[12] Taken from ESOL online and the DVD *Making Language and Learning Work 1: Integrating Language and Learning in Secondary Maths and Science*

researcher. However the participants are important *research collaborators* (Hendricks, 2006). The research process is a collaborative exercise where teacher participants can help to develop the focus of the study and where student participants can help by researching themselves and their own thinking and actions in the classroom. This can be compared to the normal process of quality assurance that takes place in a mathematics department where participation may not be voluntary and consensus is not a prerequisite (Hatten et al., 2000). However, it is hoped that the research participants see the benefits of participating in the research.

The following sections outline the background of the school, teachers and students that participated in this study.

3.7.3 The background of the school

The school that provides the context for this research project is a multicultural, decile three Auckland secondary school. It is a co-educational school with a roll of approximately 750 students. The school has a diverse student population with students that represent over 25 different national backgrounds. The current ethnic composition of the school is shown in table 1 below. The gender composition of the school is 58% boys and 42% girls.

Table 1 Ethnicity of students

Ethnicity	Percentage
Samoan	26 %
Tongan	23 %
Indian	11 %
NZ European//Pākehā	11 %
Māori	6 %
Asian	6 %
Filipino	6 %
Niuean	3 %
Fijian	2 %
Cook Island Māori	2 %
Other	3 %

3.7.4 The background of the teachers

There are approximately 50 teachers working in the whole school. Almost as diverse as the student population, the teacher population represents people from over a dozen different national backgrounds. There are seven teachers in the mathematics department. The teacher profile of the department is just as multicultural as the rest of the school. All teachers in the mathematics department have mathematics qualifications and teaching qualifications. Interestingly, no teacher, including myself, has statistics as their major mathematics qualification.

Three teachers in the department participated in this research. I believe that the teachers agreed to participate in the research because they wanted to change their practice in the teaching of statistics and statistical literacy. I believe that this was especially true after the signalling by the Ministry of Education of curriculum change. Teachers in the department had participated in department discussions on the implications of the curriculum reform and had made submissions to the draft curriculum project in 2006.

Teacher A is an experienced teacher. He is a teacher of statistics in the senior school and holds a position of responsibility in the department. Teacher A was born and educated in Fiji. He moved to New Zealand in the 1990's. Teacher A has been teaching for over 10 years.

Teacher B is also an experienced teacher. Teacher B was born and raised in Tonga. Like all the teachers that participated in the research, he is multilingual and has a keen interest in helping students deal with the language demands of teaching and learning mathematics.

Teacher C is new to the New Zealand education system. She began her teaching career in Tonga before moving to New Zealand. Teacher C has been teaching 3 years.

3.7.5 The background of the students and the classrooms

The student participants in this study were in Years 9 and 10. The students range in age from 12 to 15 years old. Mathematics is compulsory for all students in Years 9 and 10 with students having four 50 minute periods of instruction per week. The school broadly bands students by ability at Years 9 and 10. The school uses language focused tests to band students on entry into Year 9. The results from a series of asTTle [Assessment tool for teaching and learning] diagnostic tests in English and mathematics are used to reassess class composition in Year 10. The students involved in this study represent a cross section of the school population with a learning support class, middle band class and an extension class.

Mathematics is generally taught in the same block of classrooms in the school where two of the four classrooms have pods of five computers with access to the internet. Because classrooms are shared the arrangement of classrooms and desks are very similar with desks in pairs facing the board at the front of the room.

Teacher A's class was a Year 10 extension class of 32 students. Teacher B's class was a Year 9 learning support class of 24 students. Teacher C has a middle band class of 28 students.

3.7.6 Data collection methods

The planning for this research project involved evaluating the participant teachers and my, understanding and capabilities in statistics and statistical literacy. We attempted to map the demands of statistics and statistical literacy on students and teachers. I specifically looked at the research and accounts of studies that reported on ways in which statistical literacy could be integrated in literacy-related teaching and learning. I reported this research back to the other teachers involved and then we analysed gaps between possible practices and current capabilities and what we agreed would be an achievable target for instruction. We identified needs in terms of materials and resources as well as professional development needs. We then attempted to design classroom interventions and customised professional development to address these gaps.

The data collection for this research project involved:

- Interviews with teachers
- Interviews with students
- Observations of lessons
- The collection of artefacts from both teachers and students

As per an action research methodology, preliminary data analysis occurred throughout the research study. Reflection, redefinition and conclusions involved identifying what worked and what did not work in the classroom. This enabled the group of teachers to identifying some implications for future units and possible teacher professional development in respect of statistical literacy and literacy teaching and learning. We also endeavoured to reflect on the challenge posed by the task of designing and implementing strategies for integrating statistical literacy into our secondary school Mathematics programmes. Finally, the publication possibilities to disseminate findings of the research undertaken were considered.

3.7.7 Data collection phases

The teachers started by first analysing their own notion of statistical literacy in the current situation with respect to teaching and learning and then redefined this understanding to create a new mutually shared understanding of statistical literacy. Secondly, the researcher collaborated with the teachers in designing and trialling a series of lessons intended to enhance students' statistical literacy. Next, the teachers evaluated the process of implementation with respect to teaching and learning to help design future units for the development of statistical literacy and hopefully a method of changing practice in instruction. This research methodology can be seen as an adaptation of the work of Pfannkuch and Horring (2005). However, this study documents only one cycle of planning and implementation whereas the Pfannkuch and Horring study of Year 11 statistics teaching and learning spanned 3 years.

3.7.8 Interviews with teachers

The interviews with teachers were used to document both the initial problem and planning phases of the action research and to document the first cycle of reflection and evaluation.

Teachers participating in the research were requested to attend an initial meeting of approximately two hours. It was hoped that this meeting and subsequent follow-up interviews could be accommodated in normal non-contact time in the school day or during normally scheduled meeting times. Notes were taken by me as principal researcher as part of the data collection for this research. However, this meeting was not particularly different than any other planning meetings that normally take place in the department. One of the ethical concerns of this research was the overburdening or overloading of already busy teachers. Hence, special effort was taken to not place any extra burden onto teacher participants in terms of time or workload. The questions and themes addressed in this initial meeting can be found in Appendix F.

The interview methodology was chosen to give opportunities for the principal researcher and the teacher participants to talk about whatever arose during this initial meeting. The intent was that the conversation would flow freely, without the intrusion of a formal interview structure. It was hoped that the teachers would see no distance between researcher and participant and that they would see that they had control over the direction and focus of conversations. This was very important as it was a central part of the research that the teachers involved became to see themselves as teacher-researchers themselves.

At the end of the unit of work a follow-up interview took place with all the teacher participants meeting in the department offices. Again, the interviews were able to take place during normal non-contact or professional development, appraisal and meeting times. However, because of the limitations of the school timetable one teacher was unable to attend without having a class covered by another teacher. Special thanks must also go to other members of the department who covered this lesson. It is acknowledged that this was an imposition and we were thankful for their support of our endeavours. The interview questions and themes can be found in Appendix G.

The information collected from the group interviews was raw data. Notes were taken during the initial interview while the final interview was videoed. Afterwards the final interview was transcribed from video and from notes taken. Hopefully, this provides a complete record of the discussion and facilitates analysis of the data. The aim of the analysis is to look for trends, themes and patterns that reappear within the data.

3.7.9 Classroom Observations

Classroom observations were undertaken for one or two lessons per week per class over approximately a six week period. The lessons took place during the third term of the school year. Some selection of classes was done so that there was time before or after the lesson to talk with the teacher about what was happening. However, the timetable structure did not always allow this to happen.

I spoke to all observed classes before video recording at the start of the consent process. When observations began I again spoke to the class and spent some time allowing them to become comfortable with the presence of another teacher and researcher. My role as Head of Department [HOD] for Mathematics in the school made this easy with Year 10 students because most of the students were used to seeing me in their classrooms in the previous year. It was somewhat more problematic with Year 9 students where I had to rely much more on the teacher to help develop a comfortable and trusting working relationship. I was aware that it was important for the teachers to be in control of what is going on in their classrooms and for the teachers themselves to determine the best possible learning experiences for their students. Therefore I took the lead from the teacher about when and where I could video.

3.7.10 Interviews with students

Three groups of students were interviewed towards the end of the statistics unit with four students from each class. Selections were made primarily by the teacher. However, I had input into the student selections as I had also observed the students and wanted to follow up on some of the things I had seen or heard. Selection was made on the basis of engagement with the learning and interest shown. However, selection was also made for equity in terms of ethnicity, gender and language ability. In each class two boys and two girls were selected. Each class included at least one ESOL or EAL students. A summary of the students is shown in table 2. Students had the opportunity to decline the interview. However, all students approached showed a willingness to be involved.

Table 2 Student participants

	Student	Class	Gender	Ethnicity	ESOL/EAL
Teacher A	Student A_1	extension	boy	Filipino	Yes
	Student A_2	extension	boy	Indian	No
	Student A_3	extension	girl	Samoan	No
	Student A_4	extension	girl	Asian	Yes
Teacher B	Student B_1	support	girl	Tongan	Yes
	Student B_2	support	girl	Samoan	No
	Student B_3	support	boy	Asian	Yes
	Student B_4	support	boy	Filipino	Yes
Teacher C	Student C_1	mainstream	boy	Samoan	No
	Student C_2	mainstream	girl	Tongan	No
	Student C_3	mainstream	boy	Other	Yes
	Student C_4	mainstream	girl	Pākehā	No

Student interviews took place during lesson time. Lesson time was seen as critical for learning by the teachers involved and it was acknowledged that interviews in class time would be disruptive to students. However, because the teachers include time for student evaluation in their normal teaching the time taken for interviews was accepted. Every effort was made to minimize disruption to student participant's class work and preparation for assessments. This was done in consultation with the classroom teachers and students involved. The interviews took no longer than one lesson of class time. The interviews took place in empty teaching spaces and were videoed.

3.7.11 Artefacts

Examples of student work were also gathered, along with teacher produced materials. This collection of artefacts tended to occur after particular incidents in the classroom that I or the classroom teacher had noticed. Both teacher and student artefacts are identified in the research by the teacher's class that they came from.

3.7.12 Ethical issues

There were a range of ethical concerns raised by this research. Care was taken not to overburden or overload already busy students and teachers. A reason for choosing Year 9 and 10 classrooms for the investigation was that there are no external assessment pressures such as National Certificate of Educational Achievement [NCEA]. However, lesson time was seen as critical for learning and every effort was made to minimize disruption to teacher and student participants.

The research site is a diverse school with a strong Pasifika flavour. Reference was made to the *Pasifika Education Research Guidelines; Final Report* (Anae et al., 2001) which state that it is important to allow participants the opportunity to view transcripts, audiotapes and videotapes so that participants can build trust in the researcher and the integrity of the research. I believe this sits well with an Action Research model that seeks to be collaborative as well as self reflective.

Many students have English as a second [or third/fourth] language. Care was taken to make sure that all students understood the research information and consent process. This was achieved by using peer translators and the teachers themselves. With videoing lessons I made rearrangements to normal classroom seating plans and organisation to ensure that no non-consenting student in the class was included in video footage.

3.7.13 Approval from University of Waikato Ethics Committee

The ethical procedures set down in the *Human Research Ethics Regulations* (The University of Waikato, 2005) were followed in this study. Application was made to the University Of Waikato School Of Education Ethics Committee for ethical approval for this supervised Postgraduate research project. Approval was granted for the project.

3.7.14 Informed consent from the school, teachers and students

Consent was initially sought from the Principal for research to take place in the school. An information letter and consent form was given to the Principal [Appendix A] to gain consent from the school. Teachers [Appendices B and D] and students [Appendices C and E] in the classes involved were also given an information letter and consent form to take home. As some of the possible participants were under the age of 16 at the time of the study I also asked for parental consent.

The consent outlined that the content of any interviews, video or recording remain confidential to the researcher and my academic supervisors and to the research participants. Permission and consent was sought for use of any artefacts. Participants were informed that readers of the research study or of any reports resulting from the study will be unable to identify individual students, teachers, classes or the school involved and that pseudonyms would be used so that no teacher, student or school name will appear in any publicly available report or article without the agreement of the respective student, teacher or the school. The consent forms stated that participation was voluntary and that consent could be withdrawn at any time without reason.

There were three issues that caused concern and discussion during the consent process. The first was my role as principal researcher and the conflicts that this had with my usual role as HOD in the department. For example, one of my responsibilities as HOD of the mathematics department was the lead in the appraisal and attestation processes for other members of the department. That process had already begun in 2007 before I left on study leave. I was aware that a potential unequal power relationship could exist between teachers and HOD as in the relationship between appraiser and appraisee where the appraiser is also the HOD. Participation and responses may have been affected by this relationship. However, there were factors that mitigated the situation. The fact that I was on study leave from the school was important. The teachers involved could see that I was interested in what was going on in the classroom with statistical literacy. The appraisal and attestation duties were completed by the acting HOD while I was on study leave. Finally and most importantly, it had not been a feature of the relationships with my department colleagues in the past.

Secondly, there was the issue of my own place in the research. There was an acknowledgment that while it was hoped that the research would benefit the students, the research would also be of personal benefit for me in my studies. It was important that the teachers felt that there was no pressure on them to gather data just for me, as I was using the research towards my own personal qualification. This was mitigated somewhat by the teachers own desire to change practice and professional learning.

The final issue raised during the research was anonymity and confidentiality. There was a hope that the action research would result in some positive changes to the teaching of statistical literacy. Some of the teachers expressed an interest in sharing their results with a wider audience than the group itself. It was conceded that if this was the case it may be difficult to ensure anonymity for teacher participants in the future as participants that chose to remain anonymous may be identifiable through association with those participants that wished to have their real names used in any future published materials. However, as the consent agreement states [see Appendix C] there will be no way a reader of the research study or of any reports resulting from the study will be able to identify the responses of individual participants.

These consent issues were addressed throughout the research process, from the ethics approval process to the consent process both in the initial phases and throughout the research process.

Chapter 4: Analysis and results

4.1 Introduction

The initial results and analysis from the first cycle of the action research are presented in this chapter. For organisational purposes the findings have been documented chronologically. The timeline is taken from the parts of the action research cycle: problem, planning, action and reflection. The first sections, 4.2 and 4.3 expand on the problem and planning phases where a plan of critically informed action was developed to improve practice. Section 4.2 explores the data collected in the initial planning meeting with the other teacher participants. Section 4.3 describes the planning phase for the statistics unit for the Year 9 and 10 mathematics classes. Sections 4.4 and 4.5 of this chapter attempt to document the action phase of the action research. Section 4.4 looks at data collected from classroom observations during the statistics unit as well as data from other sources such as student and teacher artefacts and discussion with teachers gathered during the action phase. The last two sections in this chapter document the reflection phase. Section 4.5 looks at the students' perceptions of statistics and statistical literacy as well as their response to the teaching programme. Section 4.6 is an analysis of the data collected in the teachers' interview undertaken at the end of the statistics unit.

At the same time as documenting the different phases of the action research cycle I have attempted to describe the dominant themes that have emerged from the data. As mentioned in the methodology chapter, these themes emerged during my initial research and literature review as well as in response to discussions and observations between teachers during the actual teaching and learning interventions. Most of the themes came from the research questions posed. Further themes emerged when I looked at the data collected. The dominant themes highlighted in this chapter are:

- The concepts of statistics held by students and teachers,
- The concepts of statistical literacy held by students and teachers,

- The adoption of particular teaching principles as an aid to teaching statistical literacy,
- The importance of language and literacy in statistics, and
- The difficulties of adopting a critical literacy stance in the statistics classroom.

4.2 Themes emerging from Initial meeting

The initial planning meeting took place at the end of term two in 2007. I met with the other participating teachers in a normal Mathematics department meeting time after Monday after school. The first part of the meeting was an explanation about the intent of the research and how I wanted to document the teaching of statistics and statistical literacy by a group of teachers in our department. I then presented some ideas about statistics and statistical literacy to the group. My presentation of statistical resources and models of teaching led to a discussion around teachers' views on the nature of statistics and statistical literacy. These views were then examined in relation to: our current programme, the current and proposed Mathematics and Statistics curriculum, literacy practices in the school, and teaching styles.

4.2.1 Concepts of statistics

As this was our first formal meeting for the action research I felt some obligation to set the scene for the research. While meetings to discuss scheme planning are a normal occurrence I did feel it necessary to try and advance, and advocate for, many of the ideas about statistics and statistical literacy that I had found during the research and literature review process. As an action research project there was also the need to introduce materials that could bring about change in the teaching of statistics. I therefore bought a wide range of materials to the meeting to encourage discussion.
These included curriculum materials, our current scheme and unit plans, materials gathered from out of school professional development sessions hosted by the mathematics advisor, web based materials from *Census at*

Schools[13], *Numeracy in the News*[14] , Assessment Resource Bank [ARB][15] materials and a video clip taken from www.TED.com of Hans Rosling[16].

I had clearly brought my own perspectives about statistics and statistical literacy to the meeting. However, it quickly became apparent that there were different attitudes towards statistics and a variety of conceptions of statistical literacy amongst the group.

All the teachers involved were generally positive about the teaching and learning of statistics. I have not always found this to be the case with secondary mathematics teachers.

Teacher A was generally very positive about statistics teaching in the classroom. However, teacher A had changed his attitude towards teaching statistics over time.

Teacher A I didn't really use to enjoy teaching statistics. But now after teaching the Statistics and Modelling course[17] I understand what we are doing and where we are going. I used to not like the lack of exact answers [in statistics] but now it is some of the most enjoyable stuff I do.

Teacher B was extremely positive about the statistics part of the mathematics programme and looked forward to the statistics topic.

Teacher B Statistics is a chance for the students to get more involved. I want them to do investigations.

As a teacher new to the New Zealand school system, Teacher C was unsure what was expected from students at the Year 9 and 10 levels. She was interested in the research project as a way to come to grips with the New Zealand curriculum.

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[13] The Census at Schools is a biannual census and further teaching and learning resources for the classroom.

[14] Numeracy in the News is a web-based resource of statistically related newspaper articles. Numeracy in the news is based in Australia http://ink.news.com.au/mercury/mathguys/mercindx.htm.

[15] The Assessment Resource Banks [ARB's] are collections of assessment materials available on-line for use in schools. The ARB's are hosted by the New Zealand Council for Educational Research [NZCER]

[16] Hans Rosling is a public health medical researcher from Sweden who argues passionately for the better use of statistics to inform people about key issues.

[17] The Statistics and Modelling course is a NCEA Level 3 subject taken by Year 13 students.

Teacher C This will be good for me as I need to know what you do here and how it compares with what we do in Tonga.

We started the meeting by viewing the Hans Rosling video clip. In the clip, Hans Rosling uses different data representations to tell stories about world health and population data. Rosling uses technology to bring the statistics alive. There is extensive use of scatterplots and graphs of distributions to look further into the data. There was a lot of discussion in response to the clip. The clip was seen as inspirational for the teachers rather than aspirational for students. The initial reactions were that the subject matter was beyond most students and that the approach was too difficult and unrealistic for use with Year 9 and 10 students. While the content involved was within the curriculum objectives of the scheme and the software used were available to the group the teachers felt that trying to tailor similar activities for Year 9 and 10 students would not be possible. Teacher B's comment summed up the mood of the meeting.

Teacher B My students couldn't do that.

However, there was some agreement about the potential for motivation and engagement by using such a statistical literacy approach. For example;

Teacher A But that is what my class would want to do – if they could spend the whole period arguing they would.

My reason for including the Hans Rosling clip was that it fit with my definition of statistical literacy where statistical reasoning and thinking are a part of a wider statistical literacy. The clip focuses on real-life data and engages with the viewer with contexts that demand more that just statistical competency. The clip is a wonderful example of how the analysis of data requires not only an understanding of statistics but general knowledge and an understanding of context as well.

Here a difference in beliefs about teaching statistics amongst the group was highlighted. The move from teaching statistical skills to teaching statistical literacy or critical thinking skills was seen as a real challenge for both the teachers and students. For example Teacher C typified much of the discussion when she commented.

Teacher C When will we teach them how to calculate the statistics?

Questions and responses such as the one above showed how persistent the idea that statistics could be taught as transmitting of a range of arithmetic or mathematical skills. This concept is further discussed in the planning phase in Section 4.3.

There was a tension within the group between statistics as a set of techniques and statistics as a tool for change. Teachers felt that it was their responsibility to teach statistics first before they attempted to teach general knowledge. The responsibility for teaching the wider contexts was seen as the responsibility of other learning areas. As Teacher B states;

Teacher B That is more like Social Studies.

Teacher B also felt that using data in such a way was value laden and could leave us open to criticism as teachers for pushing particular points of view about social issues.

Both sides of the debate were articulated by the teachers. Both Teacher B and C teachers were interested in developing units of work that focused on mathematical processes and thinking as well as delivering content. There were various reasons given for wanting this. A key reason was the belief that students did not understand the concepts behind the skills and that by contextualising problems it would be possible for students to gain greater understanding of the statistical ideas. Teacher B's comment was typical of the discussion.

Teacher B The students often do stuff that they don't understand. They can give you the right answer but don't have any idea what it means.

The impact of information technology was also seen as a major influence on how statistics could be taught or learnt. Teachers felt that the availability of appropriate technology had made many of the skills and techniques previously taught obsolete. With time free in the unit to focus on more than calculations and graphing, teachers felt lessons could be filled with tasks that dealt with greater amounts of data and more time for analysis.

Teacher A The computer can do all that [calculating statistics, drawing graphs] for you now anyway.

Teachers also expressed concerns about the suitability of using real-life contexts and data in classes and the maturity of students. While the teachers admitted that they were personally interested in wider issues, such as those exemplified in the Hans Rosling clip, they did not see it as a necessary part of a Year 9 and 10 statistics scheme.

We looked at the *Census at Schools* online questionnaire and the large amount of associated materials taken from www.censusatschool.org.nz. Teacher A and Teacher B had both taken part in the *Census at Schools* programme in 2005. *Census at Schools* was seen as a positive addition to the programme. Both Teacher A and B were keen to explain to Teacher C, who had no experience of the resource, features of the *Census at Schools* programme.

Positive features of *Census at Schools* were seen as wide and varied. The teachers focused on the novelty of the resource, the greater motivation and engagement of students, the real-life nature of the data and the potential for linking across the subject and subjects.

Teacher B The students enjoy something different.

Teacher A It's something real to have a go at. They can use their measurement skills as well.

Teacher B It is real life data and it takes the kids heads out of the classroom.

This was in complete contrast to the previous conversation following the Hans Rosling clip. Teachers A and B felt much more comfortable with the resource because they were at the students' level.

It was agreed that all students would participate in the online survey. Of particular interest during the meeting was the data analyser function on the website which enables users to create a variety of different graphical representations to summarise and compare data. Some of the tools for manipulating data on the website had not been extensively used in the previous years.

Computer use in the classroom highlighted two major concerns about using the Census at School materials. Firstly, it was felt that there was a major problem accessing computers in classrooms. As noted, there are a small number of computers available in some of the mathematics classrooms. It was felt that there would be classroom management difficulties if teachers were expected to complete the parts of the unit with students working solely on the computer. Secondly, teachers felt that they needed more time to familiarise themselves with the program and support materials. In the meeting the availability of computers was seen as the most pressing issue. However, on reflection I am not sure if concerns about access to computers were secondary to our lack of knowledge on how to integrate the use of computers and computer applications into the classroom.

Much more palatable to the group was the *Census at Schools* activity *Being Typical*[18]. This activity involved students going through a statistical investigation cycle using data provided to them. The multivariate data is taken directly from the *Census at Schools* database. The data is presented on cards that can be manipulated by the students. There is scope in the activity for students to develop a wide variety of questions using the same data set. Watson and Callingham (1997) give a description of similar activities. I had previously attended some professional development sessions on how the activities could be used in class.

The focus of the data card activity from the *Census at Schools* was the investigations cycle rather than evaluating statistics. However, it was agreed that there were lots of opportunities for students to evaluate the work of others in the class. There was an enthusiasm amongst the teachers for the activity because it was seen that there would be more time to spend on explaining and analysing of data.

Teacher B The kids will do less busy work from the textbook and spend more time on the writing.

Teacher A This is making them [students] do more.

[18] The *Being Typical* activity uses Census at School data from the 2005 round. I had had some excellent professional development on using the Census at Schools data from sessions run by the Auckland mathematics advisor, Pip Arnold.

4.2.2 Concepts of statistical literacy

Throughout the research there was a tension between statistical literacy as competency with data and statistical literacy as being critical with text. The next resource that we looked at during this meeting was the *Numeracy in the News.* The *Numeracy in the News* website uses newspaper articles taken from Australia. On the site, there are a number of full-text newspaper articles from *The Mercury* in Hobart, and other newspapers throughout Australia. Most articles have linked questions for students and discussions for teachers.

The *Numeracy in the News* resources are overtly about statistical literacy. The *Numeracy in the News* materials require the use of basic statistical skills and literacy skills to interpret real life situations and contexts and make judgments.

In the current school scheme the only identifiable achievement objectives for statistical literacy were 'discuss and recognise misleading graphs'. This had previously been a one or two lesson exercise looking at textbook graphs that showed how data could be displayed to mislead. The focus was on graphic literacy.

There was some concern that too much time would be spent on this one particular aspect. It was here that I tried to explain my position that this could be in fact the core of the unit of work. This tended to stop the conversation and discussion. In hindsight, I would see this as one of the many times where my colleagues humoured me and out of politeness and chose not to give their honest opinions.

However, concerns were raised about the use of the *Numeracy in the News* articles. There were concerns in the group about the amount of text involved, the reading levels of the text and the reading levels of students. These concerns were voiced by all teachers.

Teacher C There is a lot of writing in some of these articles.

Teacher B Too advanced for Year 9 and 10 students at levels 3 or 5 [MiNZC curriculum].

There was also a concern that we, as mathematics teachers, may not have enough skills to use such materials in class. This was typified by Teacher B.

Teacher B We don't want to have to teach them to read.

Teacher A was much more comfortable about the materials and the consequences for teaching. This may have been because of his experience with literacy techniques gained as part of his involvement the school literacy programme.

Teacher A We can use the Pasifika literacy stuff.

What the discussion of literacy showed was that there was an understanding amongst the group that there were wider issues impacting on students than just mathematical or statistical ones. A number of comments were made in relation to this, including literacy skills, thinking skills, student motivation and classroom management. The whole school focus on literacy was referred to frequently as was the work done by the school's Special Needs Coordinator about lesson structure. These are described more in Section 4.3.

The differing response by the group to the *Census at Schools* data card activity and the *Numeracy in the News* materials appeared to highlight the mismatch between my concept of statistical literacy and the concept of statistical literacy held by the other participants. I was pleased that the *Census at Schools* investigation activity was warmly received. However, I was disappointed about the lack of enthusiasm for the *Numeracy in the News* materials. Again, this seemed to illustrate that my concept of statistical literacy may have been inconsistent with the group definition of statistical literacy. The other teacher participants were comfortable with teaching statistics as the investigation process but were less comfortable with statistics instruction as evaluating and critiquing statistical data and information of others.

4.2.3 Adoption of teaching principles

The discussion on how to introduce activities such as the *Census at Schools* and *Numeracy in the News* resources led to a discussion of possible pedagogical approaches. An article from Kazemi and Franke (2004) and the principles from the *Making Language and Learning Work 1: Integrating Language and Learning in Secondary Maths and Science* (Ministry of Education, 2007a) resource were introduced. My hope was that they could be looked at to see how they may integrate into the teaching of the statistics unit.

The cognitive guided instruction model of Kazemi and Franke (2004) was abandoned quickly by the teachers. It was felt that it was poorly introduced and not particularly well understood. In hindsight, this was a key point where the other participating teachers were able to bring the focus back to the planning of the scheme. The teacher focus was on the teaching and learning of statistics and not on my research interests. However, positive comments were made about any focus on what students were thinking.

In contrast, the principles described in the DVD were seen as a good template for teaching and particularly useful for teaching statistical literacy. Again there was a certain amount of 'being nice' because the teachers could obviously see that I had participated in the DVD resource. However, my own interests' aside, I believe that the principles in the DVD resonated with all the teachers in the research. All the teachers articulated a conviction that language was a key to success for their students.

Another perceived strength of the DVD resource was that all of the teachers had participated in some whole school professional development looking at the principles. How the principles were to be enacted in the scheme is discussed in the following section.

4.3 Themes emerging from the planning of the unit

In the final part of the first meeting/ interview the teachers undertook the planning of the unit. We discussed the present scheme and its links to the national curriculum document. We looked at the time allocation and assessment for the unit of work. We then looked at the proposed curriculum draft and discussed the implications. The group expressed a level of frustration of the present statistics programme.

Teacher B You know, each idea, like mean median, range is straightforward. But our students find it difficult to put it altogether.

Teacher A It is because of the way that we teach it

Teacher B We teach it all too much lesson by lesson. I think we need longer investigations to show the whole process is all connected.

This theme was revisited repeatedly in the meeting as in Teacher B's comment.

Teacher B It's taught separately and students never link it to making decisions about data and the question that you are trying to answer.

There were concerns expressed about teacher workload due to the implementation of the new curriculum. All teachers voiced some trepidation about the implications of curriculum changes in relation to statistics. In one exchange all three teachers voiced concerns about the new curriculum.

Teacher A Does the new curriculum mean that ⅓ of what we do will have to be statistics and probability? What will leave out? How will we allocate the time to each topic?

Teacher B Not enough time already to complete everything at present

Teacher C We are very busy completing work now.

Time was an issue in the planning meeting. A decision was made that we would take our existing scheme and modify in light of our discussions. The meeting decided that I would make the alterations to the scheme documents and present back to the group for comment. Both the existing scheme and new scheme are shown in Appendix H.

Most noticeable in the revised scheme of work was the move from skill based activities and lessons to problem or task based lessons. However, the scheme was not overly prescriptive as the scheme was to be used for teaching as well as the research. Several suggestions were given for resources that could be used, but teachers were free to find, create or use their own resources.

It was established that there would be a shift from the existing scheme that was focused on students as producers of statistics only to the proposed scheme where students would aim to work as both consumers (and evaluators) of statistics and as well as producers of statistics.

It was agreed that all the classes would participate in the Census at School online questionnaire and that this would be the starting point for the unit of work on statistics. All classes would also trial the *Being Typical* activity. Finally all classes would trial some of the *Numeracy in the News* articles.

4.3.1 Language and literacy in the statistics classroom

The adoption of the language learning principles allowed literacy to be a key focus for the statistics unit. The scheme included language objectives alongside statistical objectives. This was seen as formalising in the scheme document what had already been occurring in many classrooms.

Because of the importance placed on language, the teachers were open to adopting some of the strategies and methods explored in the *Making Language and Learning Work 1: Integrating Language and Learning in Secondary Maths and Science* DVD (Ministry of Education, 2007a) and accompanying resources available on-line. The teachers felt that the principles could be used to aid the planning of the scheme. However, there was a desire for some guidance on how to incorporate some strategies into lessons. The principles are;

- Knowing the learner and their language background, their language proficiency.

- Identify the learning outcomes including the language demands of the teaching and learning.
- Be explicit about the learning outcomes with the students.
- Using context embedded tasks which make the abstract concrete.
- Provide multiple opportunities for authentic language use with a focus on students using statistical language.
- Balance receptive and productive language
- Include opportunities for self-evaluation.

Other changes to practice were also identified in response to the principles. Identifying the language demands of the lesson was to be done by all teachers. The teachers agreed to write language aims as well as content aims on the board at the start of lessons. Similarly, 'Do it now' tasks, tasks for students to complete at the start of the lesson on entering the classroom, were chosen to focus on particular language skills and language interpretation. Resources were shared between teachers.

I believe that the emphasis placed on language and literacy in the planning of the statistics unit was very significant. Remarkably, over the following weeks each teacher offered examples of language focused tasks and scaffolding materials from a wide variety of resources from reference books, off the shelf literacy materials, internet resources, teacher handbooks and teacher generated materials. While there was a prominence of vocabulary activities teachers were also trialling language focused tasks to teach mathematical content. Again, the agreement was that I would edit the scheme of work and pass to teachers for comment and discussion. Many of these materials can be seen in the scheme in Appendix H.

The scheme also provided more opportunities for authentic language use with a focus on students completing their own investigations and analysing statistics. The balance between receptive and productive language was addressed by the scheme expecting students to focus on thinking and doing statistics rather than focusing on content. Teachers were to be explicit about language and modelling tasks. There was a commitment to use appropriate statistical vocabulary correctly in the classroom. It was hoped that with the repeated usage of terms, statistical vocabulary and some of the concepts associated with them could become a part of the students' own statistical language.

The investigations and activities to be completed by students were to be supported by the extensive use of cloze activities, writing frames, exemplars and templates to help students with writing. Many of the activities were taken from publications such as the *Effective Learning Strategies in Years 9 to 13: A Guide for Teachers* Ministry of Education (2004a).

4.3.2 Critical literacy and the statistics classroom

While a consensus was reached for what would be included in the statistics scheme, I personally felt that we had not gone far enough. While the statistics unit did include much more analysis and evaluation of statistics I did feel that we had not moved appreciably towards adopting a critical literacy focus. I felt that the statistical investigation part of the scheme was dominating the statistical literacy part. I also felt that an emphasis on statistical investigation would allow a process view of statistics to persevere. I wanted the students to have more opportunities to respond to statistical data rather than generate. This is not because I do believe that statistical investigation

We did all agree that more time would be needed for language tasks and real life context problems. Hopefully students would spend more time evaluating their own and others work including appropriateness of methods, data displays and conclusions drawn from data. This was encouraging to me as this seemed more like a notion of critical literacy.

Adaptation of materials was also an issue. For example, the *Numeracy in the News* articles and questions are not designated for particular year or curriculum levels. The articles range across data reduction, data representation and data collection and sampling. The data reduction articles look at how statistics are used to support conclusions. The data representation articles explore whether different graphical representation of the same data tell the same story. Both of these are features of the achievement objectives of the curriculum. The data collection and sampling articles look at sampling from the population. However, sampling was not a feature of the New Zealand curriculum at this level. Many of the articles had a range of questions and applications. We needed to check the articles and questions to find those that we thought were appropriate for particular students and classes.

It was agreed that I would source the materials and organise for the other teachers. This was no different than a normal unit of work where a teacher would take responsibility for resources.

A recurring theme in the planning of the scheme was the availability and training in the use of new resources. Any resource that provided teaching materials or student materials was viewed with enthusiasm. The limitations of the available textbook were acknowledged. However, the lack of any replacement materials was seen as even more damaging to the good teaching of the unit of work.

4.4 Classroom observations and data

Classroom observations were undertaken over six weeks of term 3 of the school year. Classes were at different stages in the year plan. Teacher A's class was first to start the statistics unit. Teacher B and C started the unit of work a week later. Over the six week period I observed eight lessons of Teacher A, and six lessons of Teacher B and Teacher C. Data collection was undertaken by all teachers. All the teacher participants observed lessons of the other teachers at least once.

As the statistics unit progressed it became apparent to me that the data collected by video not as useful as I had hoped. My lack of skills at using video for observations meant that the video was often a distraction in the class. Also my role as a participant observer was also a factor. My presence in the class was difficult for some students. Despite the prolonged nature of the observations, the presence of the video camera never stopped being a source of fascination and distraction for some students

Other data collection techniques such as photos, artefacts and notes became just as important in documenting the research. As the project progressed more and more of the artefacts came from the teachers as they noticed student work changing or where they wanted to illustrate the pleasure or frustration with student responses to activities.

Other important data collection occurred in the conversations between teachers that happened straight after lessons. These spontaneous conversations were not recorded. However, as the statistics unit progressed I made an attempt to be more structured in these discussions and take notes.

4.4.1 Concepts of statistics

Initial comments from teachers about the statistics unit were very positive. Participating teachers preferred the teaching unit to the traditional approach. Importance was placed on the opportunity in the classroom for discussion between teachers and students (Teachers A, B and C); on the more practical real-life situations (Teachers A and B); and the view that it was a more statistical way of teaching (Teachers A, B and C). The general agreement was, as Teacher B stated after three lessons;

Teacher B It is better than just teaching skills.

All of the teachers felt that the students engaged more with the topic. There were different theories suggested for this. Teacher B thought that students were responding to something that was new. Teacher A felt that his students liked the way of working.

As the statistics unit progressed teachers said that they were learning a lot. All the teachers commented that there was a need for ongoing professional development on things such as managing classroom discussions, reading and writing. These comments were often made after lessons where the teacher had attempted something new or different to their normal practice.

All the teachers agreed that students were forced to use higher level thinking skills often commenting that the students were operating at a higher curriculum level than they would normally expect. Comparisons were made with the demands made on students completing NCEA assessments in Years 11 to 13.

In a data cards lesson, where students used writing prompts to help draw conclusions about the data, Teacher A commented;

Teacher A This feels much more like what we would do with Year 12 and 13 students.

Similarly, Teacher C and Teacher B both commented about an activity on writing summary and comparison questions

Teacher C This is very similar to AS 1.5. I could easily use these things with my 12MAB class.

Teacher B Really good preparation for NCEA Level 1

My own observation was that the work produced by these Year 9 students was indeed better than some of the work achieved by Year 11 students. During one lesson I shared this comment with Teacher B. Teacher B shared this with his students who took it with some pride.

What was obvious was that the activities were well designed and provided good hints for teachers on how to support students. The *Census at Schools* data card activity is shown in Appendix I.

Both teachers and students commented on the success of the *Census at Schools* data card activity. Teacher A remarked that the cards met many good teaching principles such as concrete materials and working with kinesthetic learners.

Teacher A Students want to touch cards.

There were some concerns expressed that the unit of work was pitched too high. Teacher A commented;

Teacher A I would not normally give students so much data

Teacher A changed this view later in the statistics unit. He commented that more statistics was being done than previously because there was a focus on both competency of statistical skills and statistical thinking.

Teacher A It felt that students could do two things at once.

This was backed up by the students. Students enjoyed using the data cards. Students from Teacher B's class commented that;

Student B_2 The cards were really helpful. There was a lot of information.

Student B_3 Having the data cards is easier than having to read the paragraphs or books.

and in Teacher A' class.

Student A_2 The data is more vast this year than compared to last year. We got to do more.

Again the success of the actual data cards was evident to both teachers and students. However, there was evidence that much of the strength of the activity was the use of language learning principles that enabled students to produce much more writing than they would normally do. The activity encouraged the use of "I notice …" and "I wonder …" sentence starters. The teachers adapted these ideas into materials that could be used by students working in pair and group activities.

In Teacher A's class students wrote out a whole page of questions as "I wonder…" statements. The students then swapped them with partners to classify them into summary, comparison and relationship questions. In Teacher C's class the students worked in pairs to refine questions. In Teacher B's class the questions were collated and then used by the whole class. An example of the "I wonder …" sheet used in Teacher B's class is shown in figure 13 below.

Some students were surprised at the amount of writing expected in this activity. However, the use of scaffolds and pair tutoring did result in significantly more being completed.

Figure 13 I wonder… sheet

Summary, comparisons and relationship questions

I wonder ......

- is there a relationship between height and foot length?
- how many students get 10 hours sleep a night?
- if boys are taller than girls?
- if the length of your armspan is related to your height?
- if year 5 students go to bed earlier than year 10 students?
- if girls have a faster reaction time than boys?
- if the wrist measurement is half the neck measurement?
- what is the most popular time students go to sleep?
- what is the average height of students in year 10?
- which ethnicity is the most common?
- if year 10 boys are taller than year 10 girls?
- if year 5 boys are taller than year 5 girls?
- if primary and intermediate students go to bed earlier than secondary students?
- if NZ European students are taller than all the other ethnicities?
- if the reaction time is related to the amount of sleep?
- if the foot length is related to the height?

Teacher A commented that by expecting students to make multiple "I wonder…" and "I notice..." statements meant that students had multiple opportunities to practice skills that they would have previously only do once or twice in the unit of work.

Pair and whole class sharing of questions were important ways of sharing expectations with all students. Teacher C commented that much of the work was being done by the students themselves and the pressure had gone off her to provide all the guidance. There was evidence of students modifying their own statements to meet the class expectation of an acceptable question or statement.

Technology was not used extensively in the statistics unit. However, the cards shown in Figure 14 and 15 below allowed students to quickly construct different graphs and data representations to answer questions. All three teachers felt that this was a positive feature as it allowed the students to focus on what the data was showing rather than the skill of graph making.

Time was still spent on graph construction in all three classrooms. However, it was agreed that this was a lot less than what occurred in previous years.

Figure 14 Student investigations – comparing data.

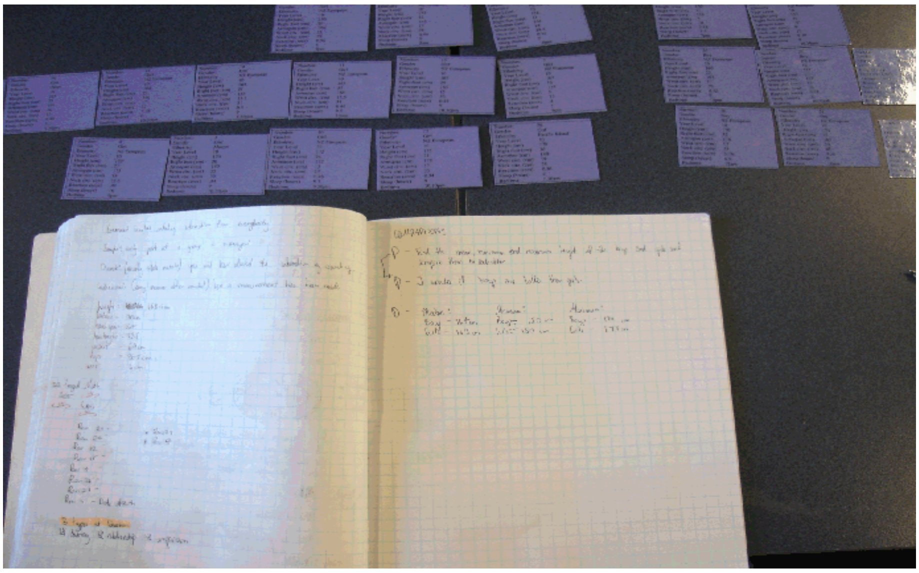
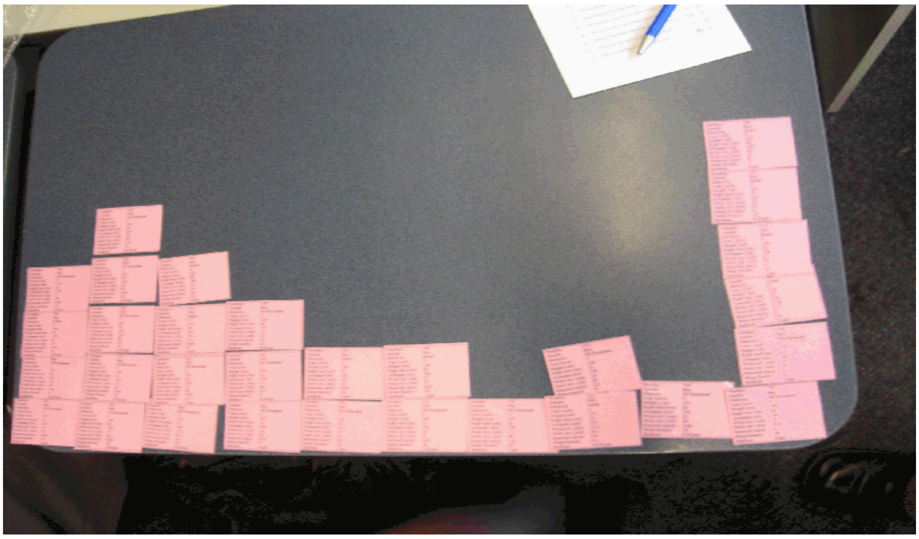


Figure 15 Student investigations – summarising data.



The move away from graphing and calculating statistics allowed time for preparing to write and writing statistical statements. The teacher had to prepare for these activities. The teachers commented that this resulted in a lot more time being spent preparing resources and teaching materials. While this was seen as a negative and a hindrance to teaching in this way, the teachers did see benefits to this as well.

Teacher B The students are getting through more work. I am spending more time discussing with students and asking questions.

The preparation of materials was a feature of the action research. Teachers noticed that students needed different resources and support in the statistics unit. The teachers then responded to those needs by providing additional resources for the next lesson. These resources and ideas were shared between teachers in the Mathematics Department Office after and between lessons.

Activities and tasks were similarly critiqued and evaluated. Teacher A completed the unit of work before the others. Lessons learnt were freely shared as well as frustrations and failures.

4.4.2 Concepts of statistical literacy

There was a shift in students' understanding of statistical literacy tasks that involved the reading of data.

There were a range of responses to articles and reports used in the classroom. Three boys in Teacher A's class gave the following responses to a *Numeracy in the News* task about shark attacks in Australia. The article compared the small number of shark attacks to the huge number of car accidents and questioned whether there was hysteria around the issue of Great White Sharks that was unwarranted.

Student What's this about?
Student Dunno.
Student Must be about sharks, look at the picture.
Student Do we have to copy the graph?
Student Dunno. Sir what do we have to do?
Teacher A Have you read the article yet?
Students No!

While there was a promising literacy strategy being used, with the student referring to the picture, there was very little engagement with the task. If these responses were to be assessed using Watson and Callingham's (2005)

Statistical Literacy Construct then students were only operating at Level 1 or Level 2 where responses are idiosyncratic and use non-statistical intuitions and beliefs.

This was not an isolated incident in this particular lesson. I personally found it very demoralising as I was sure that Teacher A would abandon the activities. However, Teacher A and I discussed this after the lesson. Teacher A suggested that he would produce a reading guide for students for the next lesson. This is shown in Figure 16 below.

Figure 16 Teacher A teaching support material

STATISTICAL INVESTIGATION
(Newspaper statistics)

Read the article given to you.
While reading the article, think of the following questions:

- **The Title**
- **The main article**

(Does the title match the article?)
If not think of a possible title

- **Discuss many different usages for numbers found in the article and accompanying graphs. Do you think different forms of number should have been used?**
- **See if you can find any statistics and what they mean.**
- **If graphs are presented in the article, why do you think it was presented this way?**

Do you think any other forms of graphs should have been drawn?

Which type and why?

The reading guide was used in the following lesson. The guide was used in conjunction with a paired reading exercise where students read the article for 3 minutes, condensed the article with a partner for a further 3 minutes and then shared with another pair.

The comparison between the previous lessons could not have been greater. For example, the two girls selected for the student interview in Teacher A's class who exhibited a growing awareness of being critical with the data in the following exchange.

Student A_3 Sir, how would you know that the claims are valid?

Teacher A You have to take it from the information that they give you….Do they tell you where the information came from

Student A_3 [scanning article] …Kiwi Global USA 2004.

Teacher A Right… So….

Student A_4 Right. So we could go and check that data. Compare that to the advert that says 'Clinical tests show'.

Student A_3 Yeah, you don't know what tests they mean.

Student A_4 [to Student A_3] So, do we trust this article? We don't know how many people were asked.

Student A_3 Is this an article or an ad?

Student A_4 It's both.

Teacher A What do they call those?

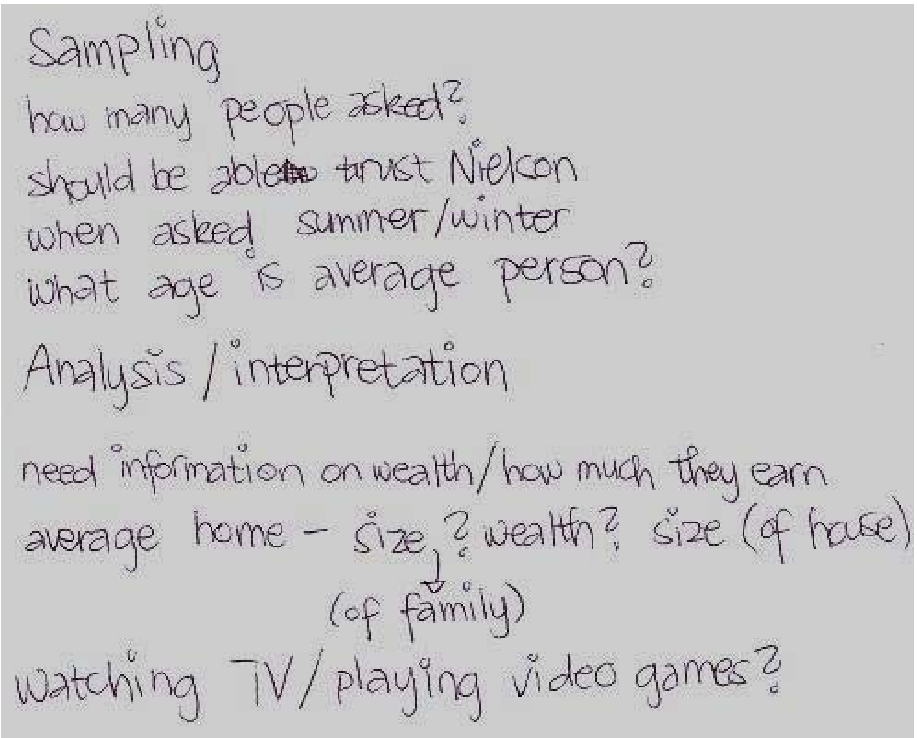
Students together An advertorial

In the above exchange the students were discussing an advertisement from a teen magazine. Students were familiar with the content and engaged with the topic. Later, Teacher A discussed with me and Teacher B about the suitability of some of the articles chosen by us to use in the unit. Teacher A questioned whether they were in fact de-motivating for students because they were too far out of their own experience and not of interest to the students. It was decided that the students would be asked to bring in their own media reports and statistical data to analyse, similar to the material used by Student A_3 and Student A_4..

In the following lesson Teacher B set a homework task for the students to collect articles that contained statistics for the following week's lessons.

Student A_2 reviewed an article about the television watching habits of Americans. His notes are shown below.

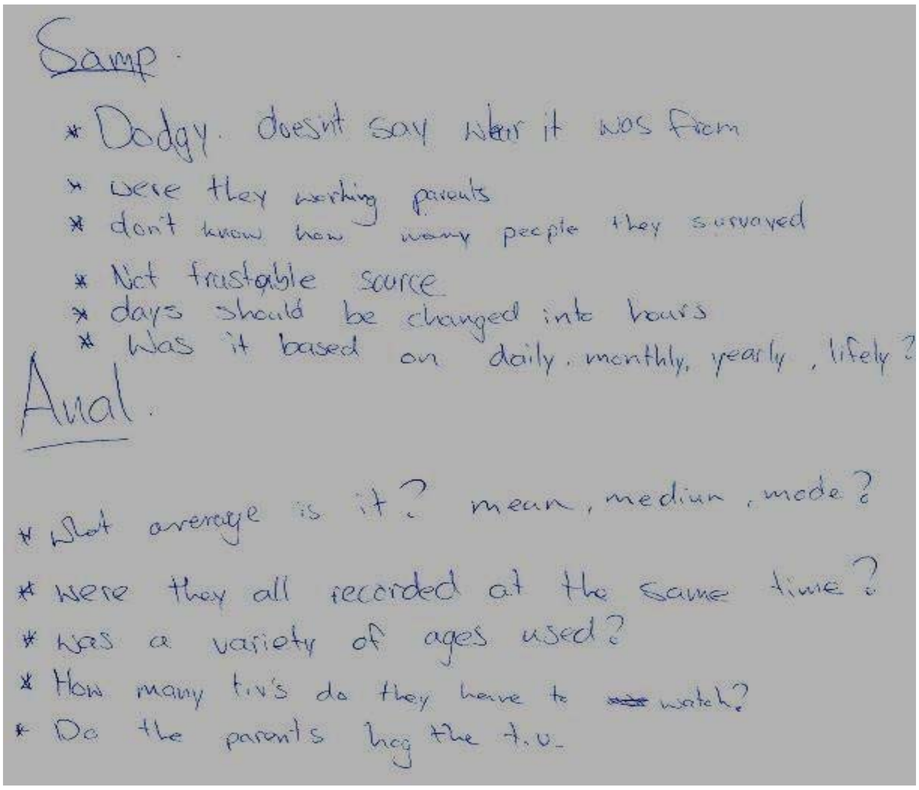
Figure 17 **Student A_2**


Sampling
how many people asked?
should be able to trust Nielcon
when asked summer/winter
what age is average person?
Analysis / interpretation
need information on wealth/how much they earn
average home - size? wealth? size (of house)
(of family)
watching TV/playing video games?

Student A_2 was able to identify concerns about how the survey had been conducted with regard to both sampling and analysis. Sampling was not a feature of the scheme. However, Student A_2 displayed a clear understanding of the context and how issues such as sample size or sampling method could influence the data. Student A_2's responses were assessed using Watson and Callingham's (2005) Statistical Literacy Construct. We came to the conclusion that this work fulfilled the requirements of Level 5 or Level 6 where students are able to respond to both the context and the statistical concepts.

Student A_1 was able to make similar statement about the same article. Both students were interested in the reason for the survey reported and questioned both its methodology and analysis. Student A_1's responses are shown below.

Figure 18 Student A_1



Samp.

* Dodgy. doesn't say wher it was from
* were they working parents
* don't know how many people they surveyed
* Not trustable source
* days should be changed into hours
* Was it based on daily. monthly, yearly, lifely?

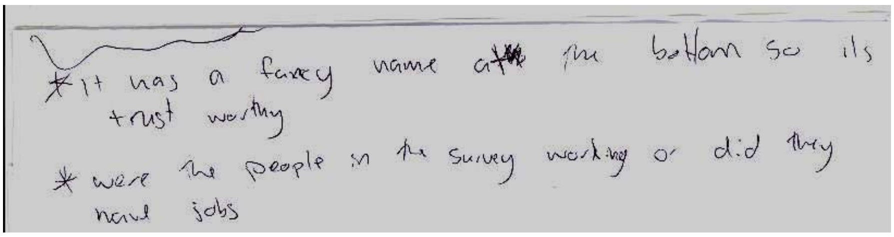
Anal.

* What average is it? mean, median, mode?
* were they all recorded at the same time?
* was a variety of ages used?
* How many t.v's do they have to watch?
* Do the parents hog the t.v.

Both Teacher B and Teacher C had similar experiences. However, both teachers did not complete as many *Numeracy in the News* tasks or work for as long on them as Teacher A did.

Student responses ranged from level 3 to level 5/6 on Watson and Callingham's (2005) Statistical Literacy Construct. For example, Student B_3 in Teacher B's class makes a selective engagement when he noted that the data could be trusted because there was "a fancy name at the bottom" (Figure 19).

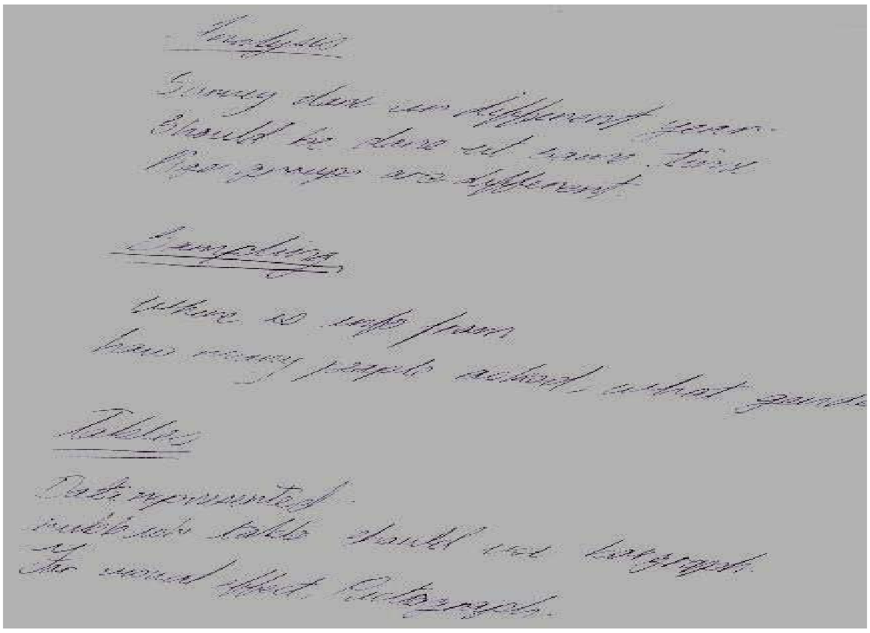
Figure 19 Student B_3



* It has a fancy name at the bottom so its trust worthy
* were the people in the survey working or did they have jobs

In Teacher C's class, Student C_2 makes reference to sampling, analysis and data representation. Student C_2 gives a critique of the table in a survey about the internet use of people by age. The student states that the table given is "rubbish" and a bar graph should be used.

Figure 20 **Student C_2**



Again, sophisticated concepts about sampling are considered. The student also picks up on the fact that the survey is in fact a composite of two surveys completed at "different times" and that the "age groupings are different". Using Watson and Callingham's (2005) Statistical Literacy Construct Student C_2 is starting to question critically with the context and is able to use statistical vocabulary correctly. This would place her at Level 4 or 5 of the hierarchy.

Most students could be supported to move beyond just responding to surface features in data and media reports. Students enjoyed taking the data to bits and trying to highlight flaws in the argument or method. The development of this attitude in students was encouraged by the teachers. However, there were other implications to this approach.

Activities focused on statistical literacy were not limited to newspaper articles. The *Census at Schools* questionnaire was a good example. While visiting Teacher C's classroom I observed an interesting discussion between students about the census. The students were questioning who the data was for and who had organised it. The students voiced concerns about the data such as:

Student Could we be [personally] identified?
Student Who wanted this information and for what [purpose]?
Student Did we have to tell the truth?
Student What kinds of students are taking the survey? Where are they from?
Student What students are not [represented] in the survey?
Student Who made up the questions? Teachers or students?

Teachers also discussed the implications of introducing data and reports into the classroom. With students prepared to critique the data, teachers felt a pressure to understand everything that they used and have knowledge of everything. It was worried that students would make reasonable sounding but incorrect conclusions from the reports that the teacher would not be able to remedy, leaving students to continue without remedy.

4.4.3 Adoption of teaching principles

Adoption of the learning principles from the *Making Language and Learning Work 1: Integrating Language and Learning in Secondary Maths and Science* DVD (Ministry of Education, 2007a) was carried out by all the teachers involved in the action research.

Focussing on both language and statistics was seen as positive. The importance of knowing the language background, and language proficiency of students allowed teachers to provide suitable support for many students. Teachers identified the learning outcomes and the language demands of the teaching and learning. By making the learning outcomes explicit for learners, teachers felt comfortable that all students would be able to participate in lessons. The data card activity and use of real-life data let teachers start with context embedded tasks which make the abstract concrete.

Multiple opportunities were provided for authentic language use throughout the scheme. There was a focus on students moving from using their own terminology to using correct academic and statistical language when solving problems. By using a variety of tasks, including investigation and evaluation tasks, teachers felt they were able to ensure a balance between receptive and productive language. A deeper description of some of the tasks used is included in Section 4.4.4.

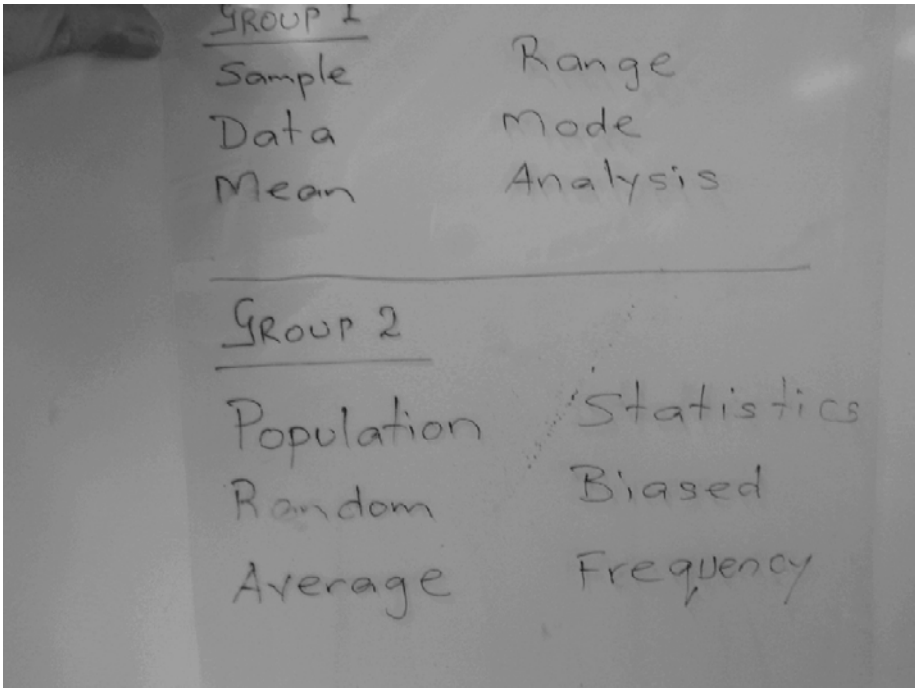
Opportunities for monitoring and self-evaluation were included in the scheme. The focus was on diagnostic and formative assessment. The teachers also felt that there was a need to look at assessment in general in the statistics scheme. It is hoped that assessment will become a focus for further investigation in subsequent cycles of the action research.

A positive aspect of action research carried out with a group of teachers is that the teachers are able to share their experiences. This was a key outcome of the research. The teachers were all at different stages in statistics unit. Therefore teachers were able to visit to other classrooms to observe teaching in progress.

For example, Teacher C observed in a lesson in Teacher A's class that he was being much more explicit about referring to the PPDAC investigation cycle. Teacher A made a point at the start of the lesson to return to the acronym PPDAC. He made the students chant out loud what each letter stood for and wrote them on the board. Teacher C commented after the lesson that she could see the benefit in continually reminding students of the 'big picture' of investigations so students understood that the investigation was the sum of all the parts and could not be divided up and intended to replicate the same in her classroom.

On another occasion, Teacher B observed Teacher A using a vocabulary lesson starter where students matched meanings. In the activity students grouped vocabulary into words they considered to be high frequency words that needed clear definitions and words that the students needed to know but not necessarily would have to use every lesson. A snapshot of the board in Teacher A's classroom is shown in figure 21 below.

Figure 21 Teacher A vocabulary focus.



Teacher B saw the vocabulary activity as a way to incorporate ‘learning to learn’ or meta-cognition strategies into lessons. The strategy was also seen as a good way to get students to take more responsibility for their own learning.

A good humoured professional rivalry developed throughout the action research project. Teachers would often bring student work to show the other teachers what they had achieved in lessons. These informal exemplars often spurred teachers on to get more from their students.

Teacher discussions occurred frequently between lessons. The talks were focused on aspects of the unit of work such as ways to integrate language activities into lessons or things that could be done to improve lessons. These talks would normally occur in the Mathematics Department office. However, they also happened on walks to the staffroom and over lunch.

4.4.4 Language and literacy in the statistics classroom

As stated earlier, language was seen as a key to learning in mathematics by all the teachers in the research. Although the teachers believed that there was an added need in the scheme designed for statistics and statistical literacy to focus on language and language structures the teachers believed that a focus on language was important whether or not the topic was statistics.

All the teachers used the ‘making language features explicit’ principle from The *Making Language and Learning Work 1: Integrating Language and Learning in Secondary Maths and Science* DVD (Ministry of Education, 2007a) a part of their teaching. Initially, I was surprised by this. However, in reflection I believe that there are a number of reasons for the teachers’ actions and attitudes.

Although I did not discuss with the teachers directly, the fact that all the teachers involved in the research had been bilingual learners themselves did come out in observations of lessons. I observed Teacher B say to his class during a vocabulary exercise that learning the vocabulary had been important to him as a student learning mathematics. Both Teacher A and C used anecdotes about students learning in Fiji and Tonga respectively in their lessons.

Secondly, the diverse student population of the school made it very difficult for teachers to ignore the language needs of many of the students. The school was involved in a school wide Pasifika literacy programme to help the high proportion of Pasifika and ESOL students in the school. Other student focused programmes included work done by the specialist classroom teacher [SCT] and the special needs coordinator in the school. Both the student need and the school responses to those needs meant that teachers involved in the research were aware of the language issues and actively engaged in finding solutions.

For example the special needs coordinator had worked with teachers to develop a consistent whiteboard layout in all classrooms across the school. The layout for two days in Teacher A’s class are shown in figures 22 and 23 below. The use of such a layout was to encourage the use of effective teaching practices. In the case of the research it made the adoption of language learning principles such as ‘identifying the learning and language outcomes' and 'making explicit outcomes for students' very easy for teachers to accomplish. The use of the PPDAC acronym can also be seen in Figure 22.

Figure 22 Board layout 21 August

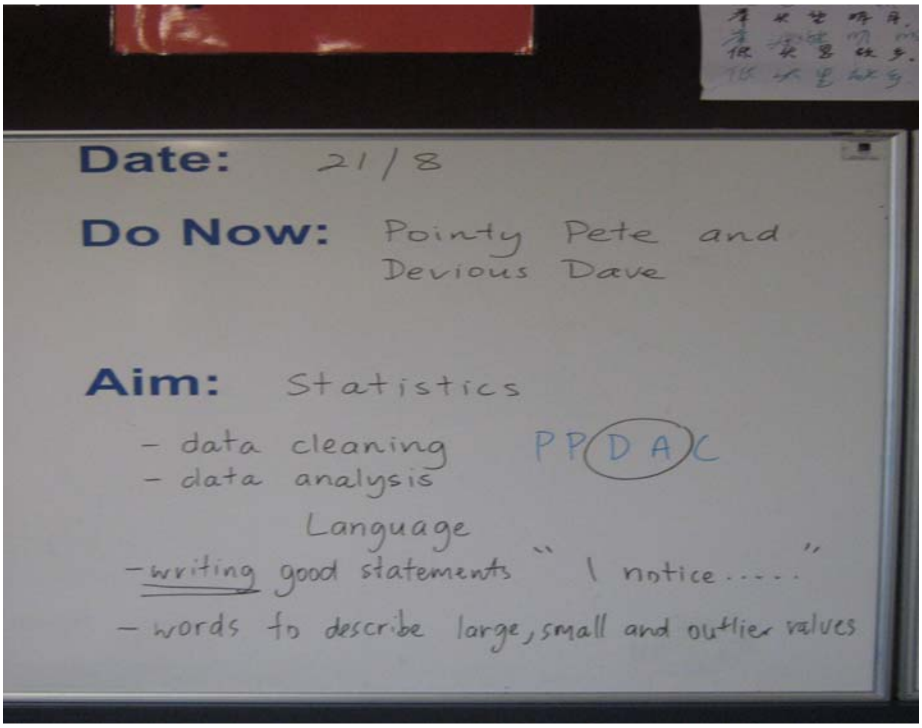
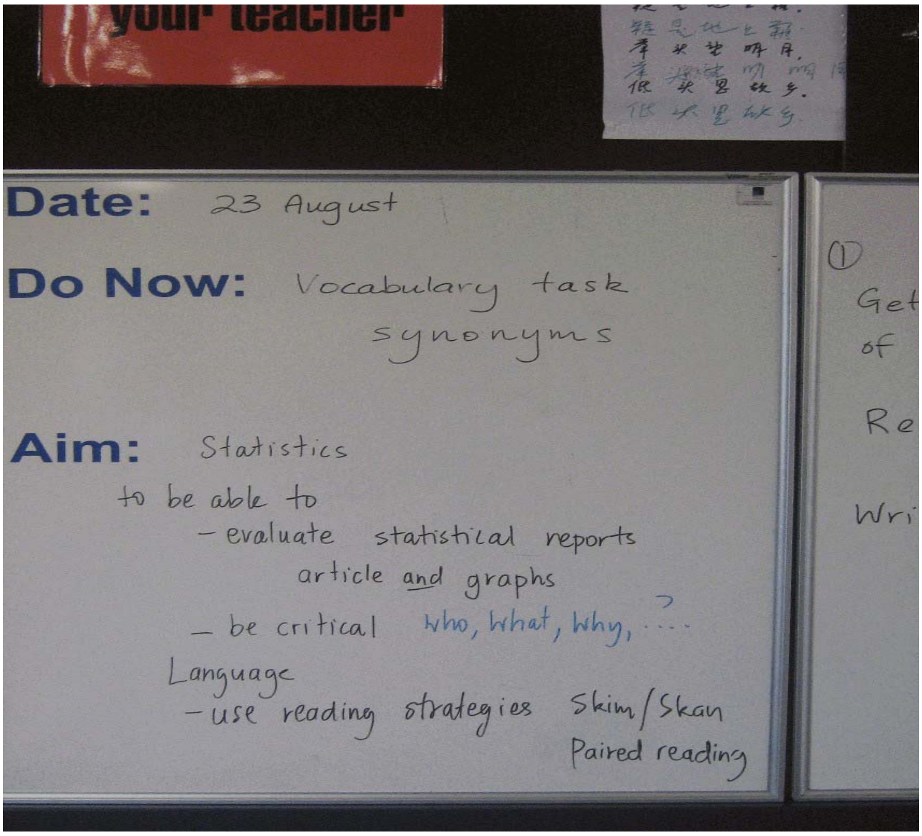


Figure 23 Board Layout 23 August



The Pasifika literacy programme also had an effect on what was going on in the classroom. The school wide Pasifika literacy programme was funded in part by the Ministry of Education and had been led by an external facilitator from the advisory service. Both Teacher A and I had attended the professional development sessions during the previous year. Teacher A had developed a range of skills in using literacy and language learning techniques. He had also feed many of the ideas and materials back to the department in professional development sessions. As a result all teachers focused on vocabulary in the statistics unit of work.

One product from the research was a resource that included all the key vocabulary printed onto magnetic paper. Teachers then used these in lessons. The words were used for a wide number of activities. The words were used as titles, prompts, graphical organisers and for revision. Two arrangements of the words are shown in Figure 24 and Figure 25.

Teacher C's arrangement is shown in Figure 24. Her arrangement was made to show steps and language used in the investigation cycle. Later in the same day Teacher B used the same classroom and rearranged the words to focus on data representation and calculating statistics.

Figure 24 Vocabulary – arrangement 1.

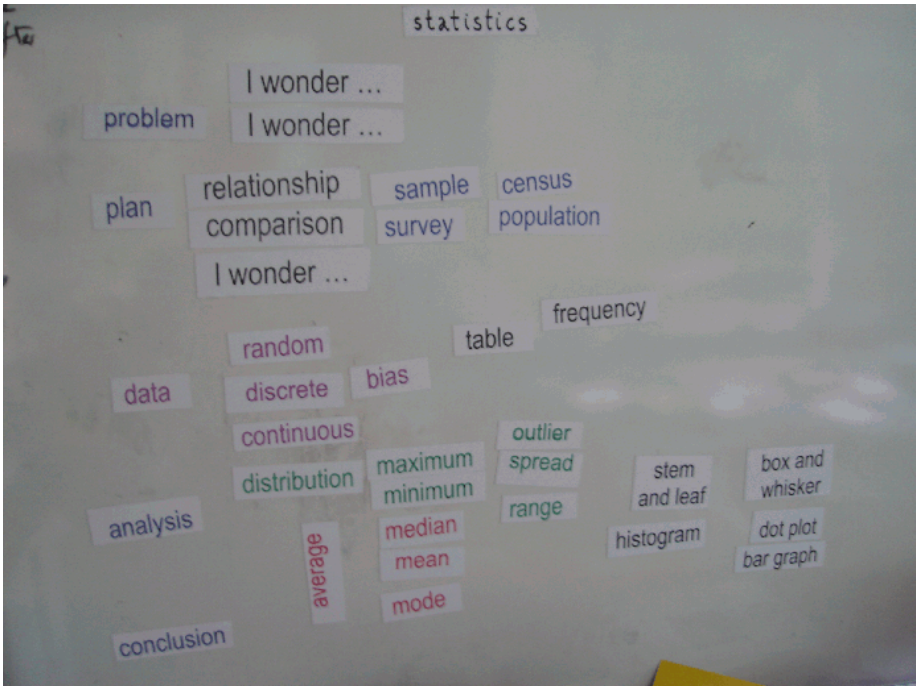
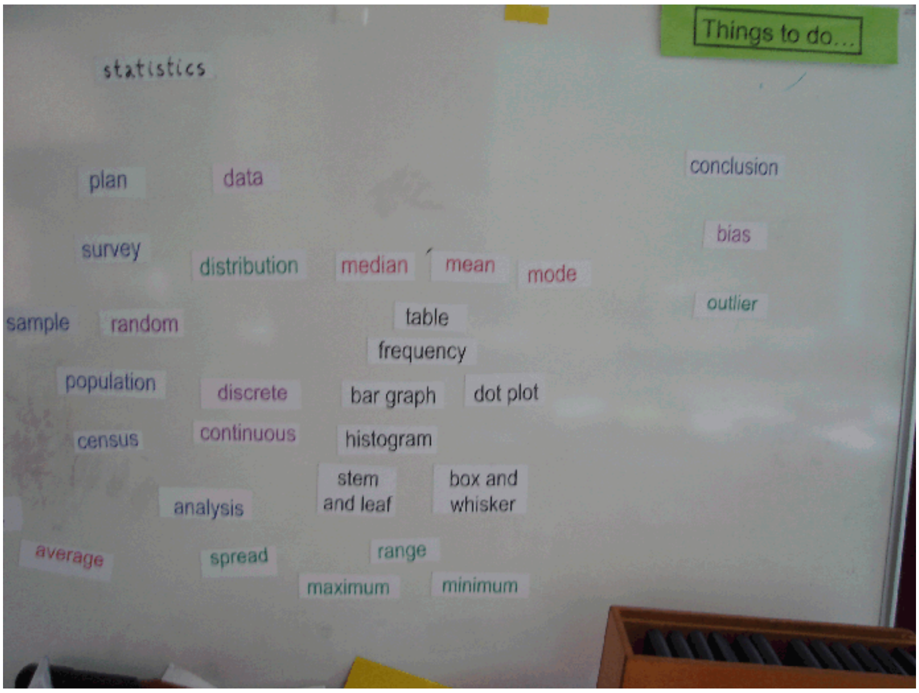


Figure 25 Vocabulary – arrangement 2



All teachers focused on reading skills. Both Teacher A and B used pre-reading, reading and rereading strategies. Teacher C focused on paired reading tasks. The teachers had varying degrees of confidence using the different reading strategies.

Again, a real strength of the intervention was the sharing of strategies between teachers. Teacher A shared reading, re-reading, guided reading strategies from the Pasifika literacy programme. There was a large teacher commitment made in terms of time and time spent talking with each other about strategies and ideas.

Teachers felt that a greater balance between receptive and productive language was achieved. Teachers were very positive about the greater input from students in the statistics unit than what they had seen previously. Teachers were surprised that small changes such as using writing prompts like “I wonder…” and “I notice…” could result in students writing more. After using the writing frame in the third lesson Teacher C commented;

Teacher C Just a small change gets so much more out of them

Modelling and the use exemplars for writing generated a lot of discussion. Teacher A and C both felt that modelling was a challenge as they were often unsure of their own writing.

Teacher C   I would like more exemplars of the writing.

Teacher A also advocated for an extending of the practice into other classes and levels.

Teacher A   Should do this more at NCEA level 1, 2 and 3.

Teachers attempted to share good examples of writing. This did result in more preparation work for teachers. At times there was also a concern that too much was being given to students. After a lesson with Teacher C we discussed how the lesson had gone.

Teacher C   It feels like I am doing all the work and just giving students the answers.

Likewise after a lesson, Teacher A expressed some concern about using exemplars for supporting students writing. After a lesson where Teacher A had modelled the task on the board he commented;

Teacher A   How much is too much?

In lessons Teacher A had made it explicit to students the particular sentence structures that he used. There was extensive use of writing frames and scaffolded writing. However, Teacher A was disappointed that the students then repeated the exact same structure back in their own responses. A goal for future action was to collate good exemplars for teachers to use across classes in the future.

Students in the classes observed did have difficulty with terms used in statistics. However, a clear intention of the scheme was to introduce the statistical language to students as early as possible to help students with their statistical thinking. Techniques teachers used included re-voicing student answers using correct statistical terms and expecting students to use them in their own answers. The teachers reported that this put extra demands on them where there were ESOL students in the class.

4.4.5 Critical literacy in the statistics classroom

The attempt to introduce critical literacy or critical thinking tools into the scheme was the most challenging part of the whole unit of work. Because of the negotiated scheme adopted by the teachers each class attempted slightly different lessons or activities from the scheme to meet the same content and language objectives.

All classes completed the *Being Typical* investigation from *Census at Schools*. The investigation was completed over an average of six lessons. Teacher A class spent the most time on *Numeracy in the News* articles with five lessons. Teacher B spent three lessons on the *Numeracy in the News* and Teacher C spent two lessons. The remainder of the unit of work was spent on other tasks such as skills development using the textbook and other investigations such as the Cookie Investigation from the Lovitt and Lowe's (1993) *Chance and Data Investigations; Volume 1*.

It appeared that the key to the success of the *Numeracy in the News* activities was the use of good reading strategies. Initially, it appeared that Teacher A's class had been the most successful because the students were in a higher ability grouping. However, subsequently it was shown that Teacher A incorporated the greatest amount of reading strategies into his lessons. While Teacher B and C also used some reading strategies \, Teacher A was also the most explicit about the strategies. For example, in a lesson Teacher A prompted students to think about a particular reading strategy when they are reading a piece of text.

Teacher A Remember we used "skim and scan". What was that?

Regardless of the reading support given, all the teachers felt that it was possible for students to become critical with text and data. It was noted that initially students would take data at face value. However, when supported students could operate at Levels 5 and 6 of Watson and Callingham's (2005) Statistical Literacy Construct.

Teachers also felt that it would be useful to develop a poster, like the PPDAC 'data detective' poster used for investigations, that could be used to prompt students to ask questions about the data and data representations given to them. It was thought that ideas like Gal's (2002) 'worry questions' or an expansion on the interrogative cycle of Wild and Pfannkuch (1999).

There was discussion about the suitability of articles used in lessons. Teacher A felt strongly that many of the articles that were used were not that interesting to students. However, the articles selected were articles that had teaching materials and language support already developed and were therefore easy to use. Using writing or data that was more engaging for students was seen as more desirable. However, it was felt that this would make more work and more worry for teachers if they had to find new articles. It was suggested that students should be made responsible for collecting their own writing and data.

Of interest to me were the reasons for introducing materials into the classroom. Teachers referred to students' engagement and motivation as reasons for trying to source materials. However, the reasons for wanting to be critical were not a feature of discussions. The adopting of a critical pedagogy would require students to interpret, evaluate, and critique the statistics placed in their social and political setting. There was still a tendency to see the statistics instruction as removed from the wider world. There was an opportunity to use the statistical literacy skills like Luke and Freebody's (1990) *text analyst*, Kalantzis and Cope's (1999) *transformed practice* or Frankenstein's (1998) *understanding the politics of knowledge*. In this way the learning of statistics could be a way of looking at issues of disparity and inequity in student's lives. Students did offer topics of interest to them during the statistics unit. Statistics used in the media that characterised their own communities (often in a bad light), economic disparities in society as well as differences in educational opportunities all emerged as possible topics in discussions with students. The possibility that these topics could be used to not only teach statistics but provide students opportunities to think about ways they could challenge ideas was intriguing but unfulfilled.

4.5 Student interviews

The three student interviews took place towards the end of the unit of work for each class. Four students were selected from each class with students A_1, A_2, A_3 and A_4 from Teacher A's class, students B_1, B_2, B_3 and B_4 from Teacher B's class and students C_1, C_2, C_3 and C_4 from Teacher C's class. As discussed earlier, the methodology used is an unstructured group interview with questions moving from more the general to more specific. In practice the interviews followed a similar format each time where the interview started with questions about the nature of statistics moving onto questions about what had happened in the statistics unit. The focus points, which can be found in Appendix G, included reflecting on what students enjoyed about the unit of work and what they did not like about the unit. Students were selected because of incidents observed in the classroom both by myself and the participant teachers. This enabled questions to be asked to expand on specific incidents that occurred in the classroom. Some of the questions were about metacognition or about what students thought helped them learn.

The interviews themselves offered another illustration of the teaching principles for language learners that we hoped to adopt in our action research. The intent of the interviews was for them to be a place where students could express their own thinking and explanation of events. However, in the first student interview transcription with Teacher C's class it was noticeable how much I had dominated the discussion and how I had allowed very few periods of silence or thinking. Similarly, I had not made the interview process easy for the ESOL students selected in each group. In subsequent interviews I did attempt to limit my input in discussions and give some written materials to students to try and support the questioning.

There were differences between classes. Teacher A's extension class students were the most comfortable group discussing their work with the other two groups being much more reticent. Putting my abilities as an interviewer aside, it was noticeable that the students for Teacher A's class were much more comfortable discussing their learning. All the students found it challenging to discuss their own learning, teaching styles and aspects of metacognition. This was often disappointing as I felt unable to triangulate student attitudes and opinions with those of their teachers and what I had observed in the classroom. I am unsure if this inability to express some of the ideas was a factor of the students' age, the interview process or the students' lack of exposure to considering metacognition. These factors are not explored any further in this research. However, the teacher participants expressed an interest in student thinking and metacognition could be a feature of future cycles of action research in this department.

4.5.1 Concepts of statistics

The first question asked was about their definition of what statistics at school. Many of the initial comments were about the collecting and displaying of data and the calculating of summary statistics such as the mean median mode. This procedural view of statistics was common to all classes. However, in Teacher C's class the responses given were solely on statistics as a process and Teacher B's class also focused on the collecting and sorting of data.

Student C_1 Statistics is collecting data to investigate a question.

Student C_4 It means collecting numbers and putting them into graphs. I think scientists use it and lots of other people.

Student C_2 There is lots of things that have to do with it. There are pie graphs and plots and box and whiskers and getting the mean and median and range.

Student B_4 Normally in maths you just plus everything. In statistics you are gathering stuff, sorting it out where it is supposed to be.

Student B_1 You have lots of different bits of information.

Student A_1 You just need mean, median, mode and how to do stem and leaf graphs and how to do a box and whisker.

Initially this was distressing as the interviews took place after a series of lessons that hoped to develop statistical literacy. However, further discussion yielded other notions about the nature of statistics. Students talked about statistics as research.

Student A_1 In statistics you need information from other people where in other maths you can do it yourself.

Student A_2 You need to research stuff.

The realness of the data and contextual nature of statistics was seen as important by other students.

Student A_3 It's not like graph line work where you go "x + 3 = whatever". There are a whole bunch of ideas and perspectives in statistics.

Student A_4 We are given everyday stuff to use.

Student A_2 Yeah. Statistics is about real information and like what people do.

Students in Teacher A's class frequently referred to the subjective nature of statistical analysis. The multiplicity of answers and was also a feature of the discussion.

Student A_4 It's more subjective and maths isn't really subjective usually.

Student A_3 In maths it is like this is the answer, the one answer.

Student A_2 Sometimes no wrong answer.

The need for analysis and evaluation in statistics was also a feature of responses. The importance of literacy skills was acknowledged by almost all students interviewed from all the classes.

Student A_4 Statistics is kind of scary because everyone is used to mathematics being black and white and then all of a sudden you have to write conclusions and explain different options.

Student A_3 It's like an English lesson in maths.

Student A_1 I am good at maths – suck at English.

Student A_3 Sometimes I wish I could just solve a quick problem. But it [statistics] is a bit cooler because it helps to link your subjects more.

Different ways of working in statistics were also identified as significant. Group work, discussion and argument were all seen as important features of a successful statistics lesson. In an exchange with students in Teachers A's class the students attempt to explain the differences in working in a statistics lesson.

Student A_1 You need to work together.

Me But I have seen you work together in other topics.

Student A_4 But with measurement you can just take out the ruler and go here is the volume of the room

Student A_2 You need to talk to others

Student A_3 You need to compare information

Student A_4 You don't really need to talk in algebra lessons because you can't argue – only say what is right and wrong – you need to argue in statistics.

Student A_1 Yes you need to talk more in statistics

Student A_2 And write more.

The perception that statistics required different ways of working and thinking was seen as a positive aspect of the topic.

Student A_2 It makes it a <u>bit</u> more fun.

The different classes did give different answers. Ways of thinking were a feature of only one response from Teacher B's class. The importance of language in statistics was recognized. An attempt was also made to distinguish between mathematical and statistical thinking.

Student B_1 Even though there are more words there are less ideas to deal with. You have to explain more. But you do less with numbers.

However, students in this class again highlighted language as an important distinction between statistics and other mathematics.

Student B_2 There are more words in statistics

Student B_3 You do more writing when you do statistics.

Student B_3, an ESOL student, also focused on the language demands of statistics.

Student B_3 New words. A lot of new words we didn't use at intermediate like frequency

Similarly, only one student from Teacher C's class offered a different way of thinking about statistics.

Student C_3 It is all about looking at things, [pause] data, and trying to work out what they mean.

All three groups of students talked about statistics in terms of an investigative cycle where you collect and analyse data. Eight of the twelve students mentioned the PPDAC cycle in a response. This was regardless of year level, class or ability grouping. Two of the three groups also mentioned language as an important concept when defining statistics. Both the high ability students from Teacher A's class and low ability students from Teacher B's class cited language as important. Only the high ability class mentioned ways of working as a difference in statistics.

4.5.2 Concepts of statistical literacy

Statistical literacy was seen as knowing what graph to use and what statistic was the most appropriate. This appeared to match the position taken by the teacher participants of statistical literacy as a competency rather than a way of thinking about data or text.

The questions asked during the interviews of students were heavily influenced by my own investigation into possible definitions of statistical literacy. However, many of the ideas were outside the experience of students. In hindsight I needed to frame questions in a way that allowed students to discuss their ideas rather than forcing them to try and decipher my conceptualisations of statistical literacy.

4.5.3 Adoption of teaching principles

Student recognition of the use of teaching principles used by their teachers in lessons was minor. Even when students were prompted about individual lessons or incidents they found it hard to give examples of strategies used.

Teacher A's class did comment in general about teaching styles.

Student A_3	What makes it easy is having something explained to you first and then going outwards.
Student A_4	It's easy because [Teacher A] is not talking the whole lesson. He's not up the front going "this, this, this"
Student A_2	Most teachers just keep talking and you can't learn.

Student A_4 You feel that you have to do it their way and you can't work it out your own. But here you have options and choices.

Very little other comment was forthcoming from students. This was disappointing for the teachers involved. However, the students' lack of comment may be due to other factors.

4.5.4 Language and literacy in the statistics classroom

While almost all the students talked about the importance of language in statistics, few of the students interviewed saw a need for any literacy skills in mathematics. However, a number of students were aware that they would need to improve their literacy skills for success in external examinations in the years to come. Again, this was surprising as we had been so explicit about language

It may be because students were unaccustomed to focusing on how they learn and how they approach texts. This was not generally part of their mathematics lessons and was not something that the students had done before. My questions were also very teacher orientated and may not have meant much to Year 9 and 10 students. Therefore it may be more about my inability to draw out responses and the students' inability to articulate attitudes about language in the mathematics or statistics classroom rather than the students' lack of understanding about language.

Students from all the classes did mention that the statistics unit did talk about the increased use of language in the statistics unit. For example;

Student A_4 He gives a lot of stuff to read and we have to like figure out where the statistics are.

Student C_2 Reading gives me a headache!

Some students did pick up that there was more to the reading in statistics than what was expected in normal mathematics lessons. Students understood the need to read to find key information in mathematical problems. However, with statistics tasks the need to look further into text, and sometimes beyond the text, was seen as another distinguishing feature of statistics.

Student A_3 You can use a newspaper article in normal maths but in statistics you learn to look into it more.

Writing as well as reading was seen as an important feature of statistics by students. The following exchange between Student A_1 and the 'devils advocate' Student A_2 illustrates the significance students put on writing in the scheme.

Student A_1 You grow up thinking maths is one thing. If you know the rules and you can do the calculations right than you can do it (mathematics). Then with statistics there is all this lingo and jargon…all this language used.

Student A_2 There is heaps of jargon in maths too!

Student A_1 Yeah but you need to write…you have to explain everything and justify it and there's heaps of writing.

Student A_2 You have to justify in normal maths too!

Student A_3 I hate all the writing

Student A_1 Yeah but the explanation is the answer in statistics. It shows you understand. You need to look at it from different perspectives.

4.5.5 Critical literacy in the statistics classroom

There was evidence that students believed that they needed different skills than normal mathematics to gain success in statistics. Students acknowledged that reading was difficult and that more effort in terms of 'thinking' was required. Students also talked about the need for background information to assist their reading and sense making. Students commented that the readings in the statistics lessons had been about a lot of different things.

Students had become more aware of the statistics found in articles and advertisements. When asked, students commented on how they had learnt: to ask questions about the things they read; to be aware of how graphs and text can mislead; about questioning about sampling and variation.

Being critical in the critical literacy sense was a difficulty. There was a perception that data was sacred and that if it was used in the classroom it must be truth. Students appeared unwilling or unprepared to question text or data. Student B_3 commented that;

Student B_3 Why do we read these things (media reports) if they are all lies. We should just read the correct stuff in.

4.6 Teachers interview

The interview with the teacher participants occurred in the last week of term. Teacher A and B had finished teaching the statistics unit with their classes. Teacher C had approximately a week to go.

The interview was a semi-structured discussion. The focus points can be found in Appendix G. The importance of the teacher interview was its function as the reflection and evaluation phase of the action research. The interview was also an attempt to involve the other participants in the research process by sharing tentative themes and ideas at final teacher interview

4.6.1 Concepts of statistics

The interview started with what the teachers saw as the key features of the Year 9 and 10 statistics programme. All three participant teachers believed that statistics was different from mathematics. The differences were seen in terms of the importance of the investigation cycle,

Teacher A Statistics is about collecting and analysing the data.

Teacher B That is what I think statistics is. Gathering information and collecting and explore the information and then we use something like the PPDAC method and then we classify problems and then solve them and come up with graphs and different ways of showing what the data means.

and the centrality of language in statistics,

Teacher A It is a different part of maths, looking at a different aspect of maths. There is a lot more words and interpretation.

Me. But before you said 'too many words'. What did you mean by that?

Teacher A There are a lot of words that you don't use in the rest of maths. It is more of a literacy thingee.

Statistics was seen as a more holistic topic than other topics in the mathematics curriculum. Teacher B described

Teacher B We need a clear picture of what statistics is. A major point is that we are looking at for kids to understand the big picture, the overall picture of what statistics is. Statistics is not just calculating the mean or drawing a graph.

There was a consensus that it was important for the statistics unit to illustrate to students that statistics was more than calculations or graphing data. The importance of 'doing statistics' was still emphasized.

Teacher B Statistics is a really good chance for not giving them the answer but giving them work to do.

Teacher A Do you mean investigations?

Teacher B Yes, investigation. Rather than giving them as exercise and saying right do this exercise? What is the mean? What is the mode? Which is the traditional way? The way I did. Where we just went: Find the median! Find the mean! It doesn't make sense to the students. But by completing their own investigations they got to see why they were doing things.

The investigative process was seen as a good way of introducing students to statistical thinking. Teacher B commented on the strength of the PPDAC cycle being that it took students through the complete process of a statistical investigation.

Me The PPDAC cycle is quite a long process

Teacher B Yes, a long process. At this age the students want to work on a one to one basis. They want to answer the questions and then move on. They go from step one to step two and then will stop and will not stop to look at the overall thing [makes big circle in air with arm]. Whereas the PPDAC encourages them to look at the whole process

There was a shift in teachers' perceptions of statistics from the start of the action research to the end. No teacher made a comment about constructing graphs or calculating statistics when defining or discussing statistics.

4.6.2 Concepts of statistical literacy

Even after the unit of work, the 'doing of statistics' was seen as more important than the 'responding to statistics' by the teachers. However, the statistical literacy aims were adopted by the group to get students to spend more time on evaluation and interpretation of results. The evaluating statistical reports or statistical literacy component of the scheme was hoped to be covered when students discussed their own and peers work as well as when students completing separate statistical literacy tasks.

However, at the end of the unit of work the evaluation and interpretation components of the statistics topic were still considered to be too difficult for many students to do.

Teacher A It's [evaluating statistical reports] like the excellence part of level 1 [NCEA]. The evaluation is normally what the better kids do at the end.

Teacher B Yes, it is hard for many students to do.

Teacher C You have to give a lot more prompting with the class to get them to question the information. They do not see it as the first thing to do. They would rather spend time answering the questions.

The evaluation of the activities used in the statistics scheme was clear. The teachers believed that the materials used were superior to those used in previous years or classes.

Teacher B The activities were much more useful than what I may have used in the past.

Teacher C Yes, better than I thought.

Teacher A Better than the textbook.

Teacher C I felt they understood more.

Teacher A With the activities I felt that you could do more, get more done, in the time frame. If we went through the textbook I think it would take longer and not be as enjoyable.

Teacher B It is also my evaluation that the class has done heaps of things, more than if I had done my traditional way of teaching statistics.

Teacher C Yes. I think the activities show the students the practical work of actually doing statistics. I mean by the end they have done pretty much everything.

A limitation of the resources and reservation for the scheme was that too much of the data was provided. An essential step was being left out where students would see the need for data. Students seeing the need for data was seen as another way to start get students to be critical learners. Teacher B commented;

Teacher B The census at school activity was provided by us - All the data was provided for them – It would be a good idea in the future to get students to collect more of their own data

4.6.3 Adoption of teaching principles

The adoption of the teaching principles from the *Making Language and Learning Work 1: Integrating Language and Learning in Secondary Maths and Science* (Ministry of Education, 2007a) DVD was seen as successful. Being explicit about language and content objectives was seen as particularly powerful.

Teacher C The students could see what was expected from them.

Teacher A Students can check that they have understood what is needed. There are no hidden things so they can't say 'you didn't teach us that!'

Other principles were also mentioned as being successful, such as starting where students were at.

Teacher C When they discuss I notice that students are coming up with very good words on their own.

Teacher B A lot of them don't need to be taught the same stuff that they got last year. You can move faster.

Integrating the teaching principles into the scheme meant that we would need to continue to enhance the new scheme of work [Appendix H]. The teachers typically started a lesson with an activity focused around a graph, chart, or short reading which required the teaching of a particular statistics skill or piece of content knowledge. Teachers said that moving to an investigation focused scheme the lesson could run until the students ran into a question about a statistics skill. The teachers could then stop and teach that skill. This non-linear way of teaching and learning was seen as very rewarding. However, a scheme plan that still focused on narrow skills and techniques would not be acceptable.

4.6.4 Language and literacy in the statistics classroom

When asked what was particularly helpful or useful from a language learning standpoint teachers talked about a variety of activities and strategies used.

Teacher C The writing prompts were very good. They didn't realise that they could write a whole lot of things about one question. Like, if the question was about heights, instead of answering 'Who is the tallest?' they could describe the data much more.

Giving students multiple opportunities to write was seen as beneficial, such as the "I notice …" and "I wonder" [Figure 13] worksheets.

Teacher C The students would ask 'Do you have to write only one thing here or do you have to fill all the gaps and they could write lots of things.

Modelling tasks and using exemplars was seen as good tools to use by all the teachers.

Teacher C I would point out the statistics words and sentences and then they could start writing things down…which was very good.

Teachers were also asked what was not useful or unsuccessful about the scheme. The literacy demands of the topic and the need to use literacy strategies that the teachers felt they were not expert in using continued to be the most challenging aspect of the research.

Me What didn't work?

Teacher A For me it was the article lessons [Numeracy in the News] because it wasn't working. When I asked the students about the literacy…the literacy strategies…they couldn't see how they were useful. The couldn't link the strategies that they had used say in English class with what we were doing and bring it to a maths class or a stats class. There was no linkage. According to the English department they were using the reading strategies, they are doing the literacy programme but the students wouldn't bring it to the maths class.

Me That surprised me as well. You wrote the strategies on the board. You modelled the exercise with them. You explained to them that it was the same strategy and they still didn't get it.

The planning demands were also highlighted as an obstacle to teachers changing practice.

Me If we were to continue this way of teaching the statistics unit next year what will we need to do and what support would be needed.

Teacher B I think we should continue to teach it this way. What we need to do is keep developing new activities, similar to what we have done. I think we should keep making and sharing resources because I think more needs to be based on hands on things for the students.

4.6.5 Critical literacy in the statistics classroom

The challenges of getting students to be critical about the data were acknowledged. The teachers saw the different thinking skills that students needed for analysis and critique. However, getting students to change was seen as a difficult task.

Teacher B It is difficult to get students to think about the data or writing.

Teacher A Especially to think deeply about what they are reading.

Teachers were particularly aware of a need for further support and professional development with using materials such as the *Numeracy in the News* articles. The teachers understood the direction and intent of lessons but at times felt hesitant about how to achieve their objectives.

Teacher C I know what I want to do but I am unsure how to do it with the class

Adopting a critical stance was still seen as difficult for teachers in the classroom. Teachers continued to be worried about how to manage giving more control to the students over what is studied in the classroom. While teachers were interested in looking at issues of interest to the students they worried about 'getting out of the depth' and having to discuss or research issues that they knew little about.

Students' lack of general knowledge and lack of experience asking critical questions was also seen as a problem. Teacher A described the range of student responses after an activity where students had to question the claims in a statistical report. He saw that their response really was dependent on what they already knew rather than them being able to question the data.

Teacher A For me the strategies were really important. But how the students answered the questions was quite different. It really varies from person to person. I think that their background knowledge causes that.

While the students may have the statistical knowledge and the literacy skills the teachers felt that they lacked knowledge of context and hence were unable too engage in critical questioning.

The teachers were unsure if why the students found the critiquing of data difficult. Age was seen as a possible factor;

Teacher B These guys are only Year 9 so they don't really question it.

Other teachers felt that the students were not asked to question information as they had been asked to in their mathematics class and that it was a skill that needed to be practiced. The process of change was seen as long term goal that would not necessarily be achievable in a few lessons.

Teacher B Some students got it at the end. However, some students found it very difficult to look beyond the data, to evaluate it, to look for bias. We need to spend time on that

Chapter 5: Discussion

5.1 Introduction

Important and recurring themes that surfaced in the teaching and learning of statistics and statistical literacy during the action research project are discussed in this chapter. Section 5.2 explores definitions of statistics seen in the research. Section 5.3 looks at notions of statistical literacy. Section 5.4 evaluates the success of teaching principles including the use of the language learning principles. Sections 5.5 examine the language demands further while Section 5.6 explores the results of trying to be critical with data and text. As well as themes that emerged from the data there is also an examination of the research process itself. Section 5.7 looks at the implications and conclusions from the action research methodology.

5.2 Concepts of statistics

There were a range of positions taken by teachers and students on the nature of statistics evident in this research. The approaches taken by the teachers appear to have had some effect on the attitudes of students and what occurred in the classroom.

5.2.1 Statistics as skills

Teachers attempted to adopt an approach of teaching statistics that was more than passing on a set of skills or algorithms to students. While teachers in the research admitted that this had been a feature of statistics teaching in previous years, there was considerable evidence in the comments made and observations during lessons that teachers were actively trying to develop their teaching beyond a skills based programme. There did continue to be some lessons based on the teaching of skills and the practising of procedures. However, these generally occurred in response to lessons more focused on investigation or interpreting reports.
Despite the teachers' stance, a group of students still held views that statistics was a set of skills to be learnt. Both observations and follow-up

interviews showed that at least some students still wanted single or short answers to questions posed or tasks provided.

What is not clear from the research is whether the beliefs held by students in this group were due to the message not being clear from teachers or whether it was due to other factors. Wider issues about the nature of mathematics and statistics or the nature of learning may be more important. Graham (2006) states that teaching statistics as a set of mathematical skills impacts on the attitudes and beliefs of students. If students are ever to see statistics as investigating data or critiquing statistical reports then teachers will have to model that in their teaching programmes.

5.2.2 Statistics as process

All of the teachers in the research embraced the notion of statistics as an investigation process. The adoption of the PPDAC statistical investigation cycle from Wild and Pfannkuch (1999) was seen as a real success. The importance of PPDAC cycle and statistical investigations was central to the teachers' definition or redefining of the nature of statistics.

Similarly, the majority of students incorporated the PPDAC cycle into their definitions of statistics. The 'data detective' poster and the use of the PPDAC acronym were frequently mentioned.

The definition of statistics as the investigation process was the dominant definition adopted by teachers and students in this research. This was in conflict with my own definition of statistics which was heavily influenced by my research in the literature review and previous work with literacy and language. For example, Wild and Pfannkuch's (1999) model for statistical thinking encompasses four dimensions that include the investigation cycle, interrogative cycle, ways of thinking and dispositions. The other three dimensions are not generally expressed by teachers and students. Similarly, Gal (2002) and Watson (2006) both describe a wider definition of statistical enquiry that includes dispositions, 'worry questions' and being critical with data as well as investigating data.

Teachers initially voiced some misgivings about the amount of data that students would be able to deal with when undertaking an investigation. However, over the period of the statistics unit teachers became more comfortable with larger data sets. The scheme focussed predominately on teaching with data provided. There were some activities where the data was generated by the students. However, as time progressed teachers expressed a greater desire to use data collected by the students themselves.

5.2.3 Statistics as context

Both teachers and students saw the importance of context in the study of statistics. The move away from textbook activities towards the use of real data in the statistics unit was noticeable. This was consistent with what Best (2004) characterises as the 'social construction' of statistics. Best (2004) states that statistics do not exist independent of people and that an understanding of who collects what data and why is important.

5.2.4 Statistics as statistical literacy

Students were much more comfortable than teachers with concepts of statistical literacy. Including real data and media reports in the classroom was motivating for some students.

All students were able to attempt open-ended, unfamiliar and challenging tasks with support. However, students in Teacher A's extension class appeared more comfortable attempting tasks that involved analysing and evaluating than students in Teacher B's support or Teacher C's mainstream classes. Both Anthony and Walshaw (2007) and Alton-Lee (2003) cite research that illustrates similar situations where top stream classes are more inclined to tackle tasks requiring a higher level of literacy because students would have the prerequisite skills to analyse the tasks already. The research goes further to state that lower ability students often do not get to attempt cognitively challenging tasks because teachers believe students will have too many difficulties completing tasks. Unless an attempt is made to change the teaching and learning of statistics this inequity between students will be made worse. Zevenbergen (2005) echoes this sentiment claiming that many current practices in mathematics teaching are far from empowering for learners and instead encourage disengagement with the subject.

The provision of good tasks should be seen as related to teacher knowledge and pedagogy and not perceptions of student ability. Alton-Lee (2003) states "the teacher's ability to scaffold learning and to create a learning environment that scaffolds a student's understandings is crucial to teaching effectiveness" (Alton-Lee, 2003, p. 75).

5.3 Concepts of statistical literacy

The reason for the scheme focusing on statistical literacy was that statistical literacy is for data consumers; statistical competence is for data producers. It was accepted by the teachers that students would spend more time as consumers of data and statistical analysis than produces of statistics. However, teachers' felt that this view moved the teaching of statistics further away from mathematics towards more of a social science activity. There was obvious disquiet amongst the group about teaching around issues. There was concern that they did not possess the appropriate skills to teach this way. A definition of statistical literacy was negotiated by teachers. This definition entailed teachers providing more opportunities for analysing and evaluating data. There was evidence of teachers providing these opportunities throughout the unit of work.

Activities that focused solely on statistical literacy, such as the *Numeracy in the News* activities were the least enjoyed by teachers of any of the activities. However, teachers noted that more time was spent on such activities than had been previously. The research states that using media reports is an important tool for developing the statistical abilities of students. Siegel and Borasi (1992) state that teachers introducing statistics through students reviewing newspapers and magazines for everyday uses of statistics can then help students form the basis for a discussion on how statistics is interpreted in everyday usage.

Students appeared more interested in exploring media reports and the statistical investigations of others. Some students expressed an understanding of the subjective nature of statistics. Students enjoyed opportunities to argue and discuss. This is consistent with Gee (1996) who states that statistics is not neutral and therefore teachers can not develop statistical literacy by giving students a set of skills or techniques.

Assessment issues arose during the research. The use of Watson and Callingham's (2005) Statistical Literacy Construct was useful for diagnosing where students were at. However, in future cycles of action research it will be interesting to see how we can match those levels with the summative assessment levels assigned students for reporting and tracking. Student achievement must also be part of assessing the effectiveness of teaching methods. Different ways of assessing students also need to be explored so that it can be determined whether or not students' statistical literacy is improving. This may entail some other measurement instruments, apart from assessment-similar tasks being developed.

By the end of the first cycle of this research, statistical literacy was seen as important by all teachers involved. However, statistical literacy not seen as important by all the students involved. Only one teacher was able to complete more than a weeks worth of lessons focussing on statistical literacy while the other teachers completed only parts. By not valuing it I believe that the teachers were sending messages to their students about the nature of statistics. More time was still spent in the scheme with students being producers of statistics rather than consumers of statistics.

Teachers felt that being statistically literate with students would be easier if appropriate materials could be found that would engage the students. Weinberg and Abramowitz (2000, Section 1, ¶ 4) describe the challenge as the need "to find ways of presenting information to our students so that it is accessible, relevant, applicable, and even vital to their own areas of interest". However, using materials that might challenge students in more social or political ways was rejected by the teachers. The need for a resource like the PPDAC 'data detective' poster was evident. In the next cycle of research it will be interesting to see if the teachers can develop a poster that highlights the worry questions or dispositions of someone who is statistically literate.

5.4 Adoption of teaching principles

The adoption of the principles outlined in the DVD *Making Language and Learning Work 1: Integrating Language and Learning in Secondary Maths and Science* (Ministry of Education, 2007a) changed the way the statistics unit was taught. There was much more of what Frankenstein (1998) calls ‘nonlinear teaching’. Teaching was often responding to student need rather than teacher need to complete the syllabus.

There may be other pedagogical approaches that may be suitable for teachers to use in teaching statistics and statistical literacy. However, the language learning principles are particularly good as the focus is on language. In another setting where the students do not exhibit such a wide range in language skills or where there are less ESOL students other approaches may be successful. However, in the particular setting of this research the adoption of language learning principles into mainstream lessons was successful.

The sharing of resources between teachers did raise some issues for me as principal researcher or documenter of the action. Firstly, the power of these immediate exchanges over transcribed video was obvious. The goal of the research had been to improve the teaching of statistics and to introduce a notion of statistical literacy. By sharing strategies and observing other teachers, the participants were able to quickly modify practice in their own classrooms in response and so change took place.

All teachers created language resources independently. The resources created often catered for particular needs of particular students. The resources also depended on the teacher’s view of language and the view of positive interactions in the classroom. However, there is a need for leadership from teachers who have literacy skills to share them with their colleagues just as it is important for students to share with their peers.

Teacher A was a good example of this. A critical mass of knowledge is needed for change.

Those teachers who were able to more fully integrate language and learning had a greater knowledge of language learning and literacy pedagogical principles. At times teachers struggled to identify the literacy demands of lessons. When teachers did identify literacy challenges, some teachers felt ill prepared and unable to address them. This highlights the importance of identifying teacher prior knowledge and professional development needs.

A need to find a balance in the approaches was also evident. For example, the importance of the direct teaching of metalanguage, questioning and careful text selection for guided reading came into conflict with the principle of being explicit with language and wanting to use materials that would be of interest to students.

5.5 Language and literacy in the statistics classroom

What was remarkable to me was that all teachers had collected and developed their own resources independently because they saw the importance of language in student learning. There was a lot of discussion about the materials during the unit of work between teachers in the department office. It also appeared that by adding language objectives to the scheme alongside the statistics achievement objectives we had provided a forum where it was possible to discuss best practice around language. In previous years, when the scheme was planned without a focus on language, the conversation between teachers around language and literacy did not occur despite all the teachers adopting some strategies in their own teaching practice.

Both Anthony & Walshaw (2007) and Alton-Lee (2003) state that students need to tackle challenging and demanding tasks. This is seen as just as important for students who may be perceived as low ability or for students in multi-lingual classrooms and that all students must be given opportunities to use language to explain and to justify concepts like expert mathematicians.

Language is seen as critical to success for students. However, Anthony and Walshaw (2007) asserts that language in the mathematics classroom is much more than just vocabulary and technical usage and that a focus on the syntax and way of communicating in mathematics are just as important. Alton-Lee (2003) highlights research that describes scaffolding of tasks that can be used to assist students to achieve. Many of the scaffolding techniques can be seen in the principles described in the *Making Language and Learning Work 1: Integrating Language and Learning in Secondary Maths and Science* DVD (Ministry of Education, 2007a).

There is a tension between scaffolding and supporting students on the one hand and the "path smoothing" of Watson (2002, p. 462) where tasks are over-simplified and students just spend time filling the gaps rather than thinking or reasoning. This is exacerbated in classrooms with low literacy levels etc because as Anthony and Walshaw (2007) describe tasks that are to be used for instruction that put more demands on the teacher in terms of organisation were less likely to be used.

Meaney and Flett (2006) state reading in the mathematics classroom must be an active part of the learning process. They maintain teachers must support students in their reading by the use of reading strategies.
Teacher implementation of new approaches was supported by observations and feedback from other teachers. In each instance, the teachers involved spoke about the importance of the opportunity for time to reflect on their own and on their colleagues' teaching as an aid to understanding more about literacy and as a means to think about the implications of their learning to their own practice.

Once the unit of work was finished it was important that the action research was geared to making sure that the teaching and learning approaches adopted were trialled again and that ways to promote them so they could become part of wider school practice. Teachers wanted to reinforce the ideas learnt by reviewing the scheme regularly and address professional development needs from it.

The need for the use of reading strategies was highlighted. Siegel and Borasi (1992) state that reading strategies promote social interaction between students which supports their efforts to work out a meaning for the text. It also encourages them to take ownership for their reading/learning experiences and promotes an inquiry orientation to learning. Moreover, Siegel and Borasi (1992) state that such a format works well for ESOL students who may have difficulty reading textual materials on their own. By working with a partner, they are given extra support for developing both reading skills and their knowledge base on statistics.

It is interesting to question whether teachers in other schools and situations would take language as a focus. The particular context of the school may make it easier to adopt language learning principles.

Teachers did not resolve the conflict between providing support for students and providing too much support for students. They were aware of the difficulty of producing resources (vocabulary lists of keywords and phrases, reading guides etc...) that support student learning rather than substituting for student learning where the teacher does all the work.

5.6 Adopting a critical statistical literacy

A tension existed throughout the research between my goals of critical literacy compared to the functional literacy of other teachers. I feel some ambiguity existed because we chose to use language learning principles in the teaching of statistical literacy. This made it difficult for the teachers to move from focusing on English literacy skills to focusing on a critical literacy stance in statistical literacy. Part of the problem was also my lack of ability to describe a useful definition of critical literacy for the teachers involved or describe the implications of adopting a critical literacy stance.

However, critical literacy has been described by others. For example, Sandretto et al.'s (2006) research describes a study undertaken in primary classrooms where the students often "don't know what they don't know" (p.26). In the research this did not stop the researchers/teachers from continuing and they continued to make students aware of possible multiple readings of the text. Critical literacy is a critical thinking tool that “encourages readers to question the construction and production of texts” (p.23). Compare this with mathematics and statistics education researchers like Schield (2005b) and Watson (2006) who assert that statistical literacy is critical thinking.

Understandings of critical literacy are emerging in the group of teachers involved in the research. Brown and England (2004) state that the shifts depicted in an action research project “are not so much in moving towards the perceived solution, but rather in successively reframing the parameters in which the research situation is being understood” (Brown & England, 2004, p. 77). Therefore, it can be accepted that no final solution has been reached but rather the beginnings of a different and much deeper understanding of the situation has began.

These small steps of reframing the situation and trialling approaches are a process that I, the other participants and we as a group of teachers are going through. The differences in the way that I see the situation and the other participants see conceptions of statistical literacy or critical literacy help with both our own understandings and may help us keep the conversation going beyond the first cycle of action.

The research participants were able to see statistical literacy as more than just literacy skills. Skovsmose’s (2005, p. 186) call for a “…broadening of the notion of literacy to include a competence of critical citizenship” that describes a more radical view of mathematics and mathematics teaching which should foster critical mathematics literacy and empower students to become critical citizens in modern society was not adopted by the teachers involved in the research.

Researchers in both the literacy and statistical arena maintain that texts are socially constructed and that text is not neutral (Best, 2004; Sandretto et al., 2006). Sandretto et al. claims that the authors, of say media reports used in

the classroom, draw on particular ways of viewing and talking about the world and that these are often the majority discourses. The assumption is made that the student will be able to draw on them as well. Teachers in the research believed that students in our context are not necessarily able to do this for both social and linguistic reasons.
Therefore an important goal was attempting to make these ways of looking at situations obvious and explicit for students so students could see that ‘texts have consequences’ (Sandretto et al., 2006, p.24).

How this could be achieved in the classroom is emerging. Teachers saw their responsibilities in the classroom as creating the environment where they modelled a questioning stance by giving students multiple understandings of text or data. This enable teachers to help students “develop a metalanguage of critical literacy, or a language to talk about critical literacy” (Sandretto et al., 2006, p.24).

Another consequence of attempting to adopt a critical stance were changes to the pedagogical practices of teachers.

In lessons where teachers started the short activities before moving to deeper investigations and analysis the learning was changed. Teachers felt more able to respond to students’ misunderstandings and questions. Skills were also addressed as teachers could stop and teach that skill when the need arose.

As stated previously, these ideas are developing and emerging. As Skovsmose (2005, p.44) states “critical mathematics education is not to be understood as a special branch of mathematics education. It cannot be identified with a certain classroom methodology. It cannot be constituted by a specific curriculum”. Similarly, Lankshear (1994, p.4) states “ideas of critical literacy are at best provisional”. The action research that we undertook may move us to a greater understanding of critical literacy in statistics. However, we are not there yet.

5.7 The research process

The success of this research can be measured by how the teacher participants looked at practice and changed. The teachers involved in this project have a story to share. Action research that allowed for reflection and opportunities for collaboration was all important for us as teachers. As stated by Jaworski and Watson (1994), this way of learning but also reflecting on how we learn was seen as what we as teachers want from our students as well.

Reflection meant that teachers noticed significant events, shared them with the other teachers. The critical analysis and subsequent action were all features of how we acted as a group. I believe that this was a successful first action research cycle and we are well placed for further improvements in the future.

Using an action research methodology compared favourably with what we were asking students to do like becoming critical. The act of attempting research, especially non-scientific or non-mathematical research, also helped teachers understand what students might possibly have to go through to become critically statistically literate.

The participant teachers were able to critically reflect on their teaching with the researcher. What other processes are needed to allow opportunities for all teachers to critically reflect?

Some questions arise out of the action research. It is stated that this is a collaborative curriculum development. However, it is arguable that the teachers were not involved in the full and final analysis of the data used in this thesis. How could an even more collaborative partnership be developed amongst the participants?

The statistical literacy framework and the language learning principles are referred to as the foundation for the curriculum development. Was this imposed by me as the principal researcher and how is the framework amendable to adaptation and change?

There was a tension throughout the research between my own beliefs and attitudes and those of us as a group of teachers. I did not see myself as an expert but I did have a view that I wanted to share. How much of the research is due to the focus and biases of me as the principal researcher?

As principal researcher I also selected the methods of data collection and data analysis. Were the methods and analysis tools used the most effective in generating data? Does the research show the importance of impromptu meetings and discussions and that much is done on the fly? Does the research describe the cycles within cycles of action research?

My place as principal researcher or documenter was a challenge to grounded theory approach adopted in the action research. Participants definitely noticed things tried actions and then looked at outcomes. Questions and themes emerged from the data. However, actions were influenced by theories such as the language learning principles and statistical literacy. Literature and theory was a feature of research. However, I believe that data did dictate the selection of an action research methodology.

In this action research I wanted to show what was happening to teachers and students in the classroom and describe the reflexive action. However, the research was conducted in actual classrooms there were constraints on its implementation such as the relatively small of teaching time and availability of resources. The actions implemented suggested were for actual change in the classroom. Change was often immediate. However, sometimes I felt that it in writing for this thesis I was removing the reflection from the classroom. Was the situation looked at for long enough? Were the right questions asked and were they asked for the right reasons?

In the end the teacher commitment in terms of time and talking with each other, the class visits with each other, the discussions in department office and the sharing of concerns were key to any success in the research.

As Teacher B's and Teacher A's observations from the teacher interview shows, the strength lay in the teachers themselves.

Teacher B It depends on the mathematics department. There are other departments, maths departments that don't work together like ours or share. But, in our department it is very close and we share, our ideas and resources, and also if you want to ask something to any teacher here you are free to just to do it and ask ' (Teacher A) can you help me with this?' or 'what do you do with this?' In that sense whatever comes or happens in the class we can just talk to each other.

Teacher A Approachable and accessible

Chapter 6: Implications and recommendations

6.1 Introduction

This thesis has attempted to investigate ways to develop statistical literacy in the secondary mathematics classroom.

In the literature review a brief description was given of the nature and state of statistics education both internationally and here in New Zealand. An attempt was made to describe differences between mathematics and statistics. In doing so a tentative definition of what is meant by statistical literacy was made. Theoretical frameworks for statistical literacy were then discussed and links made between the goals of statistical literacy and literacy education. Particular emphasis was placed on literacy with respect to critical literacy, including the possibility of a critical statistical literacy. Finally, action research was suggested as an appropriate method to investigate the implication of developing statistical literacy in the classroom.

In Chapter 3 the methodology adopted in the research was discussed. An explanation of the action research process was undertaken. Methodological issues of trustworthiness, data collection and data analysis were discussed. My influence and biases in the research were discussed. Finally, a detailed description of the research setting and participants involved was given.

Analyses of the results of the research were presented in Chapter 4. The chapter attempts to chronicle the action research process as well as explore the dominant themes that emerged from the data. Data collected from the planning phase, classroom observations, student interviews and teachers' interview undertaken are presented. The themes explored are:

- The concepts of statistics held by students and teachers,
- The concepts of statistical literacy held by students and teachers,
- The adoption of teaching principles,
- The importance of language and literacy in the statistics classroom, and

- The challenge of adopting a critical literacy stance in the statistics classroom.

Chapter 5 was a discussion of the main findings and conclusions taken from the first cycle of the action research project. The themes were discussed and links made between the review of the literature in Chapter 2 and the data and analysis in Chapter 4. Some new ideas emerged and reference was made to further research.

In this chapter the implications and recommendations of the research are discussed. In Section 6.2 I hope to give some tentative answers to the research questions posed by the action research. The large numbers of new and unanswered questions generated by the research are also discussed. In Section 6.3 the implications for the participants are discussed, including a description of possible next steps for the participants. The limitations of the research are highlighted in Section 6.4. The Chapter finishes with a discussion of the wider implications of the research and a call for further research in the area.

6.2 Research questions

The research question posed was;

How can we help students and teachers develop statistical literacy in the secondary mathematics classroom?

To answer this broader question a number of other questions were posed. In the following section I will address each of these questions in turn.

> *What are teachers and students views about the nature of statistics and statistical literacy in the Mathematics [and Statistics] curriculum?*

The research shows that teacher and student views are generally aligned to the goals and objectives of the 1992 curriculum. The teachers involved in the research also saw the wider goals of statistical literacy, such as developing critical thinking and a critical literacy. The teachers were prepared to make changes to their practice to achieve these goals.

The inclusion of statistical literacy goals into the Mathematics and Statistics achievement objectives of the new curriculum (Ministry of Education, 2007c) may lead to further changes in the views and attitudes of teachers and students. I believe that this is a real strength of the new Mathematics and Statistics curriculum (Ministry of Education, 2007b). However, I believe that there may be issues around the implementation of the new curriculum. Literacy skills, critical literacy and critical thinking skills need to be taught to students in mathematics to achieve the goals of a broader definition of statistical literacy.

Teachers views of statistical literacy match Gal's (2002) model. Gal focuses on literacy and critical questions. I feel that the importance of general literacy skills cannot be underestimated in Gal's model. This facet is often missing or avoided by other researchers. It may be because they see it as so obvious or perhaps because they see it as not as significant as the statistical literacy. However, teachers in this study felt that students have no chance of comprehending tasks without literacy skills.

The teachers in this research choose to participate because of their understanding that some change was needed to the way we taught statistics. Yet even for our group many of the ideas and concepts were outside our experience and competence. I would suggest that if the implementation of the new curriculum is to be successful many mathematics and statistics teachers will need to go through a similar process of investigation to understand the demands.

> *What is needed to facilitate the development of statistical literacy with students and teachers in secondary mathematics classrooms?*

Statistical literacy concentrates on the application of critical thinking skills to arguments involving statistics. Emphasis is needed on the learner as a consumer of statistics rather than a producer of statistics. Critical thinking and critical literacy are all signalled throughout the new curriculum, in the key competencies and accompanying achievement objectives. However, being critical is not an extra that can wait until students have mastered the basics of statistics. A critical approach should be adopted from the very beginning. Through statistical literacy, students are presented opportunities to learn to critically evaluate the statistical information presented to them.

Students need to recognise that statistics and statistical reports either in teaching materials or in media reports have been written by someone who made decisions about what meanings are (and are not) represented in the text. For many of the learners in this research with low literacy levels or who are perceived as low ability because of literacy issues, this change in awareness and perspective is one that has rarely appeared in traditional statistics teaching and learning. However, there is some evidence that being critical is achievable at all ages and across all literacy levels.

A critical stance ha not often been a feature of teaching in a low decile secondary school such as the school in this research. Teaching continues to be dominated by traditional transmission style teaching. While this approach may be being adopted by teachers trying to be explicit with students about what is needed for success, teaching of the much more challenging critical literacy is being avoided.

There is a huge array of suitable resources available for teachers to use in a statistical literacy classroom. There is easy access to current, topical and engaging content. However, teachers need to adopt pedagogical approaches that enable the use of large amounts of data and information in the classroom

Statistical thinking [literacy] cannot take place in New Zealand classrooms without access to the appropriate information technology.

> *How can using language learning principles help students and teachers to develop statistical literacy in secondary mathematics classrooms?*

And

> *How can using the 'principles of effective teaching for learners from diverse language and cultural backgrounds' help students and teachers to develop statistical literacy in the secondary mathematics classroom?*

I believe that the research shows that language is a key to success for students in statistics. This appears to be especially the case in such a school that has a large percentage of Pasifika or ESOL language learners. If we are going to try to help students become statistically literate we are going to have to become better at dealing with language in the mathematics classroom.

The important changes are about classroom methodology rather than content knowledge. The adoption of language learning principles appears to achieve this.

I would advocate for teacher professional development that adopts pedagogical approaches such as *Making Language and Learning Work 1: Integrating Language and Learning in Secondary Maths and Science* (Ministry of Education, 2007a). Approaches that acknowledge the centrality of language should be part of professional development programmes used with teachers of mathematics and statistics.

Literacy skills need to be taught to teachers. This can be a challenge for some teachers of mathematics. However, teachers need time and the resources to trial, reflect, observe and discuss before they can make significant differences to their teaching.

> *What are the appropriate professional development strategies for teachers to use in this context?*

We need to be supported as teachers. However, that support can come from our peers working in schools. Adopting action research as a process of changing practice meant that real changes can occur in classrooms.

Further, observations of others and the sharing of resources allows for relatively quick changes to practice that have been evaluated and reflected on by both the teachers and colleagues.

There is also the need for skills and approaches that may not present in the members of the research. Outside expertise must be sought. We need to encourage better links between mathematics and statistics teachers. We need to encourage better links between mathematics and statistics teachers and teachers working in literacy and language learning. This commitment of time and energy by teachers needs to be matched with other supports such as a supportive school climate. Again, this needs to be done within schools and between schools and outside groups.

6.3 Limitations

The research explored the developing of statistical literacy with students and teachers. I believe that the data collected in the research is sufficient for the teachers involved to respond to the research questions posed. However, I do not believe that I am able to make any statements for others or provide any well formed or clear guidelines on how to introduce statistical literacy into Year 9 and 10 mathematics classrooms.

There are limitations in the study that have to be acknowledged. First of all, the research only involved three classes of students and four participating teachers. Any findings may not be generalisable to all Year 9 and 10 students and their teachers. Our way of working as a group of teachers and our perspectives on statistics may be idiosyncratic or peculiar to our setting.

Secondly, it would be unusual for an action research project to only go through one action research cycle. More cycles will hopefully continue until the teachers are satisfied with the outcomes. There is also the possibility that the project does not end. This does not mean the questions and problems would be the same or that the teachers never reach any conclusions about the situation (Hughes & Seymour-Rolls, 2000). However, this research is restrained by my need to provide a written thesis for publication.

Outcome validity is where there has been a successful resolution of the research problem. It would be presumptuous to claim any successful resolution in our case. The process is an on-going one and claims made are restrained. However, activities and schemes have been altered, adapted and redesigned as the research has progressed. There was always the possibility that the research will not offer any solutions or incites.

Finally, there is the limitation of subjectivity versus objectivity. As a participant in the action research it is difficult to know the extent to which the data has been selected and, perhaps, other significant data down-played or ignored. As Bell (1993, p.9) points out; “Inevitably, where a single researcher is gathering all the information, selection has to be made.....and so there is always the danger of distortion”. Reliability and validity are, therefore, issues in the research. It is hoped that I have been able to honestly describe the research setting and actions.

Research can not be conducted without students and teachers being affected. It may be impossible to establish the effect of the research itself on the development of statistical literacy with students and teachers. The effects of having observers in lessons and being asked to participate in interviews may have been that participants, both teachers and students, did and said things that they would not normally do. However, change is one of the reasons for undertaking action research. Teachers and students reflecting on their own learning could be considered as good things to occur.

6.4 Wider implications and further research

There needs to be a lot more action research projects undertaken by teachers. It is in the classroom where any changes to practice as a result of curriculum change will occur. I would encourage teachers to trial ideas and importantly work in groups of teachers. It is vital that teachers find time to reflect and share. I would caution teachers that they will have to make adjustments to the strategies depending on their own particular contexts.

In terms of statistics and statistical literacy there are a number of issues and questions still to be answered. For instance, there are clear descriptions of what constitutes good statistics and statistical literacy instruction and we are fortunate that these are communicated in the New Zealand curriculum. It is exciting to see terms like statistical thinking and statistical literacy described in the curriculum document as well as notions of critical thinking and critical literacy in the key competencies and descriptions of effective pedagogy. However, many of the theories and developments in statistics education are still relatively new, at least for teachers in schools. I am unsure how many teachers are aware of the theories and developments in statistics education.

For the a successful implementation of the new curriculum in schools and classrooms it is necessary that there be an unpacking of what is meant by statistical literacy for secondary mathematics teachers by the Ministry of Education, school support services, schools and teachers themselves. While the production and dissemination of resources will be important it is not nearly as important as developing the pedagogical practices of teachers. The new Mathematics and Statistics curriculum must be introduced thoughtfully and progressively to allow sufficient time for teacher professional development. Effective professional development that provides ongoing support is needed for long-term change

There are great models for use in statistics teaching and learning, especially ones developed by New Zealand researchers. Wild and Pfannkuch's (1999) model for statistical thinking is a good start for teachers. The success of their PPDAC cycle as a description of the investigation cycle is obvious. However, Wild and Pfannkuch's model for statistical thinking encompasses four dimensions that include not only the investigation cycle, but the interrogative cycle, ways of thinking and dispositions. How the other three dimensions will be articulated or expressed in the classroom needs to be researched.

A further piece of research could be into the development of a statistical literacy poster that to help students like the PPDAC cycle *Data Detective* poster for statistical investigations or critical literacy poster from (Sandretto et al., 2006, p.25).

The linking between different learning areas needs to be explored. There is a need for learning communities to be established of both mathematics teachers and teachers of language and language learning. Ways of developing links with ESOL teachers must be investigated. Alternatively, links to other teachers who may be comfortable being critical with information must also be developed. For example the possibility of creating an interdisciplinary mathematics and social studies curriculum could be explored.

6.5 Final word

This thesis set out to examine ways to develop statistical literacy in the secondary mathematics classroom. The research shows that teachers see that a change is needed in the classroom. The evidence showed that it is possible for groups of teachers to make changes to their teaching programmes to start to address the teaching of statistical literacy

This research asserts that language and literacy are fundamental to success in teaching statistical literacy. By starting from a language focus teachers have a framework that enables them to move from a skills based process view of statistics to a view of statistics that lends itself to investigation, analysis and critique. Adopting language focused teaching principles allows teachers to focus on the skills needed to be statistically literate, with students able to analyse and interpret the data and information around them

This thesis has also argued that teachers need to move towards a critical literacy in statistics so as to give students the opportunity to become active citizens prepared to question the world around them.

Finally, the research hopefully shows that teachers can take action to change their practice by working together, sharing ideas and reflecting on their practice

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Philip Doyle
M. Education

Appendix A Introductory letter to the Principal

143 Paihia Road
Onehunga, Auckland 1061

Date

Developing statistical literacy
.... maths. classrooms

The Principal
[redacted]

Dear [redacted]

As you are aware I am completing a Research Thesis as part of a Master of Education degree through the University of Waikato while on study leave in 2007. I would like to work with a small group of mathematics teachers and students researching the teaching and learning of statistics and statistical literacy.

I have already had preliminary discussions with the teachers involved. However, I would like to ask your permission to undertake this study at [redacted].

As already stated the research will involve teachers in the mathematics department. I will also be observing and videoing students in Year 9 and 10 classrooms. Participation will not interfere with normal teaching and learning. The hope is that participation will enhance what is happening in the classroom as teachers get to discuss and examine more closely their practice.

All information and data collected will be treated in complete confidence. There will be no way a reader of the research study or of any reports resulting from the study will be able to identify the responses of individual students or teachers. All participants will be asked for consent form. Participants will be free to withdraw at any time, without penalty, and without giving a reason. Information gathered will be used to produce a final report. When complete, I will make this available to the school for mathematics teachers and students to read if they wish. I would also want to share findings with the wider school community.

If you have any questions about the study please do not hesitate to contact me at school or at (021) 02447268 or at [redacted]. Approval for this study was given by the University of Waikato School of Education Research Ethics Committee on .... for a period of .... If you have any questions or concerns about the ethics of this research that can not be addressed by me, please contact Dr. Sashi Sharma School of Education, University of Waikato [sashi@waikato.ac.nz or 07 8562889 ext 6298]

Yours Sincerely
Phil Doyle

Appendix B Participant Information Sheet for Teachers/School

Title of research:

Developing statistical literacy with students and teachers in secondary mathematics classrooms.

Explanation of research:

As you are aware, I am interested in language learning and mathematics. I am presently working towards a further qualification in Education. I am hoping that my study will help me improve the quality of my teaching and benefit the teaching and learning of mathematics at our school.

As part of my studies I would like to research what we have been doing in our mathematics classes around statistics and literacy. Over the next two terms I would like to undertake a small research project with you and your class that will involve observations of lessons, videoing of lessons & interviews. The research will document a unit of work focusing on statistical literacy.

It is up to you to decide whether or not to take part. Refusal to take part will involve no penalty or loss. Participation will not interfere with your normal teaching. There are no benefits to your participation other than knowing that you are helping me and hopefully other teachers examine what is effective practice. I am aware that I am in a privileged position as the HOD of the mathematics department. Your participation or non-participation will not affect the normal functioning of this relationship.

All information and data collected will be treated in complete confidence. There will be no way a reader of the research study or of any reports resulting from the study will be able to identify the responses of individual participants.

If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part you are still free to withdraw at any time, without penalty, and without giving a reason.

To indicate your consent to this request for your participation, please complete and sign the attached consent form and return it to me. Signed permission is required before any research can take place.

If you have any questions about the study please do not hesitate to contact me at school or at (021) 02447268 or at [redacted]. Approval for this study was given by the University of Waikato School of Education Research Ethics Committee on .... for a period of .... If you have any questions or concerns about the ethics of this research that can not be addressed by me, please contact Dr. Sashi Sharma School of Education, University of Waikato [sashi@waikato.ac.nz or 07 8562889 ext 6298].

Many thanks for considering this request.

Mr. Phil Doyle

HOD Mathematics

Appendix C Participant Information Sheet for Students and their parents/caregivers

Title of research:

Developing statistical literacy with students and teachers in secondary mathematics classrooms.

Explanation of research:

I am studying at the University of Waikato for a Masters in Education. I am interested in language learning and mathematics. I want to look at how we teach statistics. I am hoping that the study can help me become a better teacher so I can help students learn better in mathematics.

As part of my studies I would like to research what we have been doing in our mathematics classes. Over the next two terms I would like to visit your classroom. The research will show your Mathematics class at work. The visits will involve observations of lessons, videoing of lessons and interviews. I will observe the whole class. After looking at what is happening I may ask to interview some of you to find out more or to ask for further explanations I want to look at good statistics teaching that makes it easier for students to understand statistics.

It is up to you to decide whether or not to take part. You can say no if you do not want to be involved. Participation will not get in the way of your normal learning and you will not be disadvantaged in any assessment. There are no benefits to being involved other than having a chance to have your say and knowing that you are helping your teachers become better teachers.

All information and data collected will be treated in complete confidence. A report will be written at the end of the research. However, a reader of the research will not be able to identify you in any writing that comes from the study.

If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part you are still free to withdraw at any time, without penalty, and without giving a reason.

If you are happy to be involved, please complete and sign the consent form and return it to your teacher. Signed permission is required before any research can take place.

If you, or your family, have any questions about the study please do not hesitate to contact me through school or at (021) 02447268 or at [redacted]

Many thanks for considering this request.

Mr. Doyle

Appendix D Consent form Teacher

Title of Project: Developing statistical literacy with students and teachers in secondary mathematics classrooms.

Name of Researcher: Mr. Phil Doyle

Please initial box

1 I confirm that I have read and understand the information sheet for the research project and have had the opportunity to ask questions. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason. ☐

3. I understand that my participation or non-participation will not affect the normal functioning of the HOD-colleague relationship. ☐

4. I understand that all data collected, by interview, observation or video, will be treated in complete confidence and that there will be no way a reader of the research will be able to identify the responses of individuals. ☐

5. I agree to take part in the research project. ☐

______________________	______________	____________________
Name of Participant	Date	Signature
______________________	______________	____________________
Researcher	Date	Signature

Copies: One copy for the participant and one copy for the researcher.

Appendix E Consent form Student and Parent/Caregiver

Title of Project: Developing statistical literacy with students and teachers in secondary mathematics classrooms.

Name of Researcher: Mr. Phil Doyle

Please initial box

1	I have read and understood the information sheet for the research project and have been able to ask questions.	☐
2.	I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason.	☐
3.	I understand that all information collected by Mr. Doyle will be confidential and that I will not be identified.	☐
4.	I agree to take part in the research project.	☐

Name of Participant	Date	Signature
Parent / Caregiver [if student is aged under 16]	Date	Signature
Researcher	Date	Signature

Copies: One copy for the participant and one copy for the researcher.

Appendix F Focus Interview Questions and Themes

Title: Developing statistical literacy with students and teachers in secondary mathematics classrooms.

During our initial meeting I would like to explore all or some of the following

- Listing and evaluating our capabilities in statistics and statistical literacy
- Mapping the range of activities to use in the classroom to address the needs of statistics and statistical literacy
- Analysing gaps between possible practices and current capabilities in order to identify professional development needs.
- Designing a customised programme to address these gaps.

Because I intend to use an Action Research methodology, responses will somewhat guide the process.

Appendix G   Follow-up Interviews

Title: Developing statistical literacy with students and teachers in secondary mathematics classrooms.

Teachers

Reflection will involve:

- Identifying what worked and what didn't work in the classroom;
- Expansion on specific incidents in the classroom;
- Identifying some implications for future lessons and years in respect of the topic of statistics and statistical literacy;
- Identifying some implications for other teachers;
- Reflecting on the challenge(s) posed by the task of designing and implementing strategies for integrating statistical literacy into the mathematics programme.

Questions will include;

- What do you see as any extra demands in the way that you taught this year compared to previous years?
- Did this new way of studying make any difference to how you feel about mathematics and statistics?
- Is learning statistics different from learning mathematics?
- Do you see those differences [if any] expressed in mathematics [and statistics] curriculum?
- Do you feel prepared for the proposed changes to the mathematics [and statistics] curriculum?
- What changes, if any, would you want to see in our planning, teaching and assessment of this statistics unit?
- What further support would you like in the area of literacy and statistics?

Students

Reflection will involve:

- Identifying what worked and what didn't work in the classroom;
- Comparisons to previous year's statistics programme.
- Expansion on specific incidents in the classroom

Questions will include;

- Do you see any differences in the way that you were taught this year compared to previous years?
- Did this new way of studying make any difference to how you feel about mathematics and statistics?
- What things help you learn in your mathematics lesson?
- Is learning statistics different from learning mathematics?

Appendix H Census at Schools data card activity

evel: 4 – 5

Teacher's Notes: Being Typical

Allow at least one lesson for this activity; it could take up to three separate sessions depending on your students and the depth to which you want to take it. Begin by spending sometime discussing the context with the students. Some context is provided in the introduction. Most questions are discussion questions with a summary statement required at the end of each section. Discussing the problem, planning and gathering the data will take most of time. The purpose of this activity is to carry out a statistical investigation in the same way a statistician would.
The activity may also strengthen students' measurement skills.
After this lesson students will know:

- How the statistical investigation process works
- What is meant by cleaning the data
-

Resources checklist

For each group:

* data cards

_ Graph paper or access to computer or calculator

_ Access to Census at School online

Introduction

The data cards are made up from the 2005 Census at School (NZ) database. 30 students were randomly selected using the random sampler for each year level. Both genders and all regions included. The attributes or questions selected were designed so that students could begin to explore the statistical investigation cycle and start to explore stem and leaf graphs, medians, modes, range...

Some ideas for exploring that come up in this investigation

- cleaning data – a number of students have entered incorrect data
- equal number of boys and girls for each year level?
-

Problem

Formulating and defining a statistical question is important as it tells students what to investigate and how to investigate it.

Give each pair of students a subset of data cards. Suggest each pair gets a different year level. For a normal class will need approximately 2.5 sets of data cards. Data cards have 30 students at each year level. There are six year levels, total 180 data cards.

Get the students to look at the data that is on one of the cards. Get them to start to think about the different questions they could ask from the data. Using the starter I wonder... get students to make I wonder statements about the data set they have been given. Talk to the students about the different types of I wonder statements (questions). They might think about summary questions, comparison questions or relationship questions. We want to focus primarily on summary and comparison with the emphasis being on comparison.

Summary questions are ones like: I wonder ...
How many students get 10 hours sleep a night?
What is the most popular time students go to sleep?
What is the average height of students in Year 10?
Which ethnicity is the most common?

Comparison questions are ones like: I wonder...
If year 10 boys are taller than year 10 girls?
If year 5 students go to bed earlier than year 10 students?
If boys are taller than girls?
If girls have a faster reaction time than boys?
If year 5 boys are taller than year 5 girls?
If primary and intermediate students go to bed earlier than secondary students?
If NZ European students are taller than all the other ethnicities?

Relationship questions are ones like: I wonder...
If the length of your armspan is related to your height?
If the wrist measurement is half the neck measurement?
If the reaction time is related to the amount of sleep?
If the foot length is related to the height?

Get each pair of students to come up with about 10 I wonder statements. Once these are generated then record them on the board, taking a selection around the class. As each question/statement is read, decide as a class if it is summary, comparison or relationship. Collate under each of these headings (may like to do this on big paper to keep for later).

Collated questions onto A3 or bigger and stick these on the wall for future reference.

Appendix I Schemes

Old Scheme

STATISTICS	YEAR 9

TIME ALLOCATION: **7 weeks (25 lessons)**

ASSESSMENT: **Exam**
asTTle Diagnostic Test

ACHIEVEMENT OBJECTIVES:

MiNZC Reference:

Level 4
Statistical Investigations**:**
Within a range of meaningful contexts, students should be able to:

- plan a statistical investigation arising from the consideration of an issue or an experiment of interest;
- collect appropriate data;
- choose and construct quality data displays (frequency tables, bar charts and histograms) to communicate significant features in measurement data;
- collect and display time-series data;

Interpreting Statistical Reports
Within a range of meaningful contexts, students should be able to:

- report the distinctive features (outliers, clusters, and shape of data distribution) of data displays;
- evaluate others' interpretations of data displays;
- make statements about implications and possible actions consistent with the results of a statistical investigation.

Level 5
Within a range of meaningful contexts, students should be able to:

- Plan and conduct statistical investigations of variables associated with different categories within a data set, or variations of variables over time.
- Consider the variables of interest, identify the one(s) to be studied and select and justify samples for collection.
- Find and authenticate by reference to appropriate displays, data measures such as mean, median, mode, interquartile range and range.
- Discuss discrete and continuous numeric data presented in quality displays.
- Collect and display comparative samples in appropriate displays such as back-to-back stem and leaf, box and whisker, and composite bar graphs.

Mathematical Processes Level 4/5

Lesson Aim	**Textbooks**	**Worksheets / Equipment**	**Group / Pair activities**	**Literacy activities**
Formulate questions involving social and environmental issues. Discuss how to answer these questions.		Making graphs Activity 1 Activity 2 Activity 3	'What's wrong with our world?	Word Find (MM250)
Define discrete and continuous data	Math 9: pp.191	Big foot Arm and a leg Nappies	"Information please" Survey classmates Censusatschools	
Population, Samples, Census, Questionnaires		Pencil case Pencil case 1 Pencil case 2	Comparing Languages Task; Sampling vs. Census	

Choose and construct quality data displays - Bar (column) Graphs, Dot plots, Picture graphs, Strip (Divided bar) graphs	Alpha pp.392-401 Ex28.1, 28.2, 28.3, 28.4, 28.5			3 level guide Bar graph 1 Bar graph
Pie Graphs	Alpha pp. 403 Ex28.6			
Frequency tables	Alpha pp.425-427 Ex29.5			
Computer Graphs - using excel				
Stem and Leaf Graphs	Alpha Pg407 Ex28.7	Guess how many “macaroni spirals”, and “packaging thingy’s” are in the bags? Weight of school bag OHP		
Averages Mean/ Median/ Mode	Alpha Pg417 Ex29.1, 29.2, 29.4	RIME pack – Estimating Averages		3 level guide - Data
Spread Range/ Interquartile Range	Beta Pg			
Box and whisker graphs	Beta Pg			Mix and match graphs
Grouping data and Histograms	Alpha Pg 428 Ex29.6 Math 9 Pg212-218			
Time-Series Data	Alpha Pg410 Ex28.8 or, Maths 9 Pg 231-232	Sum Fun 106, or BL 62		
Discuss and recognise misleading graphs	Alpha Pg Beta Pg			
Plan a statistical investigation		NZMaths – Censu@schools	Figure it out	
Carry out a statistical investigation		NZMaths – Cars	Figure it out	

New Scheme

STATISTICS	YEAR 9

TIME ALLOCATION: **6 weeks (25 lessons)**

ASSESSMENT: **Exam**
Investigation

ACHIEVEMENT OBJECTIVES:

MiNZC Reference:

Level 4
Statistical Investigations**:**
Within a range of meaningful contexts, students should be able to:

- plan a statistical investigation arising from the consideration of an issue or an experiment of interest;
- collect appropriate data;
- choose and construct quality data displays (frequency tables, bar charts and histograms) to communicate significant features in measurement data;
- collect and display time-series data;

Interpreting Statistical Reports
Within a range of meaningful contexts, students should be able to:

- report the distinctive features (outliers, clusters, and shape of data distribution) of data displays;
- evaluate others' interpretations of data displays;
- make statements about implications and possible actions consistent with the results of a statistical investigation.

Level 5
Within a range of meaningful contexts, students should be able to:

- Plan and conduct statistical investigations of variables associated with different categories within a data set, or variations of variables over time.
- Consider the variables of interest, identify the one(s) to be studied and select and justify samples for collection.
- Find and authenticate by reference to appropriate displays, data measures such as mean, median, mode, interquartile range and range.
- Discuss discrete and continuous numeric data presented in quality displays.
- Collect and display comparative samples in appropriate displays such as back-to-back stem and leaf, box and whisker, and composite bar graphs.

Mathematical Processes Level 4/5

Language Learning Outcomes

- Use statistical vocabulary and language forms
- Write definitions of statistical and mathematical terms.
- Say and write. (oral language).
- Identify key words in type problems.
- Pose questions
- Write conclusions (statement + evidence)

TEACHING AND LEARNING ACTIVITIES

Each lesson starts with a learning outcome and language outcome (in student appropriate language).

Pre-unit work:
Find out about your students' language and mathematics concepts using sources such as:

- **previous assessments in department;**
- **maths assessments not dependent on language;**
- **ESOL department;**

talking with students about their oral and written literacy in their first language and English.

Lesson Aim	**Language Aims**	**Activities**	**Thinking**	**L S T**	**Managing Self**	**Relating to others**	**P & C**
An overview of current knowledge of statistics. Explore current knowledge							
Formulate questions involving social and environmental issues. Discuss how to answer these questions.	Writing questions Question forms I notice … I wonder	Making graphs Activity 1, 2, 3 ‘ What's wrong with our world? Word Find (MM250) NZmaths Averagelooking Census@School Time Use Survey What is a Typical Year 8? Census at schools Nosey parker	-				
Discuss features of small amounts of discrete data	*Vocabulary* *Population, Sample, Census, Survey discrete and continuous* Language of comparison	Math 9: pp.191 Big foot Arm and a leg Nappies" Information please" Survey classmates Figure it out Level 4+, Statistics, Book Two, Action and Reaction, page 6 Level 4+, Statistics, Book Two, Testing					

Compare features of sets of small amounts of discrete data Collect and display discrete numeric data;	use their own language to talk about the distinctive features, such as outliers and clusters, in their own and others' data displays Language of comparison	Pencil case Pencil case 1 Pencil case 2 Comparing Languages Task; Sampling vs. Census Census at schools Figure it out ARB's					
Choose and construct quality data displays *Bar (column) Graphs, Dot plots, Picture graphs, Strip (Divided bar) graphs*	Vocabulary technical vs everyday 3 level guide	Alpha pp.392-401 Ex28.1, 28.2, 28.3, 28.4, 28.5 Bar graph 1 Bar graph 2 Figure it out ARB's Census at schools Are you a masterpiece? The case of the missing cake					
Constructing Pie Graphs		Alpha pp. 403 Ex28.6					
Constructing and Using Frequency tables		Alpha pp.425-427 Ex29.5					

Collect information Sort information into categories	answer questions by sorting, organizing and arranging information make sensible statements about the information with supporting evidence	Figure it out ARB's					
Use spreadsheets to display and analyse data (as bar graphs and pie charts)	Discuss features of data display						
Displaying data using Dot plots and Stem and Leaf Graphs	Vocabulary	Alpha Pg407 Ex28.7 Census at schools Big Foot Activity Guess how many "macaroni spirals", and "packaging thingy's" are in the bags? Weight of school bag OHP Figure it out ARB's					
Comparing data displays	Language of comparison	Census at schools Bear Hugs					

Lesson Aim	Language Aims	Activities	Thinking	L S T	Managing Self	Relating to others	P & C
Calculate mean	Vocabulary technical vs everyday	Alpha Pg417 Ex29.1 Figure it out ARB's					
Finding median	Vocabulary technical vs everyday	Alpha Pg419 Ex29.2 Figure it out ARB's					
Finding mode	Vocabulary technical vs everyday	Alpha Pg421 Ex29.4 Figure it out ARB's					
Using Averages Mean/ Median/ Mode	Language of comparison 3 level guide - Data	Alpha Pg417 Ex29.1, 29.2, 29.4 RIME pack – Estimating Averages Figure it out ARB's Census at schools Sugar Guzzlers					

Finding Spread Range/ Interquartile Range		Beta Pg 358 Figure it out ARB's					
Displaying data Box and whisker graphs from dot plots		Beta Pg 365 Mix and match graphs Census@schools Figure it out ARB's					
Grouping data and Histograms		Alpha Pg 428 Ex29.6 Math 9 Pg212-218 Figure it out ARB's					
Display time series data Compare features of time series distributions	Discuss features of time series distributions	Alpha Pg410 Ex28.8 Maths 9 Pg 231-232 Sum Fun 106, or BL 62 NZmaths Time Series (L5) Time Series (L6) Figure it out					

Discuss and recognise misleading graphs		Alpha Pg 321 Beta Pg 378 Numeracy in the News Census at schools Chocolicious Rumbling Tum					
Analyse media reports and statistical reports of others Report on possible sources of error and limitations in displayed data.		Alpha Pg 321 Beta Pg 378 Numeracy in the News					
Plan and conduct an investigation to ascertain information from a set of data		NZ Maths Measuring up* Sports statistics * Cars * Travel to school 1 * Travel to school 2 * Marble Roll Census@schools Figure it out					
Report the results of the investigation concisely and coherently	make sensible statements about an assertion on the basis of evidence from a statistical investigation; make statements about implications and possible actions consistent with the results of a statistical investigation	Census at schools					

Notes:

Please highlight Activities/Resources used for each lesson aim for unit evaluation

Please add new Activities/Resources to grid for unit evaluation. Master copies may be needed for resource room.