Young Children's Statistical Reasoning: A Tale of Two Contexts

by

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Abstract

This century is an age of information, where complex data are widely available and accessible. Statistical information and arguments impact on decision making, and the ability to reason statistically, to make sense of, and reason about statistical information has become increasingly important. Researchers advocate developing critical, flexible reasoning with data from the beginning years of school. Young children begin school with powerful mathematical ideas, including data and probability sense that should be nurtured in meaningful learning contexts. Some aspects of knowledge and reasoning that contribute to young children making sense of data have been identified. Prior research however has tended to focus on individual statistical concepts rather than statistics as a distinct problem solving process, and positions children's learning as deficit. Accordingly, little is known of children's existing prior-to-school knowledge and reasoning competency and capacity and how this may inform pedagogical and content knowledge for statistical learning in the classroom. Furthermore, there is a curriculum imperative for understanding young children's beginning statistical reasoning, as *Statistics and Probability* is one of the three content strands in the newly introduced Australian Curriculum: Mathematics (ACARA, 2013).

The aim of this qualitative study was to explore the knowledge and reasoning young children brought to data handling activities within the classroom learning context in their first term of formal schooling. Statistics is essentially a new discipline developed in the twentieth century, which has drawn from, but is not founded in mathematics. Disciplinary distinctions between mathematics and statistics are important when considering the concepts and reasoning which are distinctly statistical and what this means for beginning statistical learning. This study defined core statistical concepts that emphasise the critical role of *data context* and *task context* in engaging statistical knowledge and reasoning, and the central role of inductive reasoning in statistical problem solving.

A design-based research method, informed by the Models and Modeling perspective (Lesh & Doerr, 2003) was adopted as an appropriate theoretical and methodological approach for eliciting statistical reasoning in young children. Data modeling activities initiated by picture story books were implemented to trigger core statistical processes as children engaged in statistical problem solving. The picture

books served to contextualise the data for the modeling problems, and were embedded in the design of the task context. The study explored young children's responses to the initiating picture story books, and their use of knowledge and reasoning as they found solutions to the modeling activities. Data were collected with 5 year old children in their first term of primary school in a classroom setting. Video and audio taping of whole class and small group work, children's models as representations of their problem solutions, researcher field notes, journal and teacher-researcher discussions were analysed theoretically and thematically.

The study found that young children brought inductive reasoning and a range of intuitive and prior-to-school knowledge to make sense of data and find solutions to data handling problems. The modeling problems engaged generating, selecting and measuring attributes, organising and representing data, and analysis and inference through interaction with data representations. The study also revealed that as task contexts, data modeling activities provide young children with conceptual access to statistical ideas and stimulate statistical reasoning processes. Children used their existing knowledge and reasoning skills to reason and make sense of data. In addition, the use of engaging picture story books to initiate and contextualise data for a modeling problem influenced the context knowledge children drew from to make sense of data.

This study identifies that young children have competency and capacity to participate in statistical practices and that task conditions and characteristics can instigate, mediate and support the statistical knowledge and reasoning young children reveal. The study recommends further research on the role of picture story books in the task design of data modeling activities. In addition, future research should address engaging young children's prior-to-school knowledge and reasoning skills, particularly their intuitive knowledge, as powerful resources that can be applied to reasoning statistically to make sense of data.

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Statement of Original Authorship

The work contained in this thesis has not been previously submitted to meet requirements for an award at this or any other higher education institution. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made.

Virginia Kinnear

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Definitions

Data Context

"Real world phenomenon, settings or conditions from which data are drawn or about which data pertain" (Langrall, Nisbet & Mooney, 2006, p. 1). In this study, the data context is provided by the picture story book.

Informal knowledge

An integration of real world knowledge and less formalised knowledge from prior formal instruction. (Zieffler, Garfield, delMas & Reading, 2008)

Real world knowledge

"Everyday real world knowledge that students bring to their classes based on out-of-school experiences" (Zieffler, Garfield, delMas & Reading, 2008, p. 42).

Statistical knowledge

Knowledge children bring to the judgements they make or the actions they take to make sense of data.

Task Context

The data modeling activities and the tasks that comprise them, including the use of the picture story book to initiate and contextualise the modeling activity problems.

Chapter 1 INTRODUCTION

1.1 Introduction

This chapter introduces and identifies the research topic problem and positions it within the context of the current focus on statistical learning. Statistical learning is a key social and curriculum concern that has been driven by the increased availability of quantitative data in society. Disciplinary differences between statistics and mathematics are briefly provided as requisite to meaningful research that informs young children's engagement with core statistical concepts and processes. The Models and Modeling perspective (Lesh & Doerr, 2003) is presented as a theoretical and methodological basis for exploring young children's statistical reasoning and the task context in which it occurs. The research problem and the aims and significance of the study to young children's statistical learning are described. Finally, an overview of each chapter in the study is presented.

1.2 Topic and Research Focus

This exploratory study investigated young children's statistical reasoning when engaging with statistical problem solving in the first months of commencing formal schooling. A central assumption for this study was that statistics and mathematics are distinct disciplines and defining the characteristics of statistics was necessary to research young children's statistical reasoning. The process of defining statistics as a discipline revealed two integrated contexts that are core elements in statistical reasoning. First, the setting that a statistical problem is drawn from that contextualises the problem, the *data context,* and second, the learning or *task context,* comprising the activities that engage statistical problem solving. The study employed a Models and Modeling (Lesh & Doerr, 2003) theoretical perspective to explore the reasoning and knowledge young children brought to data modeling problems as statistical problems. The study also explored the characteristics of the problem solving tasks that supported children's statistical reasoning, particularly the role of picture books in initiating modeling activities and providing knowledge of the data context children used when problem solving.

The terms “young children”, “children”, and “child” are used throughout the study. “Child” is defined by the United Nations (1989) as persons below the age of 18 years however this study is concerned with children in the period of early childhood defined by Early Childhood Australia (2006), and the Organisation for Economic Co-operation and Development (OECD) (2001) as persons between the ages of birth and age eight. In addition, the term “young children” for the purpose of this study refers to the child participants (aged 5 years), who had been in prior-to-school settings and were commencing formal primary schooling. The study participants are representative of children identified by Perry, Dockett and Harley (2012) as moving between two national curriculum frameworks covering early childhood education introduced in Australia in 2009; *Belonging, Being & Becoming: The Early Years Learning Framework for Australia* (EYLF) (Department of Education, Employment and Workplace Relations [DEEWR], 2009) for children in prior-to-school settings, and the *Australian Curriculum: Mathematics* (Australian Curriculum, Assessment and Reporting Authority [ACARA], 2013) for children in the early years of primary school.

1.3 Research Context

1.3.1 Statistical Literacy, Data and Future Citizenship

Increased availability of mass media and computer technology has impacted our lives. Vast amounts of quantitative information as data are available and accessible to all members of society, including young children. Statistics is increasingly used to add credibility to the way data are presented (Ben-Zvi & Garfield, 2004) and how data-based arguments are used to persuade (Lehrer & Schauble, 2002). The notion that we live in an increasingly data oriented world led Steen (1999) to deem statistics as one of the staple and essential tools for being quantitatively literate in an age of numbers where society is “data-drenched”. “Quantitative literacy”, a term for numeracy, has been argued as key to understanding, and social and individual liberty in the age of data (Steen, 1999). Consequently, the ability to reason statistically, that is, to be able to understand statistical concepts and make sense of statistical information has become increasingly important (Moore, 1990; Shaughnessy, 2007; Watson, 2006). Complex data are embodied in the systems that operate in society. The capacity to reason effectively

about data is integral to an individual's ability to engage meaningfully in democratic discourse and decision making, as well as being necessary for economic prosperity and scientific discovery (Middleton, Lesh, & Fennewald, 2008). The link between numeracy, statistics and effective decision making is reflected in key definitions of "statistical literacy" (Gal, 2002; Wallman, 1993). Deemed as essential for educated citizenship, the connection between being literate and statistics is the need for informed citizens to be able to interpret, understand and critically evaluate statistical information.

Advocates for engaging young children in statistical learning at school argue that school based, everyday practice of data investigation activities is essential for critical, flexible reasoning with data (Lehrer & Schauble, 2002). Young children are competent participants in their worlds and capable learners and have powerful mathematical ideas and proficiency that develop in their prior-to-school settings (Perry & Dockett, 2008). Young children's powerful mathematical ideas include data and probability sense (Perry, Dockett & Harley, 2012). Such powerful ideas are demonstrable in familiar and personally meaningful contexts and should be nurtured in respectful, collaborative, environments that transition children's experiences from prior-to-school settings to school settings (Perry, Dockett & Harley, 2012). Young children's development of powerful statistical ideas at school should be informed by knowledge of children's current competency and the development of their knowledge and thinking.

1.3.2 Positioning Statistics in the Australian Curriculum: Mathematics

In 2011, States and Territories across Australia began planning or implementing the new national *Australian Curriculum* (ACARA, 2013). Development of the curriculum was facilitated and informed by the national agenda embodied in the Melbourne Declaration (MCEETYA, 2008). The Melbourne Declaration documents State and Territory agreement for 21st century educational learning goals to support Australian citizens to be informed, active citizens and confident, creative and successful learners. The *Australian Curriculum's* Foundation to Year 10 curriculum in mathematics includes *Statistics and Probability* as one of three content strands. The philosophical and policy issues raised by curriculum that seeks to promote citizenship is not unproblematic (e.g., Biesta, 2010; McCowan,

2009; Yates & Collins, 2010) and the introduction of the *Australian Curriculum* and its contribution to national goals has not been without critique (e.g., Atweh, Miller & Thornton, 2012). The explicit use of the terms Statistics and Probability however, reflects broader, international research foci on the role of statistics in 21st century decision making (English & Sriraman, 2010; Garfield & Ben-Zvi, 2008; Watson & Neal, 2012).

Viewing statistical literacy as a citizenship goal fits the tenor of the framework developed and set out in the Guidelines for the Assessment and Instruction in Statistics Education Report [GAISE Report] (Franklin et al., 2007). The GAISE Report (Franklin et al., 2007) is the document relied on by the Australian Federal Government to develop the content of the Statistics and Probability strand of the *Australia Curriculum: Mathematics* (ACARA, 2013). The GAISE Report positions statistical literacy as a combination of statistical problem solving and statistical understanding that develops and progresses in parallel. Being statistically literate also includes the disposition and ability to apply knowledge to interpret and critically evaluate data. The emphasis placed on statistics and probability in the curriculum is stated to be "in recognition of the need for students to be able to interpret data in the 21st century" (ACARA, 2013, p. 1).

Naming Statistics and Probability as one of three strands in the *Australian Curriculum: Mathematics* (ACARA, 2013), has moved statistics as a discipline from the curriculum back seat to the front seat. Children are mandated to be taught statistics and probability from the commencement of their formal schooling. Prior to the development of a national curriculum in Australia, teaching and learning statistics as a discipline had been a component of variously labelled topics of "Data" in the mathematics content of State and Territory curriculum documents (ACT, 2006; NSW, 2002; NT, 2009; Qld, 2007; SA, 2001; Tas, 2008; Vic, 2009; WA, 1998). Although descriptions of the content under "Data" topics in the State and Territory curriculum documents incorporated elements of statistical thinking and working, they neither explicitly stated nor comprehensively defined statistics. The relationship between statistics and mathematics as disciplines and what characterises statistics as an integrated and distinct discipline were not openly addressed. The *Australian Curriculum: Mathematics* replaces the eight State and Territory curriculum

documents and changes the previous position and description of statistics found in State government curricula. Positioning statistics as a separate strand can be seen as a deliberate shift in terminology to focus on the significance of the discipline of statistics in its own right. The inclusion of Statistics and Probability reflects the pragmatic value of developing statistical literacy in evaluation and decision making across disciplines and in everyday life (Watson & Neal, 2012).

The perceived pragmatic and citizenship values in statistics is clearly indicated as an important consideration in formulating the educational goals expressed in documents leading to both the development of the *Australian Curriculum* (ACARA, 2013) as a whole and in particular, the Mathematics curriculum. The draft and working documents that have culminated in the fourth version of the Australian Curriculum acknowledge rapid, complex, global and technological changes and the impact of such changes on education and achieving national educational and social goals (Atweh, Miller & Thornton, 2012). Ongoing learning is stated as dependent on being both literate and numerate (ACARA, 2013.), focusing attention on the need to equip students for contextual and real-world application of mathematical understanding and skills.

The value of mathematical competency is further reflected in the four proficiency strands in the *Australian Curriculum: Mathematics* (ACARA, 2013); Understanding, Fluency, Problem Solving, and Reasoning. The proficiency strands, drawn from the work of Kilpatrick, Swafford and Findell (2001), interact and integrate with the three content strands to describe how content is explored and developed. Atweh, Miller and Thornton (2012) note that Kilpatrick et al.'s choice of the word "proficiency" was designed to try to capture what successful mathematical learning means. Reasoning then, as the development of "an increasingly sophisticated capacity for logical thought and actions, such as analysing, proving, evaluating, explaining, inferring, justifying and generalising" (ACARA, 2013, p. 3), is integral to successful statistical performance. The integration of curriculum proficiencies with mathematical and statistical content results in a clear emphasis on learning outcomes that reflect the international focus on statistical learning. These include analysis, inference, interpretation, critical evaluation and reasoned decision making from the Foundation year onwards.

The description of the content strand for the 'Statistics and Probability' strand for Foundation – Year 2 (ACARA, 2013) does not modify the previous State and Territory curriculum approach to children beginning work with Data. The persistent view reflected in State curriculum documents, and now replicated in the content and description of the Statistics and Probability content strand, is that young children's statistical learning is about sorting, classifying and recording data as a means of answering simple questions. The content description may reflect the limited research around young children's statistical learning and thinking, particularly with respect to children's capacity and ability to understand, work and reason with core statistical concepts when engaging meaningfully with data. It could reflect that statistics is viewed as essentially mathematical in nature, and that young children's mathematical knowledge is considered a primary factor in determining competency and access to statistics content. Irrespective of the underlying reasons that may exist for the current statistics and content and sequencing in the *Australian Curriculum: Mathematics* (ACARA, 2013), research is needed to inform theoretical and pedagogical knowledge for effective support for young children's beginning statistical learning and reasoning that the curriculum now mandates.

1.4 Research Problem

Children live in a data-driven and information rich society. The early years of education provide the foundation for the conceptual understanding, knowledge, dispositions and skills needed for further learning. Children need skills required to engage in the complex thinking requisite for statistical reasoning. There is a genuine need to give young children the opportunity to develop statistical concepts and processes that underlie statistical reasoning (Langrall, Mooney, Nisbet, & Jones, 2008; Lehrer & Schauble, 2005). The early school years comprise the educational environment where all children should begin a meaningful development of core statistical concepts and processes, and the development of educational practices to support this has been described as "one of the most critical pedagogical problems of our age" (Middleton et al., 2008, p. 35).

To begin to achieve effective, beginning statistical learning for young children, educators need to be able to recognise and capitalise on young children's existing competency and potential to engage and reason effectively with statistical

concepts and problem solving. Currently, the knowledge and understanding that would enable educators to achieve this is limited. The paucity of research on young children's statistical learning may be partially due to the relative newness of statistics as a discipline, as research in students' understanding of statistical concepts has only really occurred in the last two decades (Watson & Neal, 2012).

The literature highlights the perceived dichotomy between mathematics and statistics as disciplines. Statistics is essentially a new discipline developed in the twentieth century, which has drawn from, but is not founded in mathematics (Pfannkuch & Wild, 2004). The origins of statistics as a discipline has generated debate about whether it is part of mathematics or a separate discipline with its own core ideas and modes of reasoning (Greer, 2000), with the latter view being supported by statisticians (Bessant & MacPherson, 2002; Moore & Cobb, 2000). Statistics education then, is an emerging discipline, and despite the relatively recent inclusion of statistics as part of the mathematics curriculum, little is known about how young children learn and reason with core statistical ideas.

The debate about the distinction between mathematics and statistics is important when considering the nature of concepts children will encounter which are distinctly statistical, and how they will work with these. Specifically, the debate raises the question about what types of knowledge and reasoning strategies children will bring to working with statistics. If statistics differs from mathematics, then understanding the knowledge and reasoning children bring to engaging with mathematics will not fully inform our understanding of how children engage with statistical concepts. Research is needed to tease out the elements of knowledge and reasoning that are 'statistics specific' and to understand the role that mathematical knowledge and reasoning play in the statistical reasoning process.

Statistics has been defined as "the science of learning from data" (Papaistodemou & Meletiou-Mavrotheris, 2008, p. 83) and a discipline that provides "a coherent set of ideas and tools for dealing with data" (Cobb & Moore, 1997, p. 801). Leavy (2008) highlights that the limited research around young children's learning of statistics has focused on specific aspects of statistical thinking rather than on how children understand key statistical concepts when dealing with the broader concepts that can be found in data handling. "Handling data" has become a key area

of research in statistics as the ability to process data is broadly viewed as central to the definition of statistics (Ben-Zvi & Garfield, 2004; Lehrer & Schauble, 2002; Moore, 1998). Research also shows that the development of students' reasoning with statistical concepts is aligned with the processing of realistic data based situations, where students are required to develop mathematical models engaging analysing and comparing data in order to solve a problem (Lakoma, 2007). Research findings therefore draw attention to two issues concerning problem-solving that are evident from the literature. First, supporting children to bring their skills and knowledge to problem-solving activities has been a central pedagogical tool in mathematics curriculum (Diezmann, Watters, & English, 2001). As the pragmatics of problem solving has become increasingly complex however, research in problem-solving has declined (English, 2008a). In Fox and Diezmann's (2007) survey of early years mathematical research carried out between 2000 and 2005, literature addressing "young children's ability to problem solve, reason and converse mathematically" (p. 301) accounted for only 1.3% of available literature.

Second, the notion of developing conceptual mathematical models or modeling as an integral aspect of mathematical learning is one that has been the subject of increased attention (English, 2008b; Kaiser, Blum, Ferri & Stillman, 2011; Lehrer & Schauble, 2006; Lesh & Doerr, 2003). Within the Models and Modeling theoretical perspective (Lesh & Doerr, 2003), the process of modeling powerfully combines students' creation and use of conceptual models as a means of understanding and making sense of complex real-world systems where statistics are integrated. In the course of doing this, students use existing knowledge and develop further mathematical knowledge and skills and arguably, statistical knowledge and skills as well. Although it has been suggested that modeling may begin in children as early as other mathematical problem–solving, (Langrall, Mooney, Nisbet & Jones, 2008; Perry & Dockett, 2008; Ususkin, 2007), Ususkin (2007) points out that the literature reveals very little about modeling principles in any disciplines in the context of primary school, particularly for young children entering the formal school system. The Models and Modeling perspective offers a relevant framework within which to investigate young children's statistical reasoning.

Within the context of the Models and Modeling perspective, research has emerged on modeling with data or *data modeling*. Data modeling is seen as a developmental process beginning with young children's investigations of meaningful phenomena (Lehrer & Schauble, 2005). It has been described as a "multicomponential process of posing questions, developing attributes of phenomena; measuring and structuring these attributes; and then composing, refining, and displaying models of their relations" (Lehrer & Schauble, 2000, p. 52). Data modeling takes on significance when considering what the key statistical concepts are and how young children engage with them. From a data modeling perspective, the processes children use to generate, test and revise their ideas that arise from questions they ask about the world around them are central early statistical thinking and reasoning and its development (Lehrer & Schauble, 2005). Children decide what aspects or attributes they examine, how to measure them and how to structure, organise, analyse, visualise and represent the data that results from this. These processes allow children to subsequently draw informal inferences that can be used to consider other similar problems. Data modeling in this context reflects the structural components identified in statistical investigation at the elementary level (Leavy, 2008).

Lehrer and Schauble (2005) argue that statistical reasoning processes are triggered when children are engaged in data modeling and that the statistical processes that ensue mirror the data modeling processes. With the exception of the work of Lehrer and Schauble (2000, 2004, 2005, 2006) and English (2009, 2010, 2011), a search of the literature did not reveal studies that have examined the total process of data modeling in the early school years, particularly with a focus on the use of knowledge and reasoning across core statistics characteristics, and the characteristics of tasks in engaging young children in statistical problem solving. Research was needed to investigate how data modeling in particular can be implemented with young children and what it may reveal about the knowledge base and reasoning skills young children bring to the statistical problem solving process.

Young children possess many conceptual resources and can move towards more sophisticated reasoning with appropriately designed and implemented learning experiences (Clarke, Clarke, & Cheeseman, 2006; Perry & Dockett, 2008). The

context and conditions under which such learning can occur however, needs to be further examined. The learning context, including the task design, influences what can be revealed about young children's knowledge and reasoning skills that they bring to the learning process and how these develop. Children's existing knowledge base influences both the types and quality of reasoning processes they draw from when engaging with new learning and conceptual development. Picture story books used to contextualise statistical problems for young children, form part of the task context and provide knowledge of the context of the problem that can be drawn on to solve the problem. Research addressing the role of picture story books in providing both data and task context was needed to gain insight into the impact on young children's reasoning and use of existing and picture story book based knowledge when reason statistically.

Data modeling problems emerged from an area of the Models and Modeling perspective where researchers have developed activities to help understand how children engage in mathematical problem solving. These activities, referred to as model-eliciting activities provided meaningful, engaging real world problems that need to be mathematically described and interpreted (English & Watters, 2005, p. 60). Model-eliciting activities inform aspects of data modeling problems and each have the potential to contribute to the understanding of young children's statistical knowledge and reasoning. Modeling activities using data modeling problems were able to provide theoretical and methodological support to engage young children in statistical concepts using task contexts designed to reveal young children's statistical reasoning and learning.

In summary, this study investigated young children's use of knowledge and reasoning skills when engaging with core statistical concepts in solving data modeling problems using modeling activities within a classroom environment. Within the framework of the Models and Modeling perspective and the associated instructional innovations of data modeling problems as modeling activities, this study also investigated the role of the task context that supports young children's engagement in statistical reasoning as the begin formal schooling.

1.5 Research Aims and Purpose

The purpose of the study was to gain a greater understanding of the knowledge and reasoning skills young children commencing formal schooling bring to statistical problem solving, and the task context that supports this. The aim was to implement data modeling activities as a means of tracing, documenting and interpreting children's use of knowledge and reasoning when engaging with core statistical concepts in order to contribute to theoretical and pedagogical understanding of instructional context that can effectively support statistical learning within the classroom environment.

The questions guiding the study to achieve this aim were:

1. What knowledge and reasoning skills do young children bring to statistical problem solving as data modeling activities?
2. What characterises task contexts in data modeling activities that engage young children in statistical reasoning?
3. How does young children's use of context knowledge and reasoning skills develop as they undertake and solve data modeling activities?

1.6 Research Significance

Understanding statistics, or statistical literacy, has significant impact on individual and social function, and its importance is reflected in the specific inclusion of statistical learning in national curriculum documents and policy. Konold and Higgins (2003) summarise the importance of developing statistical literacy:

> At the practical level, knowledge of statistics is a fundamental tool in many careers, and without an understanding of how samples are taken and how data are analysed and communicated, one cannot effectively participate in today's important political debates about the environment, health care, quality of education, and equity. For those who have traditionally been left out of the political process, probably no skill more important to acquire in the battle for equity than statistical literacy. (p. 183)

Research in statistics education has increased significantly in the last two decades (Shaughnessy, 2007), however there is little research to inform what knowledge and reasoning skills young children bring to statistical problem solving in their first-year-

school classrooms, and the impact of task context that supports early statistical learning. As a consequence, there is little understanding of theory and pedagogy to support children's engagement with statistics and statistical reasoning in the early years classroom. Statistics is arguably a separate discipline to mathematics (Watson, 2012) but there is minimal research that works to tease out what might define core statistical concepts and processes for young children to work with in their first-year-school classrooms. How core statistical concepts are viewed and implemented has implications for the pedagogy and theoretical understanding needed to guide teaching statistics to young children in the classroom. There is an absence of studies that have examined the total process of data modeling in the early school years, particularly with regard to the integration of core concepts from statistics. Research was needed to examine what data modeling in particular may reveal about the knowledge base and reasoning skills young children bring to statistical learning, and the impact of data modeling activity task design on contextualised, statistical reasoning.

The research provides evidence as to the role of data modeling in supporting young children's potential for learning statistics. This adds to understanding of how core statistical concepts and processes develop within the data modeling context. This will further support the development of theory that can inform the pedagogical basis of children's early statistical experiences. The study contributes to understanding the problem-solving instructional context that best support young children's development and use of statistical reasoning.

1.7 Structure of the Thesis

This study comprises eight chapters. Chapter one introduced the research topic, context aim and questions.

Chapter two provides an analysis of current knowledge of knowledge on statistics and statistical learning by discussing literature pertaining to conceptual, theoretical and learning aspects related to young children's statistical reasoning.

Chapter three establishes the study's methodological theory and processes and provides a rationale for qualitative research. Data collection methods, data analysis and ethical considerations are presented.

Chapter four presents the content and implementation of the four modeling activities *Baxter Brown*, *Michael Recycle*, *Litterbug Doug* and *Charlie and Lola*, and the children's models developed for each modeling activity.

Chapter five presents and discusses the findings that emerged from the thematic analysis of the children's responses to the picture story book that initiated each of the four modeling activities.

Chapter six presents and discusses the findings that emerged from the theoretical and thematic analysis of two modeling activities that focused on the generation, selection and measuring of attributes and the organisation, displaying and representing of data.

Chapter seven presents and discusses the findings that emerged from the theoretical and thematic analysis of two modeling activities that focused on interpretation, analysis and drawing inference from data.

Chapter eight presents a summary of the key findings from chapters five, six and seven, and final conclusions. The chapter ends with the limitations and suggestions for future research.

Chapter 2 LITERATURE REVIEW

2.1 Introduction

This chapter presents the review of literature undertaken to gain a greater understanding of young children's statistical reasoning. The review principally draws on two areas of literature; statistics teaching and learning, and Models and Modeling perspective learning theory.

Core differences between the disciplines of mathematics and statistics are identified and a definition of the core characteristics of statistics is provided for the purposes of exploring young children's statistical reasoning in this study. The process of identifying a definition of statistics highlighted the role of two contexts in statistical reasoning, *task context* and *data context*, and the review of statistical problem solving literature focuses on each of these contexts in statistical learning. The Models and Modeling perspective (Lesh & Doerr, 2003) is presented as a theoretical framework with task design principles that facilitate young children's access to core statistical characteristics, and accommodate task and data context in statistical problem solving. Components of statistical problem solving as data modeling are identified, and research on young children's statistical learning is reviewed in light of these components. Finally, the role of picture story books in providing task context and data context in statistical problems for young children is presented.

It is argued in this review that statistical reasoning is a dynamic process that engages core statistical characteristics and is influenced by the dual contexts of a statistical task (task context) and the real-world setting of a statistical problem (data context). Research in young children's statistical reasoning as they begin formal school is limited. Exploratory research must focus on the defining characteristics of statistics, the role of task context and data context, and the influence each context has on the knowledge and reasoning young children engage and employ in statistical problem solving.

2.2 Characterising Statistics as a Discipline

This section describes the general characteristics of statistics as a discipline in order to position generating a definition of statistics for young children. Statistics is essentially a discipline that has drawn from, but is not founded in, mathematics (Garfield & Ben-Zvi, 2006; Pfannkuch & Wild, 2004). Statistics emerged in the 18th century as a search began for a common logic for empirical sciences to measure and examine the consequences of uncertainty generated when working with variation found in the world (Stigler, 2003). The search resulted in the development and employment of mathematical concepts and methods to quantify the uncertainty resulting from variation found in data (Salsburg, 2001). The historical origins and development of statistics as a discipline has generated debate amongst statisticians and educators about whether it is a part of mathematics or a separate discipline with its own core ideas and modes of reasoning (Bessant & MacPherson, 2002; Greer, 2000; Moore & Cobb, 2000). Despite the debate, surprisingly little has been written about what, if anything, distinguishes statistics from mathematics and the relationships between the two.

The available literature on the question of whether statistics and mathematics are different is sparse and predominantly written by statisticians, but overwhelmingly affirms that statistics and mathematics are dissimilar (e.g., Bailey, 1998; Davies, Barnett, & Marriott, 2010; Hand, 1998; Hogg, 1991; Kempthorne, 1980; Rossman, Chance, & Medina, 2006; Stuart, 1995; Tukey, 1962). Statistics is viewed by statisticians as far broader than an application of quantitative, mathematical processes for handling data and they are keen to identify statistics as a separate discipline. The statistician Moore (1998) clearly stated that the disciplines of mathematics and statistics are separate, and that a key defining element of statistics is using and reasoning from data:

> statistics is no more a branch of mathematics than is economics...It is a separate discipline that makes heavy and essential use of mathematical tools but has origins, subject matter, foundational questions and standards that are distinct from mathematics...Its subject matter is data and inference from data. (p.3)

Snee (1988) maintains that a defining aspect of statistics is working with variation and uncertainty in data, and being comfortable with it. Mathematics and

mathematicians, he argues, rarely deal with or are comfortable with either variation or uncertainty.

Thinking statistically has been described as "a philosophy of thinking and action" (American Society for Quality, 1996) and "a general intellectual method" (Moore, 1998, p. 1254). Describing statistical thinking as a way of thinking expands statistics well beyond the quantitative arena. Statisticians' stances on distinctions between statistics and mathematics have served to reinforce that the non-mathematical and dispositional qualities of statistics are important to conceptualising and delivering statistics education. The non-mathematical characteristics identified by statisticians in literature are important delineation markers for both researching and teaching statistics. Non-mathematical characteristics of statistics that are acknowledged and identified include the central role of data handling, the role of contextualised problems and inferential reasoning in statistical learning (Garfield, Hogg, Schau, & Whittinghill, 2000; Gould, 2010). Identification of these characteristics are important elements that have informed the definition of statistics for this study.

There are contrasts between the processes and conclusions statistics and mathematics employs (Rossman et al., 2006). As a consequence, the type of reasoning engaged in each discipline differs; they "follow two quite different paths of reasoning" (Scheaffer, 2006, p. 310). Deductive reasoning has been declared "the reasoning of mathematics" (Cunningham, Schreibner, & Moss, 2005, p. 184). Deductive reasoning moves from the general to the specific (Goswami, 2011), where a statement is accepted or proved as a consequence of validation against information found in established, generalised statements (Tarski, 1995). Deductive reasoning is needed to argue for proof in mathematics (Stylianides, 2007). Statistical reasoning, however, is predominantly inductive or probabilistic (Gattutso, 2008; Gilchrist, 1976; Scheaffer, 2006; Rossman, Chance, & Medina, 2006; Wilson, 2010). Inductive reasoning moves from specific to general, where real world knowledge drives forming connections in order to decide the likelihood of a conclusion. Inductive reasoning is needed to be able to manage variation, uncertainty and multiplicity in statistical problem solving (Cobb & Moore, 1997). The difference between the two forms of reasoning each discipline predominantly uses is reflected in the aims and

outcomes of each discipline in problem solving. Mathematics deducts from data and then tests theory so that mathematical statements are correct and correctly stated (Wilson, 2010). In contrast, statistics is an applied methodology, where the aim is to infer theory from known data to make reasonable statements supported by data (Kempthorne, 1980).

Although the reasoning between mathematics and statistics differs fundamentally, the relationship between the two disciplines is seen as critically dependent (Stuart, 1995), complementary (Camden, 2009) and co-dependent. The relationship is clearly intimate, however, there have been concerns raised about the apparent dominance or "undue influence" (Stuart, 1995, p. 53) of the formal mathematical partner in statistics education and the tension created by the mathematical dominance on developing statistical disciplinary thinking and learning. This tension is articulated in the following:

> Mathematicians construct proofs that establish the correctness of theorems...although proofs and exact numbers are part of statistics, the principal function of statistics is to help solve real world problems whose answers are never in the back of the book. (Snee, 1988, p. 30)

The concern expressed here is that an over emphasis on mathematics and the formal nature of mathematical processes in teaching statistics can lead to mathematics predominating learning outcomes in statistics education. The differences in processes, conclusions and reasoning between the two disciplines have the potential to impact on statistical learning, if statistics is taught with a mathematical perspective. In mathematics teaching, there is often a need for just one correct answer, however in statistics the answer is invariably one of multiple possibilities, questions and uncertainty (Gattuso, 2008). The potential impact of taking a mathematical approach to examining data in a statistical problem creates a conundrum not lost on Paramore (2011), who notes that "data are rarely problematic when the focus is on the right answer" (p.74). The problem of teaching and learning statistics from a mathematical approach is central to this study. Statistical teaching and learning for all children, including those who are beginning formal schooling, in Australia at around 5 years of age, should engage the core disciplinary specific characteristics of statistics, not mathematics.

The identifiable differences from the literature between statistics and mathematics have the potential to profoundly impact on content and pedagogical knowledge for teaching each discipline. If statistics teaching and learning is approached mathematically, it runs the risk of ingraining students into a way of thinking and reasoning about statistics that bypasses, and is counterproductive to the reasoning processes that are critical to statistics. Statistical reasoning necessitates interpretation, and dealing with uncertainty through inference that engages inductive reasoning. The ability to draw inferences is described as a process of making "mental connections between something that we already believe is true and something we believe connects to it in some way" (Chiasson, 2005, p. 215). When reasoning inductively, real world knowledge drives inference and forming connections, and decides the likelihood of the conclusion. The process of inductive reasoning dominates determining a solution to a question in statistical problem solving and has therefore informed the definition of statistics for this study.

Approaching statistics as something that young children beginning school can engage in that is not dependent on formal mathematical knowledge opens opportunities for valuing young children's competencies in beginning statistical learning. Statistical problem solving for teaching and learning statistics can be positioned as an investigative process that is a developmental and not based on age, but on students' developing levels of statistical literacy and involving limited formal mathematics at the introductory level (Franklin et al., 2007). Currently there is not a definition of the core characteristics of statistics that can be used to inform how beginning statistical learning for young children might look as they begin formal schooling, if a statistical perspective on learning is the focus. This study sought to understand how statistics, as opposed to mathematics, can be engaged by young children as they begin learning statistics. The focus on statistics is achieved by defining the core characteristics that children should encounter as they begin statistical learning at school.

2.3 Defining Statistics

A definition of statistics for beginning school learning has not been addressed in statistics literature, curriculum documents or pedagogical resources for early school learning. This section aims to provide a definition that is relevant for studying

young children's statistical reasoning as they begin statistical learning at school. With the exception of the GAISE Report (Franklin et al., 2007), little attention has been paid to what defines the core characteristics of statistics as a discipline and how a definition might translate into providing statistical learning experiences for children in their first year of school. Endorsed by the American Statistical Association, the GAISE Report (Franklin et al., 2007) sets out a Pre-Kindergarten to Year 12 Curriculum Framework for statistics instruction and assessment and was the key document drawn on for the development of the Statistics and Probability strand in the *Australian Curriculum: Mathematics* (ACARA, 2013). The GAISE Report emphasises the need for a clear understanding of the differences between statistics and mathematics in order to conceptualise the statistics curriculum as "cohesive and coherent" (Franklin et al., 2007, p. 5). The GAISE Report highlights that the difference between mathematics and statistics lies in statistics' focus on variability in data and the role of context. The emphasis on the difference provided by the GAISE Report affords additional justification for identifying the distinctions between the two disciplines for the purposes of this study.

There are surprisingly few clear or explicit definitions in the literature of what defines core characteristics for statistics as a discipline. Kempthorne (1980) states, "there can be little agreement on how to teach statistics unless there is some agreement on what statistics is" (p. 18). Often what appears to be valued as fundamental characteristics in statistics is implied or woven disjointedly through statements about the value, purpose or aims of statistics and/or statistics education. The defining concepts of statistics are couched within categories of "statistical thinking", "statistical reasoning" and "statistical literacy" all of which are processes that action statistical concepts and content. A review of this literature provided signposts to the core characteristics of statistics that resulted in a definition of statistics for the purpose of this study. These characteristics are handling data, variation, real world problem solving and data context, task context and inductive reasoning. In order to provide definitional clarity and research focus, each of these characteristics are now examined. The identified core characteristics formed a theoretical base for this study's exploration of the key aspects of the knowledge and reasoning young children bring to statistical problem solving.

2.3.1 Handling Data

Handling data is central to statistical problem solving as according to Moore (2006), "statistics is about data" (p. xxi) and handling data is about using "a coherent set of ideas and tools for dealing with data" (Moore & Cobb, 1997, p. 801). There are various processes applied to data as it is handled to enable an answer to be found to a statistical question, and data handling processes enable the variability and uncertainty inherent in data to be balanced and quantified (Moore, 2006). Statistics is a methodological discipline and statistical concepts and organising principles for handling data are used to produce, represent, analyse and draw inference to answer a statistical question. There are many concepts and organising principles in data handling that include the types of terms that may be readily associated with statistics, such as sampling, centre, spread, distribution, measurement, graphing and probability. These concepts and principles are applied in order to come to a reasonable, evidenced conclusion about the data and so answer a contextualised question (Moore, 2006).

Young children's statistical experiences and learning therefore should engage handling data. Handling data does not require advanced mathematisation. Research suggests that young children's capacity to produce, organise, analyse and draw inferences from data is available developmentally from a young age (Goswami & Bryant, 2007). The issue for research in statistical learning is how data handling experiences for children are structured and afforded. Handling data engages variation and variability, which is inherent and omnipresent in data (Moore, 1990) and therefore inherent in statistical problem solving.

2.3.2 Variation and Uncertainty

Variation and uncertainty are statistic's most distinguishing features (Franklin & Garfield, 2006) and are complex concepts. Probability is the mathematical field that is used to quantify variation (Moore, 1990; Nikiforidou & Pange, 2010). It is not within the scope of this study to explore the definitions or mathematical management of variation in statistics. The importance of variation for the purposes of this study is that variation gives rise to uncertainty in statistical outcomes. Variation occurs inherently for example, in what is being measured, in the

way measurement is carried out, and in data sampling processes. Young children therefore engage with variation as they measure through actions such as sorting and classifying. Reading and Shaughnessy (2004) note the interchangeable use of "variation" and "variability" in the literature and distinguish between the two terms, defining variability as the observable varied characteristic of an entity, and variation as the description or measurement of that characteristic. Reading and Shaughnessy's distinction is valuable for research with young children when the observed variables in data may be found in the physical or sensory properties of objects they engage with.

The unpredictable presence of variation in data is the area in greatest need of specific instruction in statistics education (Moore, 1990). Variation is intimately coupled with the role of context in statistical problem solving (Franklin & Garfield, 2006) as where a statistical problem is situated, its real world setting, determines the source of the data. Data are inherently variable and are the source of uncertainty that has to be handled and quantified. Accordingly, the real world setting of a statistical problem contextualises the data that children work with in a statistical problem and engages variation. Variation is therefore central to statistics and has the potential to profoundly influence the reasoning processes children employ when solving statistical problems. Young children should be exposed to experiences that enable them to begin to understand the nature of variation and the impact it has on their decision making processes (English, 2009, 2012).

2.3.3 Real World Problem Solving and Data Context

Real-world problems provide the impetus for, and end point of, the statistical problem solving process. Statistics is used to solve, describe, measure and understand real-world problems (Schaeffer, 2006; Snee, 1988). When variation is encountered in a real-world problem it "makes sense only in the context in which it occurs" (Watson, 2006, p. 63). A real-world problem supplies the setting for the problem, and at the same time, engages the problem-solver's real-world knowledge of that setting as he or she finds a solution. The relationship between the real-world origin or setting (context) of a problem and the statistical concept of 'context' creates a definitional conundrum, as each serve to define the other. The interdependence of real-world context and statistical problems is evidenced by Langrall, Nisbet, and

Mooney's (2006) definition of statistical context as "real world phenomena, settings or conditions from which data are drawn or about which data pertain" (p. 1). The definition highlights that as a statistical problem is based in the real-world context, all data needed to solve the problem pertains to, and is drawn from, the real-world context.

The *data context* is the setting of a statistical problem that contextualises the data. Data context is a core concept that shapes statistical reasoning and thinking processes, because "data have no meaning when separated from their context" (North & Ottaviani, 2002, p. 1). Data collected in order to solve the problem, "engage our knowledge of their context so that we can understand and interpret, rather than simply carry out our operations" (Moore, 1990, p. 96). Young children engage their existing knowledge of the setting for a statistical problem and their experiences of the world, including knowledge of the way data has been created, defined and measured, to find a problem solution (Pfannkuch, 2011). Data context provides meaning for the data and so becomes the framing structure for data analysis and reasoning (Cobb & Moore, 1997; Garfield & Ben-Zvi, 2007; Rossman et al., 2006). The need for context is in direct contrast to mathematics, where the context of a problem is inevitably obscured or irrelevant to finding a solution to a problem. As statistical problems are always drawn from, and therefore always situated within a context, statistics has been described as a "servant discipline" (Wild & Pfannkuch, 1998, p. 336). Put simply, statistical analysis cannot occur without considering the data context. Where data context and interpretation of that data meet is a flashpoint for statistical reasoning, and research that focuses on statistical reasoning must therefore forefront data context.

2.3.4 Task Context

Task context is "the presentation of data or the way they are encountered" (Langrall, Nisbet, Mooney, & Jansem, 2011, p. 50). The task context influences the way data are approached, engaged, analysed and interpreted by students and hence how statistical problems are reasoned and what knowledge is engaged to find a solution. The literature draws attention to the multiple dimensions of task context and their influences on *statistical* analysis and reasoning. Studies have found that context for a statistical problem is more than the data context, and includes the task context.

Pfannkuch (2011) draws from the work of Hershkowitz, Schwarz, and Dreyfus (2001) to distinguish between "data context" and "learning-experience-contexts" in learning informal inferential reasoning. Task context, as part of the learning-experience-context includes "task sequence and motivating story" (p. 28) as a key influence in impacting and facilitating statistical reasoning. The presentation of a task has a role in students' task perception and so task context can influence student engagement and reasoning (Langrall et al., 2006).

The attention given to role of the task context in statistical learning is recent in the statistics literature, however it is a key defining characteristic for the purpose of this study, as the interrelationship between the data context and the task context in statistical reasoning are considered pivotal. Task context is expanded on later in this chapter in the section pertaining to Models and Modeling (section 2.4.2.1, p. 39).

2.3.5 Inductive Reasoning

As previously presented in section 2.2 (p. 27), one of statistics' primary defining qualities is inductive reasoning from uncertain data that is, reasoning about variation that is inherent in the data. Drawing inferences is a core process in statistical problem solving and requires making decisions that extend beyond the immediate data to a broader context and so engages inductive reasoning (Paparistodemou & Meletiou-Mavrotheris, 2008). Scheaffer (2006) points out that the principal differences between mathematical and statistical reasoning is most apparent in inferential statistical analysis when reasoning is done from evidence that does not necessarily have an explainable cause. Conclusions to be drawn in statistical problems are based on quantitative results, but the answers are not necessarily straightforward or certain (Gattuso, 2006). Inductive reasoning is the process used to come to uncertain but reasonable conclusions from analysis of the data, and conclusions reached must be informed by and defensible by the evidence available from the statistical data (Rossman et al., 2006). Different yet reasonable conclusions can be drawn from the same data. Accordingly, inductive reasoning relies on and draws from statistical data to make judgments, be they decisions, predictions or generalisations.

2.3.6 Contextualising Statistical Reasoning: Data Context and Task Context

In the previous sections, core characteristics of statistics have been identified to provide a definition of statistics for this study. In this study it is argued that young children's learning experiences for statistical reasoning must place this definition of statistics at the forefront of the learning experience. In summary, a statistical learning experience for young children beginning formal school requires considering how data is contextualised. It must provide an opportunity to handle data and so work with variation that exists within the data. A statistical problem must be drawn from a real world context and facilitate the use of inductive reasoning. The task presentation of the statistical problem needs to have a sequence and motivation that facilitates statistical reasoning. Research on young children's statistical reasoning must engage those core elements of statistics and explore the interdependency of statistical problem solving, problem context and task presentation.

With these defining characteristics and the research purpose in mind, two contexts are identified. First, the *data context* of a statistical problem. Data context connects all core statistical characteristics identified in the previous sections; it generates the problem to be solved, it provides the data to be handled, it is the source of variation and it serves as a source of knowledge for finding an answer to the initiating question. Second, the *task context* for the statistical problem. The task context situates the data context, and provides the content, structure and sequence of the statistical problem to be solved. The task context influences engagement with the statistical problem and has the potential to impact the type and use of knowledge and reasoning young children bring to finding a solution.

The data context and task context inform the core argument in this study; that understanding the value and impact of context when the core concepts of statistics as a discipline are engaged in statistical problem solving is needed to support research to understand statistical reasoning for young children beginning school. In the following sections the theoretical and pedagogical issues that influence young children's statistical reasoning are presented and reviewed. These issues are; (a) theoretical approaches to young children's statistical problem solving; (b) children's use of reasoning, knowledge and context in statistical problem solving; and (c) engaging statistical context through task design.

2.4 Statistical Problem Solving

Central to conceptualising statistics education for young children is how to frame the definition of statistics in statistical problems that are both accessible to young children beginning school and trigger children's use of statistical knowledge and reasoning processes. The following section introduces statistics as a problem solving investigation that captures the definition of statistics used in this study. Next, the Models and Modeling perspective (Lesh & Doerr, 2003) is presented as a theoretical framework that provides a conceptual and pedagogical alignment between statistical problem solving investigations and task designs that enable young children to access and engage with statistical reasoning.

2.4.1 Statistical Problem Solving as Data Investigation

A "data investigative cycle" or "problem solving process" as a basic model of question, data collection, data analysis and data interpretation has been described as a "generic thinking process" (Wild & Pfannkuch, 1999, p. 231) and "a framework to build and develop statistical problem-solving" (Fielding-Wells, 2010, p. 1). Descriptions of statistical problem solving as data investigation engaging a cycle or problem solving process appear widely in the literature (e.g., Franklin et al., 2007; Friel, O'Conner, & Mamer, 2006; Holmes, 2000; Wild & Pfannkuch, 1999) and there is more similarity than difference among the available proposed models (Fielding-Wells, 2010).

In statistical problem solving, multiple decisions need to be made in order to process the investigation, such as deciding what attributes to measure, how to collect and display data and how to analyse and interpret the data. The inferential aspect of statistics in particular, is about interpreting data to draw evidenced conclusions that extend beyond the immediate, available data (Makar & Rubin, 2009). Inference goes beyond the available information and so, by definition, engages inductive reasoning. Engaging with statistical inquiry processes therefore involves attending to data and data context, and engaging statistical reasoning activities (delMas, 2004; Wild & Pfannkuch, 1999). Research that explores statistical experiences with all processes in a data investigation with young children beginning formal schooling however, is limited. At the time of this study, with the exception of Lehrer and Schauble's

(2006b) data modeling work with 4 and 5 year olds and English's (2010, 2011, 2012) data modeling work with 6 and 7 year olds, there were no further studies that engage 5 year old children as they begin formal schooling with statistical problem solving as an investigative process that incorporates data collection, data analysis and data interpretation. In addition, existing studies have not focused on the role of data context and task context on young children's statistical reasoning as they find a solution to a statistical problem.

2.4.2 Models and Modeling Perspective

The Models and Modeling theoretical perspective [Models and Modeling] (Lesh & Doerr, 2003) is a conceptual framework that theorises that children are developing conceptual schemes or models as they make sense of their world. In this study, the use of the term "mathematics" found in and referred to in Models and Modeling literature includes statistics. Models and Modeling focuses on the way that conceptual tools and knowledge are developed and used by individuals and groups to interpret and inform real-world problem solving in ways that are re-useable in other contexts (Lesh & Doerr, 2003). Models are created, interpreted and re-interpreted for making sense of experiences, and the process of creating and interpreting new experiences engages representational behaviour (Lesh & Doerr, 2003; Mousilides, Sriraman, & Christou, 2007). Initiating young children into modeling activities that reflect the mathematical systems embedded in their social environment provides access to recognising, interpreting, evaluating and assessing such systems (Mousilides, et al., 2007). Statistics is one such system where children should have opportunities to create, organise, interpret and analyse using data in contextualised statistical problems. For statistical competency to flourish, children's conceptual systems need to be challenged, tested, and revised (Lesh & Lehrer, 2003). For researchers, understanding statistical reasoning can be achieved by examining how experiences can be structured to reveal children's existing conceptual thinking.

Young children develop primitive models to make sense of their everyday experiences, including statistical experiences (Lesh & Doerr, 2003). Pedagogical activities that seek to connect complex concepts to children's existing statistical experiences through *modeling* are rarely part of the school curriculum experience (Swan, Turner, & Yoon, 2007). Young children's school instruction with respect to

core mathematical and scientific ideas is either delayed or neglected because they are not ordinarily considered to have the basic skills or concepts deemed necessary for learning disciplinary specific concepts (Lehrer & Schauble, 2006b). Despite available research on young children's capacities for acquiring, developing and reasoning with a modeling approach to learning (English, 2010, 2011, 2012; English & Watters, 2005; Lehrer & Schauble, 2006b) there were no further studies on using modeling with children at school below the age of 6 years.

Young children are capable of accessing, and should have access to important powerful mathematical ideas in their educational environments (Australian Association of Mathematics Teachers and Early Childhood Australia, 2006; Clements & Sarama, 2004; Lehrer & Schauble, 2006b; Perry & Dockett, 2008). Young children possess powerful statistical ideas, including problem solving, data and probability, that should inform and support the inclusion of statistical ideas in mathematics research (Hunting, Mousley, & Perry, 2012; Perry & Dockett, 2008). Access to important and powerful mathematical ideas, including statistical ideas, should therefore be reflected in the types of problem solving activities young children engage with in classrooms. Models and Modeling is positioned to theoretically support researching young children's statistical learning in a way that is cognisant of existing competency and potential to engage in complex ideas. In addition, Model and Modeling tasks are designed to shift attention away from computation and towards statistics as a thinking process that involves conceptualisation, description and explanation (English, 2006) and encourages sense-making in problem solving (Doerr & English, 2003; Greer, Verschaffel, & Mukhopadhyay, 2007). Models and Modeling provide a framework for accessible statistical learning opportunities for young children beginning school, including principles of task design to inform the content and structure of the task context.

2.4.2.1 Task design and contextualised problem solving.

Task design in statistics plays a critical role in the contextualising of the statistical problem as they engage a real-world context. The types of problem solving activities that children encounter at school generally disregard the connection that should be forged between a child's real-world knowledge and experiences and possible solutions to problems (English, 2003a). Typically, mathematical problem

solving activities encountered at school are removed from a real-world context (Lesh & Doerr, 2003), however, statistical problems must by definition, engage real-world data contexts.

Modeling problems support real-world problem connections as, under the principles of their design, they use realistic contexts to authenticate and frame the problem (Mousoulides, Sriraman, & Christou, 2007). Models and Modeling problem solving activities are constructed using principles of instructional design (Lesh & Doerr, 2003; Kaiser & Sriraman, 2006). Modeling tasks are purposefully designed to be relevant to students' worlds and to motivate and interest them in expressing their understanding and inferences (Doerr & English, 2003). Model-eliciting activities, sometimes referred to as "thought revealing activities" (English & Watters, 2005, p. 60) provide meaningful, engaging real-world problems and design problems that need to be mathematically described and interpreted in order to expose the nature of children's mathematical thinking and conceptual development (Lesh & Doerr, 2003). The design qualities of modeling activities support researchers and educators to understand and assess mathematical problem solving (Lesh, 2006). Modeling activities can therefore actively accommodate and connect to the need for real world problems found in the statistical definition determined for this study.

Model and Modeling problem activities are non-routine problem situations that employ instructional principles designed to elicit the development and extension, exploration and refinement of significant mathematical constructs (Lesh & Doerr, 2003). Kennedy (2009) notes that solving non-routine problems moves away from "correct answers" and requires strategic and careful problem solving management that can focus children's attention on processes, conceptual connections and structure. Approaching problem solving as a process with conceptual connections corresponds to the intellectual method advocated for statistical learning (Moore, 1998) and the multiplicity of possible outcomes from solving statistical problems identified by Gattuso (2008) earlier in this review. The design of a problem solving task therefore forges a conscious link between the theorised learning processes considered in the Models and Modeling perspective and its associated pedagogical activities. Embedding core mathematical constructs that are "mathematically generative" is a central principle (English, 2003; English & Watters, 2005). As a

result, the key mathematical ideas are not presented "up front" in modeling problems, but are "embedded within the problem context and are elicited by children as they work the problems" (English, 2006, p. 96). As well as embedding the mathematical ideas in the problem, there is an accompanying requirement for children to explain and justify the models to others in the learning environment (English, 2006). This form of modeling activity is conceptually available to young children, and allows them "to access mathematical ideas at varying levels of sophistication" (English & Watters, 2005, p. 93) and in doing so, emphasises a heuristic approach compatible with current constructivist approaches to early childhood education (Perry & Dockett, 2008).

2.4.3 Data Modeling and the Task Context for Statistical Problem Solving

Data modeling is a specific element of the Models and Modeling perspective, where the focus of the modeling system being explored is data and how they function in solving real-world problems. The concept of data modeling has emerged predominantly from the work of Lehrer and Schauble (2000, 2002, 2006, 2007). Drawing from the theoretical framework of the Models and Modeling perspective, data modeling engages the construction and use of data and proceeds on the basis that modeling practices will be invoked when children are engaged in thinking about data (Lehrer & Schauble, 1996). Data modeling is the process where data are constructed, analysed, and used to find solutions to real-world problems (Doerr & English, 2003). Data is progressively "mathematised" as a means of coming to understand objects and phenomenon and where the emphasis is on embedding data in contexts of genuine inquiry, both in the data modeling task and in the learning environment in which it is set (Lehrer & Schauble, 2002, p. x). As an element of Models and Modeling that specifically focuses on the statistical processes that are engaged in when data is handled, data modeling is an " important and useful class of empirical thinking tasks" (Lesh, Middleton, Caylor, & Gupta, 2008, p. 115).

Lehrer and Schauble (2000) claim that reasoning about data occurs when learners are asked to construct and revise models arising from data modeling tasks. Statistical reasoning emerges from, and is enmeshed within, data modeling (Lehrer & Schauble, 2003) as data must have structure imposed on it (Lehrer & Schauble, 2002). Statistical processes, including reasoning are triggered when children are

engaged in a problem activity that necessitates generating, testing, and revising their ideas as they process data to come to a solution. Data modeling can be viewed as a starting point for engaging statistical reasoning as a developmental process (Lehrer & Schauble, 2005). Based on Lehrer and Schauble's (2004) model, as shown in Figure 2.1, data modeling comprises related systems of activity.

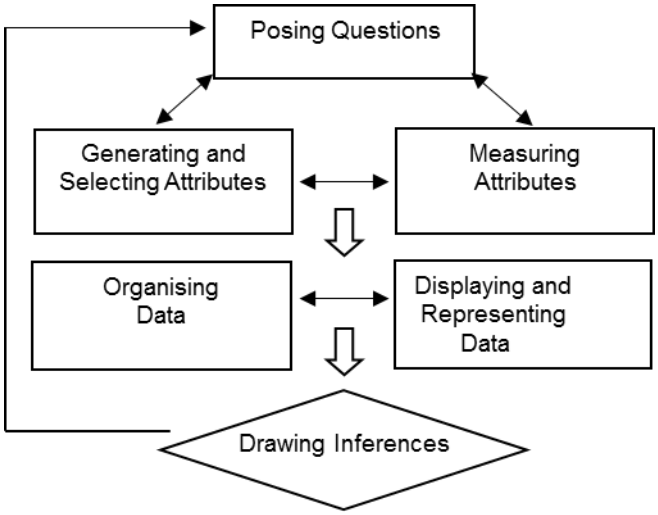


Figure 2.1 Components of data modeling (adapted from Lehrer & Schauble).

Data modeling revealed in Figure 2.1 is a model of cyclical inquiry where the investigation requires decisions about what attributes need to be measured and how that can be achieved. Following these decisions is the requirement to structure, organise, represent and analyse the data to identify relationships and patterns. The data modeling process is akin to the generic model of statistical investigation reviewed in section 2.4.1 (p. 37) that engages a basic model of question, data collection, data analysis and data interpretation. Lehrer and Schauble (2002) note that children also learn that the data modeling cycle can be used to predict or infer from existing data or other related cases. Therefore, the generation, testing, and revision of models in the data modeling cycle lies at the core of statistical reasoning.

Primary school children's data experiences are usually traditional word problem tasks and data modeling is something they do not commonly engage in (Doerr & English, 2003; Lehrer & Romberg, 1996), although primary school children are able to meaningfully engage with problems that involve complex data systems (English, 2008b, 2009, 2010, 2011, 2012). Data modeling concepts are

particularly accessible to young students because they involve concepts and skills that are "mostly straightforward extensions of basic ideas" (Lesh et al., 2008, p.116) and so are an accessible means of engaging young children in the processes of handling data. The accessibility of data modeling can be attributable to it being based on the premise that children have capability and competency in using their existing knowledge and reasoning skills to take actions and develop models that will organise data and solve a data modeling problem. By recognising and providing means for young children to access and demonstrate their capacity and competency, data modeling is well suited to early childhood mathematical experiences (Perry & Dockett, 2008).

Research focused on children's engagement with core statistical concepts and reasoning processes is able to utilise the theoretical and methodological framework of Models and Modeling, as data modeling, to explore the knowledge and reasoning young children bring to statistical problem solving. Task design, including task context is "a key feature of data modeling" (English, 2011, p. 3). The principles of design for modeling activities developed from the Models and Modeling framework enable data modeling to be presented in a task context that stimulates statistical processes and reasoning. The nature of task context and how it engages statistical reasoning is a central concern in this study, and is supported by modeling learning theory and task design principles. The component parts of the data modeling process seen in Figure 2.1, (p. 43) the *design* and *analysis* systems are considered next.

2.4.4 The Design System in Data Modeling

Within the design system of data modeling, data are created. The process of analysing data however, is involved in all aspects of a data investigation, that is, analysis occurs in the design system *and* the systems that analyse and interpret the results (Schaffer, 2006). While acknowledging the centrality of data analysis and interpretation in a statistical investigation (Hogg, 1991; Snee, 1988, 1993), the design and implementation of an investigation is considered one of the main functions in statistics (Kempthorne, 1980). Hancock, Kaput, and Goldsmith (1992) describe data production in a data investigation as "the neglected counterpart of data analysis" (p. 339). In data modeling, the design system engages data production through generating, selecting and measuring attributes and representing, organising and

displaying data (Lehrer & Schauble, 2007a). Reasoning and statistical processes engaged in data design are reviewed in the following sections, and these include measurement in data production, and data representation.

2.4.4.1 Measurement in data production.

Measurement that occurs in data production involves critical but undervalued analytical statistical reasoning. In statistics, measurement depends on valid measures of the properties being studied, many of which are hard to measure accurately (Rossman et. al., 2006). The result of measurement in statistics determines how data are analysed and the scope of conclusions that can be drawn. This is because the reliability and relevance of a conclusion reached through analysis is dependent on the reliability and relevance of the data used for analysis (Hancock, et al., 1992). The emphasis in data analysis in the *analysis* system is on the consequences of measurement, not on the measurement processes themselves that led to the production of the data being analysed that occur in the *design* system. Measurement that occurs in the design system is therefore a critical component of data production. For the purpose of this study, measurement occurs as data are produced when attributes are generated and selected to form categories and classification of objects into categories is made. In light of the undervalued but critical role measurement plays in data production, this study aimed to identify young children's reasoning and knowledge during the process of measurement.

Generating and selecting attributes results in the construction of categories. Classifying, that is, assigning objects to constructed categories, is a means of measuring selected attributes (Lehrer & Schauble, 2007). Once a category is developed, classification requires a determination of whether the characteristics of an object share the attributes assigned to the category (Sandberg & McCullough, 2009). The construction of categories and classification of objects into categories are forms of analysis of the sample objects and events worked with in a statistical problem. The analysis occurs because decisions have to be made first, about attributes that *could* be generated and selected to form criteria for the assigned categories, and second, *how* to classify objects using those attributes as a measure (Van de Walle, Karp, & Bay-Williams, 2013). Although measurement is a mathematical process, the focus in statistical problem solving differs, as the data context must be considered (Rossman

et al., 2006). The generation, selection and measurement of attributes for data production engages analysis of the sample data, as categories or objects, and that analysis of data requires knowledge of the context for the problem, be drawn on and used. The measurement process in statistics, accordingly, should engage the data context.

Concurrently during measurement, sample data collected for categorisation and classification are subject to different types of variation (Snee, 1988). Although variation and acting to take it into account are considered critical to the statistical inquiry process (Pfannkuch, 1997; Wild & Pfannkuch, 1999), the role variation plays in reasoning, and the use of data context during *design* system activities when variation is encountered, appears underplayed in the existing literature. Statistical decision making is dependent on making sense of and explaining the variability in data (Franklin & Garfield, 2006). Categorisation and classification of events and objects resulting from decisions about attributes would also involve decisions about variation. Those decisions involve uncertainty (Moore, 1990) and therefore, as the decisions involve working with uncertainty generated by variation, inductive reasoning must be employed in the process of attribute decisions in statistical reasoning.

Categorisation, classification, and the reasoning processes they engage are intimately connected to the design process in data modeling through their role in attribute reasoning. Although there are various theories of categorisation (Kruschke, 2005), in general, categorising has been described as a primary means of organising experiences that promotes inference by using past experiences to extend knowledge into the future (Gelman & Meyer, 2011). Goswami and Bryant (2007) have argued that categorisation is statistical learning when statistically structured prior events are compared with subsequent stimuli. Through inductive processes, reasoning moves from specific to general, by using a known example from prior experiences to form a generalisation, inference or analogy (Goswami, 2011). Lehrer and Schauble (2002) propose that it is children's propensity to categorise that provides a foundation for reasoning about classification. The importance of measurement in statistical investigation underlines the significance of understanding the reasoning and knowledge young children employ when they are engaged in categorising and

classifying as they measure to produce data. This study aimed to examine the knowledge and reasoning processes brought to the generating, selecting and measuring attributes as measurement in the design system of data modeling.

2.4.4.2 Data representation.

Children's representation of data has not been widely studied, although the difficulties of data representation are known (Chick, 2003). Data representation, which underpins the use of graphs, is a critical tool for statistical problem solving (Watson & Fitzallen, 2010; Watson & Moritz, 2001) and is a springboard for symbolic abstraction in mathematics (Leinhardt, Zaslavsky, & Stein, 1990). Determining the structure of data and displaying data are connected as data representation, as the process of representing data "both reflects and instigates new ways of thinking about data" (Lehrer & Schauble, 2007a, p. 157). In order to represent data, children engage in making decisions about how to group and order data, that is, they organise it. Several studies of children from grades one to five highlight the connection between the children's category and classification reasoning, and their display of data. The ability to find order in the data appears to be a necessary requirement to the creating a visual display of data, and not having objects to manipulate may contribute to difficulties in finding groups for young children (Jones et al., 2000; Nisbet, Jones, Thornton, Langrall, & Mooney, 2003). A further study by Jones et al. (2001) with Grade 2 children found that children were reluctant to use paper and pencil to reorganise data, especially categorical data, and had limited access to sorting and organising schema for representation. The reorganisation of the raw data was described overall as "tortuous" for the children (p. 128). The study of data representation is therefore critical, particularly as graphing has been viewed as a marginal topic in elementary school mathematics (Leinhardt, Zaslavsky, & Stein, 1990).

Children's graph comprehension and interpretation is developmental and is context and task dependent (Curcio, 1987; Friel, Bright, & Curcio, 1997). Konold, Higgins, Russell, and Khalil (2004) examined different ways that children attend to reading or analysing data. They identified perspectives that children tend to use to view data: as classifiers (frequency of cases with similar values are combined), case value (data is associated with an individual case), and pointers (data represents the

whole event that generated it), noting that statistical thinking relied on seeing data as an aggregate or whole. The different perspectives on how children perceive data identified by Konald et al. (2004) can inform examining young children's handling of pictorial data representation, particularly as research on children's representations of data as pictures has received even less attention than other forms of graphing (Watson & Moritz, 2001). Existing studies have not provided opportunities for children in the first year of formal schooling to organise and display picture data to represent it using their existing knowledge and experience in the absence of prior formal instruction. This study aimed to explore young children's representational practices with data when solving statistical problems.

Children arrive at school with prior-to-school mathematical knowledge and a variety of symbolic capacities from their experiences that can be used to represent their world (Lehrer & Schauble, 2006), including gesture (Cook & Goldin-Meadow, 2006). The term meta-representational competence (MRC) is used to explain children's capabilities and knowledge in constructing and using external representations, particularly prior knowledge or "intuitive ideas" that children bring to their formal learning (diSessa, 2004; diSessa, Hammer, Sherin, & Kolpakowski, 1991; diSessa & Sherin, 2000). Research in MRC shows that young children's intuitive understanding is rich and their prior intuitive ideas "are a critical resource that we should understand in detail for its theoretical and practical import in learning" (diSessa & Sherrin, 2000, p. 386). Studies of MRC however, fall predominantly in middle and upper primary grades and high school. Research using data modeling activities has found meta-representational competence in Grade 1 children (English, 2010, 2012). This study aimed to further empirical investigation into MRC, by exploring meta-representational competence with young children who are commencing their first year of formal schooling.

Children's early representational systems form the foundation for engaging in representing their world and "often have their start in fundamental symbolic capacities of pretence or imitation and in basic inscriptional capacities such as drawing" (Lehrer & Schauble, 2006, p. 158). Children's inscriptions play a role in the development of mathematical knowledge and learning (Terwel, van Oers, van Dijk, & van den Eeden, 2009) and have been described as "the act of highlighting

aspects of our experience and communicating them to others and ourselves" (Enyedy, 2005, p. 427). Inscription and conceptual development both support each other and develop concurrent opportunities for model based reasoning and opportunities should be provided across the mathematics curriculum, including working with data (Lehrer & Schauble, 2003).

From a Models and Modeling perspective, symbolic capabilities as representational competence are revealed in the systems of representation or inscription found in models students produce (Lehrer & Lesh, 2003). Lehrer and Lesh view inscription as a mediator between mathematical activity and reasoning. Model-eliciting activities are designed to challenge children to mathematise real-life situations and in doing so, they make "heavy demands on learner's representational capabilities" (Lesh & Doerr, 2000, p. 367). Lesh and Doerr (2000) reason that the processes involved in learners mathematising real-life situations focus on symbolically describing situations that are already meaningful. The Models and Modeling approach to mathematisation as an impetus and pathway to symbolic representation contrasts with more typical school mathematics problems, where the questions provide explicit symbols and the aim for the student is to find meaning in the question. Models and Modeling activities for young children inherently value the forms of symbolisation that young children employ to produce models when problem solving, which are considered valid descriptions of the mathematics they represent. This study aimed to examine young children's representation as models to gain understanding of the symbolic knowledge that children brought to statistical problem solving.

2.4.5 The Analysis System in Data Modeling

Within the analysis system of data modeling, data is analysed and interpreted and inferences are drawn. Analysing and interpreting data is described as "the core of statistical reasoning" (Jones et al., 2005, p.103) that requires finding connections to and relationships in the data. In the analysis system, inference interacts and co-ordinates with data structures and representations to find a logical solution to the problem (Lehrer, Kim, & Schauble, 2007; Lehrer & Schauble, 2007a). The inferential processes engaged in the analysis system "close the loop between data and the world" (Lehrer & Romberg, 1996, p. 70). Reasoning and statistical processes

engaged in data analysis are reviewed in the following sections, and these include inferential reasoning and explanation, and prediction.

2.4.5.1 Inferential reasoning and explanation.

Inference and explanation are interconnected and mutually supportive. Explanations can reveal knowledge relied on and internal processes and sense-making used in reasoning, including the role of context knowledge (Gil & Ben-Zvi, 2011). Many of the "habits of mind" for statistical thinking can be developed through activities that encourage communication about data being handled and children's own knowledge, ideas and understandings (Chance, 2002). The ability to make and defend a statistical decision is something that young children should be engaging with early and frequently from the commencement of their formal schooling and statistical learning.

Abductive reasoning has generated recent interest in statistics research as it reflects an inductive reasoning process in statistics where generalisations from a sample to a whole are used to determine a value for the data in the broader context (Ben-Zvi, Aridor, Makar, & Bakker, 2012). Abductive reasoning, a term developed by C.S. Peirce in the 1930s, is broadly defined as a description from data that accounts for and seeks to explain the data using relevant evidence, or reasoning towards a hypothesis (Honderich, 2005). It is in essence an informed guess that provides the best explanation for data, given analysis of the available information, and is reasoning towards a hypothesis that begins with data (Fann, 1970).

The interest in abductive reasoning in statistics research has stemmed from the role it plays in the development of informal inferential reasoning, a critical process in statistical analysis. Inferential generalisations that provide a contextually based explanation or hypothesis to account for data can be explained by abductive reasoning and so this form of reasoning acts as an extension of inferential reasoning (Ben-Zvi, Makar, & Bakker, 2009; Gil & Ben-Zvi, 2011). The nature of inference is to seek connections between information we have and what we already know, and abductive reasoning generates theories or hypotheses by relying on identification of anomalous differences and analogous similarities (Chiasson, 2005). Abductive reasoning takes into account that when the knowledge an individual possesses does

not explain what is seen, an explanation will be actively sought (Cunningham et al., 2005). Young children beginning formal schooling are limited in their life experiences by the number of years they have been alive, and so the range of knowledge and conceptual understanding available to them impacts on the range and depth of explanations that are knowledge based. Abductive reasoning may be the form of reasoning most readily available to young children and be visible as they engage in statistical problem solving, particularly when they encounter variation or data that is inexplicable.

2.4.5.2 Inference as prediction.

Probability (as expected variation), prediction (as expected outcome), variation (as uncertainty) and inference are integrated in statistics. Probability quantifies or describes random variation that cannot be explained by causal relationships (Langrall & Mooney, 2005). Outcomes for uncertain phenomena however, have observable random order over repeated measurements, and the mathematical description of measured randomness is probability (Moore, 1990). The presence of variation in data however, is about the presence of uncertainty, and is accompanied by difficulties in assigning causes or explanations about its cause. If relationships or patterns in data cannot be found, prediction about outcomes can be made from the data that are an estimate based on existing, observable variation (Wild & Pfannkuch, 1999). Probability can quantify the likelihood of something happening based on existing data. Prediction on the other hand, is about determining an outcome based on existing data, without necessarily quantifying the likelihood or determining why. The ability to predict results from being able to model and interrogate variation (Reading & Shaughnessy, 2004) and is facilitated by the ability to read data representations (Curcio, 1987).

As a response to graphical analysis, prediction engages increased complexity in reading data representations (Curcio, 1987; Friel et al., 1997). Research on young children's data prediction is limited. The available studies use tasks that required children to predict from graphs (Asp, Dowsey, & Hollingsworth, 1994 (Grades 4, 6 & 8); Moritz & Watson, 1997 (Grades 3-9); Watson & Kelly, 2002 (age 6 years); Watson & Moritz, 2001 (Preparatory to Grade 10); Watson, Moritz, & Pereira-Mendoza, 1998 (Grade 6)). Overall findings from these studies were that prediction

was generally difficult to make and explanations for predictions were speculative or drew from personal knowledge. In a study of six year olds predicting from a data table however, English (2012) found that children were able to identify and draw inferences from data to make predictions. There is a need for research to gain understanding of what knowledge young children bring to prediction activities and what aspects of task design support prediction that do not engage graphical representations.

Probability is a complex construct, and the theoretical construct of probability and intuitions people have about how the world functions, including children, can conflict. The conflict between probability theory and intuition is partially because of limited contact with orderly, randomised variation in mathematics curriculum (Moore, 1990). Early experiences that children have at school with artificial chance devices, such as dice and coins, can lead to the development of specific, deterministic reasons for chance events (Moore, 1990). Experiencing and recognising natural variation, that is, "variation that occurs through the diversity of human experience" (Torok & Watson, 2000, p. 147) is foundational to understanding concepts that underpin statistical reasoning with variation (Pfannkuch, 1996; Wild & Pfannkuch, 1999). Natural variation is variability that is "inherent in nature" (Franklin et al., 2005, p. 6), as opposed to variability generated by artificial chance devices. Working with natural variation is about seeing that chance, not just deterministic reasons can explain the existence of variation and that both explanations can be mathematically described as probability (Moore, 1990; Torok & Watson, 2000). The origins of understanding and intuitions about natural variation with young children are under researched (Torok & Watson, 2000; Shaughnessy, 2007), reflecting the emphasis on artificial chance devices that begin probability learning at school and in prior research. Much of the research on probability with young children that engages theoretical probability of events has used decontextualised, experimental learning tasks that focus on the likelihood of an event occurring (Greer, 2001). Schwartz and Goldman (1996) note that "probability instruction relies on explicit chance devices" (p. S100), and the focus on chance devices is found in much of the probability research.

Studies on young children's probabilistic reasoning have built on the work of Fischbein (1975) and the concept of young children's intuitions about probability. Intuitions are subjective, described as "a feeling of obviousness, of intrinsic certainty" (Fischbein & Schnarch, 1997, p. 96) that are either *primary*, that is, intuitions that have developed from experiences outside of systematic instruction, or *secondary*, that is, intuitions that have developed from systematic instruction (Fischbein, 1975). Statistics and probability were closely linked by Fischbein and he stated that:

> Stochastic experience is to probability what spatial experience is to geometry…The construction of the concept of probability starts from specific experiences which are stochastic in character, and whose events are inventoried according to a logical connection. (p. 16)

Fischbein's work emphasises that intuitive probabilistic reasoning develops from experiences with human behaviour, where estimations, prediction and random events are engaged. Intuitions appear at moments of "insight", where someone engaged in problem solving "anticipates the solution to a problem before the detailed steps of the solution have been found" (Fischbein, 1975, p. 117). Between 4 and 7 years of age, tasks can engage children's intuitive, informal understandings of probability in the absence of prior formal instruction (Mousoulides & English, 2009). Young children however, tend to use deterministic and subjective knowledge to judge or reason about random events in ways that affect probabilistic understanding (Jones, Langrall, Thornton, & Mogill, 1997; Langrall & Mooney, 2005). Research suggests that young children's intuitive responses may be influenced by visual perception in the task (Nikiforidou & Pange, 2007) and existing information provided by the task (Denison, Konopczynski, Garcia, & Xu, 2006; Nikiforidou & Pange, 2009). This study aimed to explore young children's intuitive knowledge and how task context, and the data context of the problem, influenced the knowledge they used and the reasoning they engaged in to solve a prediction problem.

The previous sections of this literature review have identified core characteristics of statistics as a discipline, and task and data context considerations for statistical problem solving. The next section examines reasoning, knowledge and context in statistical problem solving, and aspects of young children's knowledge and reasoning that impact statistical problem solving.

2.5 Reasoning, Knowledge and Context in Statistical Problem Solving

2.5.1 Defining Statistical Reasoning

Reasoning is a core topic of interdisciplinary empirical research that includes cognitive psychology, education and neuroscience (Holyoak & Morrison, 2007). Research and discussion with respect to children's reasoning has grown exponentially with continuing interest in how children develop, an increased understanding of brain function, and how understanding development supports pedagogy in early childhood (e.g., Berninger & Richards, 2002; Posner & Rothbart 2007). Acknowledging the breadth and depth of research in young children's reasoning, the focus in this section is on considering reasoning skills and competencies that may be relevant to refining what is understood as defining 'statistical reasoning' when engaging in statistical problem solving.

Broadly, reasoning is a cognitive process for problem solving that involves searching for and providing intellectually trustworthy reasons (to self or others) in the search for knowledge or a problem solution (Honderich, 1995). Reasoning moves us to take evidence and use it to reach a conclusion, as a means of creating new ideas and knowledge (Bjorklund, 2005). Inductive reasoning, has been identified in this literature review as a core characteristic of statistics as a discipline. Inductive reasoning is often referred to as "informal" or "everyday" reasoning used to make decisions such as generalisations, and predictions and has been referred to as "ubiquitous in human thinking" (Brown, 1989, p. 369). The ability to draw inferences is intrinsic to all purposeful thought, a process of making "mental connections between something that we already believe is true and something we believe connects to it in some way" (Chiasson, 2005, p. 215). In inductive reasoning, real world knowledge drives inference and the forming of connections in order to decide the likelihood of the conclusion, a process that is iterated whenever inductive reasoning is called into play to make a judgment. It is this process that ties inductive reasoning to statistical problem solving.

There is not a consensus on what statistical reasoning entails but it is described as reasoning from evidence (Ridgway, Nicholson, & McCusker, 2006), reasoning with statistical ideas and making sense of statistical information (Garfield

& Gal, 1999), or occurring when people are asked to justify a conclusion or make an inference (delMas, 2004, p. 85). Engaging in statistical problem solving is about reasoning with data. Although the core of statistical reasoning must be characterised as inductive, each stage of statistical problem solving requires multiple decisions and conclusions to be made in order to successfully process the investigation. Such decisions include deciding what attributes to measure in order to collect data, how to collect and display data and how to analyse and interpret the data so all processes in a statistical inquiry involve attending to reasoning processes of one form or another. Thinking specifically about inferential reasoning as a process that both relies on and draws from the data to make judgments, focuses attention on the role evidential reasoning has in coming to a solution to a statistical problem. For young children, the role of connecting knowledge with decision making in inductive reasoning raises two issues for statistical problem solving. First, what knowledge bases can, and do, children draw from when they encounter statistical problems, and, second, what inductive reasoning skills do children bring to statistical problem solving. These are issues this study aimed to explore.

2.5.2 Young Children and Statistical Reasoning

Studies have highlighted the strength and vulnerability of young children's use of their life experiences in reasoning and reaching decisions. Young children have the capacity to intuit and reason in the absence of systematic instruction but they are also prone to be bound by their beliefs, interpretations and take a subjective approach to problem solving (Nikiforidou & Pange, 2009, 2010). Children's use of intuition has received some close attention because of the impact it has on reasoning and because of the notion that for young children, reliance on the appearance of things takes precedence over logic and objective fact (Bjorklund, 2011). Intuitive understanding exists in many domains and across disciplinary competencies, and for children, is about using what they already know. Under constructivist approaches to teaching and learning, intuition should be considered as a starting point for further learning (Gelman & Brenneman, 2004). Intuition is also associated with creative thinking, as it is a quality that uses insight "to reach sound conclusions from minimal evidence" (Fisher, 2005, p. 26). The use of intuition is also an important factor in abductive reasoning and the generation of hypotheses in statistical reasoning.

Intuitive capacity is therefore an essential element in statistical learning which needs to be preserved and nurtured.

Early capacity for inferential reasoning in statistics is a focus of recent statistics education research. Young children can engage with and intuit about statistical inference in appropriately supportive environments and where there is a range of possible data available to draw from (Paparistodemou & Meletiou-Mavrotheris, 2010). Inferential reasoning includes considering the probabilistic language that young children may use to explain and reason about data (Makar & Rubin, 2009). Children's probabilistic language is a means of expressing uncertainty about the inferences they are drawing from available evidence. The link between context and the language of explanation is an important indicator of the way that the data may be connected to the creative generation of "a tentative hypothesis" (Makar & Rubin, 2009, p. 87). Makar and Rubin further emphasise the critical nature of context in moving thinking towards generalising or looking "beyond the data". Inference is the means of moving thinking and reasoning beyond the description of the immediate data to hand to the wider context in which the data have been generated.

2.5.2.1 Knowledge and reasoning.

The relationship between knowledge and reasoning in statistical learning for young children is underplayed. Lohman (2005) laments that despite the relationship between levels of reasoning and prior knowledge "the contributions of knowledge to reasoning are often ignored" (p. 228). The ability to classify both events and objects is present from early infancy and is essential to reasoning (Lehrer & Schauble, 2000). Seeing relationships between events and objects, being aware of and working out what is important is determined by one's knowledge base. A young child's ability to perceive similarity and difference provides the foundation for the ability to form judgments (Lipman, 2003). Judgements about relationships, connections and distinctions allow comparisons to be made and form an ensemble that are requisite thinking skills needed for concept formation and all other reasoning (Lipman, 2003). Differences in reasoning in individuals however, may result from limitations in both experience and knowledge, reducing the ability to know what knowledge is important and what relationships and connections may be possible (Diezmann &

Watters, 1998). The specificity, breadth and type of knowledge bases available determine young children's analogical reasoning abilities, including conceptual knowledge (English, 2004).

Young children's knowledge bases include informal knowledge drawn from everyday experiences and interaction with the world. Prior to entering school, children undertake significant informal mathematical learning and possess powerful mathematical ideas as they begin formal schooling (Perry & Dockett, 2008). Informal mathematical knowledge acts as a starting point and underpins the learning of formal mathematical knowledge (Zeiffler, Garfield, delMas, & Reading, 2008). Further, because a core component of statistics is its grounding in data context, everyday knowledge that people possess can interfere with the use of data-based evidence and the types of connections and relationships that are made when working statistically (delMas, 2004; Garfield & Ben-Zvi, 2007). The potential impact of everyday knowledge on statistical reasoning places additional emphasis on a need to understand the prior-to-school knowledge young children bring to their early statistical experiences. delMas (2004) argues that reasoning from everyday knowledge can produce errors in thinking and reasoning that are difficult to change and yet the area of research into understanding statistical reasoning is one of the most neglected. Therefore, there is a need for studies that probe for "an understanding of the processes and mental structures that support both erroneous and correct statistical reasoning" (delMas, 2004, p. 92) which this study aimed to explore.

Young children's beliefs are the source of their theories about how the world is and how it operates. Masnick, Klahr, and Morris (2007) saw the importance of young children's beliefs in statistical reasoning, arguing that engaging in reasoning is where theory, knowledge and data interact. The theories and knowledge that children hold about data impact on how they reason, including children's use of statistically specific knowledge and their searching for patterns as they consider data. Considering young children's knowledge is also important when distinguishing between mathematics and statistics influences and in defining statistical knowledge. The difference in reasoning processes distinguishes and shapes statistical thinking (Shaughnessy & Pfannkuch, 2002; Burgess, 2009). The continual interaction between statistical knowledge, data context knowledge and knowledge of the data

plays a critical role in statistical problem solving (Wild & Pfannkuch, 1999). Statistical knowledge is intimately tied with notions of statistical literacy, statistical thinking and statistical reasoning, although each of these three complex terms are contested for what defines them and their importance in shaping statistical learning foci (e.g.,; Budgett & Pfannkuch 2010; Chance, 2002; Gal, 2002, 2005; Garfield & Ben-Zvi, 2008; Gould, 2010; Wallman, 1993; Watson, 2009).

Gaining understanding of what knowledge young children bring to statistical problem solving is important. Young children beginning school do not have formal statistical knowledge and their life experience is limited by their age, criteria that can constrain their assessment of data properties, data patterns and forming data expectations (Masnick, Klahr, & Morris, 2007). Wild and Pfannkuch (1999) propose five types of statistical thinking, with the fifth being the integration of statistical and contextual knowledge, information and concepts. Arguing for this category of thinking, they state:

> one has to bring to bear all relevant knowledge, regardless of the source, on the task in hand, and then to make connections between existing context-knowledge and the results of the analysis to arrive at meaning. (p. 228)

Wild and Pfannkuch suggest that statistical knowledge is the relevant knowledge brought to statistical problem solving, that is, knowledge used to handle and make sense of data. Approaching statistical knowledge as knowledge that is relevant to data handling provides an entry point for exploring the knowledge young children bring to statistical problem solving. Defining statistical knowledge for the purposes of this study draws on Wild and Pfannkuch's work and is stated as *knowledge children bring to judgments they make or actions they take to make statistical sense of data*.

Young children's real world context knowledge and beliefs are a major influence in how they reason with data that can impact on how they resolve data that contradicts it or falls outside their sphere of experience. Young children for example, usually see data as an isolated incident, rather than within the context of a distribution (Sheaffer, 2002). Masnick, Klahr, and Morris (2007) considered that although children may recognise characteristics of and variations in data, in order to shift deeply held views and knowledge about the world, inconsistencies between pre-

existing knowledge and objective evidence may need to be both sizeable and consistent. Data based explanations draw out both contextual and statistical knowledge (Gil & Ben-Zvi, 2011), and yet the interplay between context knowledge and handling data is under researched, as is the role of context in how statistics is learned (Langrall, 2010). Metz (1998) comments that knowledge of "the key ideas that children bring to instruction is particularly important in a domain as complex as statistics and probability" (p. 150). Although there has been research on the effect of context on deductive reasoning, research on statistical context and reasoning has been limited (Schwartz & Goldman, 1996). This study aimed to explore the knowledge young children brought to statistical problems solving and the reasons young children revealed as they made statistical sense of data. The study specifically aimed to examine young children's use of pre-existing or prior-to-school knowledge and knowledge of the data context when making data handling decisions and the inductive reasoning used as data handling decisions were made.

2.5.2.2 Context and reasoning.

Making sense of context has been described as central to statistical literacy (Chick & Pierce, 2012) because the very essence of a statistics problem is the context it is embedded in. Statistical reasoning processes are shaped by contact between the data context and the collected data when finding a solution. The ability to form conceptual and evidenced connections to, and reason creatively from data with context in mind is where hypotheses, predictions, inferences and new knowledge are made (Ben-Zvi, Maker, & Bakker, 2011; Pfannkuch, 2011).

The importance of reasoning with context in statistical problem solving is found in research that first, confirms the close and critical interaction between the context of data and statistical reasoning (e.g., Langrall et al., 2011; Moore, 1990; Watson & Callingham, 2003; Wild & Pfannkuch, 1999) and second, highlights that reasoning abilities, including the ability to make connections, may be impacted by knowledge bases children have to draw on (Diezmann & Watters, 1998; English, 2004). A growing body of research has examined the development of informal statistical inferential reasoning and the role of context in its development (Ben-Zvi et al., 2012; Dierdorp, Bakker, Eijkelhof, & van Maanen, 2011; Gil & Ben-Zvi, 2011; Langrall et al., 2011; Makar, Bakker, & Ben-Zvi, 2011; Makar & Ben-Zvi, 2011;

Pfannkuch, 2011). These studies have emphasised how context knowledge impacts on interpreting data and the fundamental role that the relationship between context and statistical knowledge has for statistical reasoning, particularly inferential reasoning.

Data context is of critical importance in the process of inferential reasoning in statistics, where data needs to be moved from being simply read to being used for sense making (Chick & Pierce, 2012). The role of data context in a statistical investigation however, creates a contextual contradiction, as the context of a problem has the capacity to both motivate and mislead (Ben-Zvi, Makar, & Bakker, 2009). Students can be motivated by the data context to engage in statistical sense making when reasoning inferentially. Children's informal and personal knowledge of the data context can bring additional information and insight to data that can influence interpretation and explanation of data, justification for the use of data and conclusions drawn from data (Masnick, Klahr, & Morris, 2007). Conversely, students' data context knowledge that is potentially inconsistent or insufficient can mislead them as they consider the statistical knowledge they have from the available data. Makar, Bakker, and Ben-Zvi (2011) state that although distinguishing between statistical and context knowledge is not easily done, students must coordinate between context knowledge and statistical knowledge as they look for evidence for their reasoning in moving to a problem solution. Context therefore has the potential to make a statistical problem more accessible and at the same time constrain it (Langrall, 2010).

The tight connection between data context and a statistical problem is the crux of the contextual dilemma in reasoning in statistics. A real world statistical problem being worked on is drawn from, and is situated within a context. That context also brings with it context-specific knowledge. The goal of finding a solution to the real world problem is to use data as evidence to increase context knowledge and understanding. In data analysis, the relationship between data context and data is described by Wild and Pfannkuch (1999) as involving an interplay or shuffling between the data and context spheres, "finding something out" and "ascertain(ing) meaning of what we have seen" (p. 336). Young children's ability to reason about data can be complex if it is "extended beyond describing and interpreting data

towards making informal inferences that go beyond data" (Ben-Zvi, Makar, & Bakker, 2009, p. 2).

The central role of data context in statistical problem solving raises questions as to the need for exploratory research in children's statistical reasoning. The form of the data context for the statistical problem, that is, how the data for the problem is contextualised, may impact children's reasoning as they find a solution to a statistical problem. One pedagogical approach to teaching young children is to use picture story books as a springboard for learning. Story is a primary means of young children organising, making meaning and sharing experiences (Im, Parlakian, & Osborn, 2007). Picture story books serve to provide contextual bridges between children's experiences and the informal, vicarious experiences found between the pages of the book. The next section considers how young children's reasoning with context in a statistical problem may be supported by the use of picture story books.

2.6 Engaging Statistical Context Through Task Design

2.6.1 Task Design and Data Context.

As argued in this chapter, a core concept in statistics, and therefore a core consideration for engaging young children in statistical reasoning, is the context a statistical problem is embedded in, that is, the data context. The data context of a statistical problem influences statistical sense making and reasoning processes. In addition, the literature review has illustrated how the context that embeds a statistical problem, the task context, has the potential to engage a child's prior experiences and influence how he or she reasons the problem to a solution. Prior research has considered task design for probability activities with young children (e.g., Langrall & Mooney, 2005; Skoumpourdi, Kafoussi, & Tatsis, 2009). These studies note the importance of task structure in influencing probabilistic reasoning and the need to use children's experience as the instructional starting point. Statistical problem solving involves experiencing variability through data collection and analysis that works to solve real world problems (North & Ottaviani, 2002; Snee, 1993). An essential criterion for statistical task design for young children is the requirement to engage them in real-world data problems, and therefore, a real-world data context for the problem must be used. The content and structure of the task context to facilitate

and trigger statistical problem solving, as raised in section 2.3.3 (p. 33) paradoxically integrates the data context.

Real world statistical problems aim to move children to engage with, consider and develop, core statistical concepts and reasoning processes as they work to a problem solution. Beswick (2011) uses the term "context problem" (p. 369) to describe the multiple categories of problem presentations found in mathematics literature termed "authentic", "real-world" or "situated". Such problems she states, aim to serve various purposes including enhanced understanding of mathematical issues and concepts, and affective dispositions towards mathematics but have mixed success. Context in problems should not distract or obscure, but assist students to engage with challenging mathematics. There is however, little research understanding "how contexts assist students to make sense of mathematics and which contexts are most effective in different circumstances" (Beswick, 2011, p. 387). Children should encounter data in ways that support their interaction with, not on, data (Makar & Rubin, 2009). Task design therefore must be mindful of the impact of the tasks presentation of the problem on how data context is handled. How children encounter data context should be a salient feature of task design for statistical problems children encounter in the classroom. Research on the role of task context for young children in statistical learning is limited, and does not focus on contextualising the problem, that is, the data context that the task provides. Research that focuses on statistical reasoning must consider the presentation, structure and content of problems that are designed to draw children into statistical, not mathematical learning.

2.6.2 Instructional Picture Story Books

Oral and written stories have been used as a primary means of communication across time and culture (De Young & Monroe, 1996). Stories are a familiar part of children's lives and inform, shape, construct and reflect social practices and values (Diaz, 2007). Story reading can serve to support children's reasoning through social interaction (Kaartinen, 2010) and can provide insight into children's thinking processes (Jennings, Jennings, Richey, & Dixon-Krauss, 1992). Reading stories to young children is one of the many socio-cultural literacy practices that children are exposed to in early childhood settings that benefit the development

of young children's literacy (Harris, 2007; Van den Heuvel-Panhuizen & van den Boogaard, 2008). The Australian Federal Government's (DEEWR, 2011) commitment to universal access for pre-school children to early childhood programs from 2013 is underpinned by pre-school curriculum that encourages young children's exploration and awareness of literacy in early childhood educational settings (EYLF, DEEWR, 2009).

As a result of Commonwealth and State policy and curriculum, preschool environments in Australia, including South Australia where this study was conducted, employ curricula that actively engage children in reading and sharing books and other texts and involving children in conversations, discussions, and analyses of texts. The focus on the use of texts in early learning settings supports the argument that children entering formal schooling in Australia will have accessed and engaged with picture story books in their preschool settings as an integral part of their learning experiences. Reading and telling stories can be a unifying experience for children who are from diverse cultural, economic and ethnic backgrounds. Reading story books therefore offers the possibility of providing an interactive, social context that can serve as an entry point for children into increasingly sophisticated conversations that can move from a perceptual to a conceptual focus (Pentimonti & Justice, 2010). Consequently, it is possible to consider the picture story book for young children as providing a familiar context for learning (Hong, 1996; Shiro, 1997).

Picture story books are used as a means of instruction in disciplines such as science and mathematics (Haury, 2001; Sackes, Trundle & Flevares, 2009). The use of picture story books in instruction is an approach that is justified on the basis that books can provide an environment for children's active construction of knowledge and ideas for higher understanding (Elia, van den Heuvel-Panhuizen, & Georgiou, 2010). There are opportunities to make meaningful connections with young children's prior knowledge through the contents of a book. A picture story book can create a real issue for a child that needs to be addressed. Story books have the potential to tap into young children's ability to pretend and imagine within the context, connecting the developmental richness of play and imagination into the learning experience (Wilburne, Keat, & Naploi, 2011). Meaning making can be

achieved when cognitive conflict that occurs in a picture story is resolved and through the opportunities a story can provide for children to share and reflect on knowledge with others (Van den Heuvel-Panhuizen & van den Boogaard, 2008). Picture story books have the potential to provide opportunities for problem solving (Shiro, 1997) and this study aimed to explore the problem-solving potential of picture story books in contextualising statistical problem-solving.

2.6.3 Picture Books and Learning Mathematics

Picture story books are used in mathematics instruction to provide a stimulus and motivation for children to investigate problems by offering a "meaningful framework" for active construction of mathematical knowledge (Elia et al., 2010, p. 292). Haury (2001) argues that mathematical ideas "take shape through our attempts to communicate and therefore find their way into our literature" (p. 1). The use of picture story books in mathematics instruction has increased in popularity from the 1990s, and there is some support for the benefits of books for initiating learning of mathematical concepts. The limited literature and research that is available suggests that mathematics learning is successful when depicted in picture story books as a familiar part of everyday life and within contexts that are meaningful for children (Casey, Erkut, Ceder, & Young; Hong, 1996; Moyer, 2000; Whitin & Wilde, 1995). Picture story books can therefore offer a context that supports young children's interest in, and emotional connection to, mathematics and present problems to be investigated or solved (Van den Heuvel-Panhuizen & van den Boogaard, 2008).

The use of children's literature for teaching and learning mathematics enables concepts and problems to be depicted in different ways and to provide places to commence mathematical inquiry (Lovitt & Clarke, 1988). The context or setting of a story has the potential to provide a familiar and accessible framework for children, with "cognitive hooks" (Lovitt & Clarke, 1988, p. 439) for exploring the relationship between pieces of information. Young children's spontaneous interactions and reactions to the reading of a mathematical picture story books is a thinly researched area, and working out the responses that a book elicits needs further exploration (Van den Heuvel-Panhuizen & van den Boogaard, 2008). Increased understanding of what it is in a picture story book that provides a cognitive trigger for mathematical thinking will contribute to understanding how picture story books can support

mathematical learning. This study aimed to explore children's responses to reading a picture story books that contextualised a statistical problem, to gain understanding of the characteristics of the book that may support statistical reasoning.

Young children's responses to the reading of a picture story book raise the question of children's interest. Interest is a principal concern for task design in the Models and Modeling perspective as it is a means of realising a match between the goals of the educator and the child in ways that move a child to engage in the task (Lesh & Doerr, 2003). An aim of Models and Modeling activities is to facilitate a child's interest in a task through its design in a way that places the child "squarely within the activity" (Middleton, Lesh, & Heger, 2003, p. 415). Models and Modeling design principles of personal meaningfulness, and model construction are pivotal for an initiating activity (Lesh & Doerr, 2003). In Models and Modeling, interest begins with initiation into the modeling task, termed the elicitation stage, which challenges children with the need to develop a model to solve a problem (Lesh & Doerr, 2003). Whatever is chosen as the initiating stimulus for the problem context is the stimulation for interest in the modeling activity. A child's motivation, reactions and engagement are dependent on circumstances (Fredricks, Blumenfeld, & Paris, 2004; Martin & Dowson, 2009). The role of interest in the specific role it plays in Models and Modeling, is under researched and appears to be limited to the work of Lesh and Doerr (2003). This study aimed to explore the characteristics of picture story books of interest to young children for books that were used to initiate data modeling activities with young children.

2.6.4 Picture Story Books as Task and Data Context.

Picture story books have the potential to fulfil a dual contextual role in a statistical problem for young children, as task context and data context. As a key element of the task design, a picture book also provides the data context for a statistical problem. The dual nature of the picture story books role in both task and data contexts alters the learning purpose the book fulfills in statistics, that differs from the role of a book chosen for specific instruction in mathematics. This is because there are differences between statistics and mathematics as disciplines. These differences impact on the role of the content of a picture story book, as the

concepts and outcomes of statistical and mathematical teaching and learning differ. As a result, the criteria for selecting a picture story book must differ.

There have been a number of classification schemes developed that provide criteria for selecting published children's literature for teaching and learning mathematics (e.g., Hellwig, Monroe, & Jacobs, 2000; Hunsader, 2004; Shiro, 1997; Whitin & Whitin, 2004). A recent classification scheme for selecting picture books for promoting mathematical development (Marston, 2010; Marston & Mulligan 2012) categorises books by the mathematical content. Although helpful, the statistical role of a picture story book is not readily supported under existing mathematical literature selection frameworks. Existing frameworks for selecting picture story books for mathematical teaching and learning rely on identifying known mathematical concepts that are visible, clearly identifiable, or where the potential for mathematics specific concepts to be drawn out or used as a springboard for other mathematical learning is apparent. Published texts to support teaching practitioners selection of mathematical fiction books offer few or no recommended texts for handling or analysing data, particularly for five to six year olds (e.g., Burns & Sheffield, 2004; McKinney & Hinton, 2010; Whitin & Whitin, 2004). Identifying content for supporting learning statistical concepts is not accommodated by the existing classification frameworks.

A difficulty in choosing books for initiating and contextualising statistical learning arises from the nature of the discipline. Statistical problem solving is a contextualised activity and until elements of the picture story book are drawn on by the children, the statistical content of the books is unknown. It is only in finding a solution to the problem that the "statistical content" of the book, that is, the knowledge from the book children choose to employ to problem solve, is visible. Picture story books have the capacity to provide a meaningful context for a statistical problem and cognitive lure for young children's statistical learning, however, examining comparable research in children's literature and mathematical learning is problematic for two reasons. First, with the exception of English (2009; 2010; 2011), children's picture story books have not been used to initiate statistical problem solving or modeling activities. And second, young children's response to the characteristics of a picture story book that initiate and contextualise data modeling

activities for statistical problem solving has not been researched. Consequently, this study aimed to identify children's responses to a picture book story that fulfilled both data and task context, and the knowledge children draw from the picture story book when reasoning a solution to a statistical problem.

2.7 Chapter Summary

This literature review emphasises that differences between mathematics and statistics are critical to conceptualising and informing teaching and learning statistics from the commencement of formal instruction as children begin school. Core characteristics of statistics identified from the literature provided a definition to inform beginning statistical learning for young children. This definition offers a conceptual framework for researching understanding of the knowledge and reasoning skills young children possess and bring to statistical problem solving.

The review identifies the Models and Modeling perspective, specifically data modeling, as a compatible learning framework for engaging the characteristics of statistics defined in this chapter. Models and Modeling, specifically data modeling, is argued as accommodating young children's access to statistical problem solving and statistical reasoning. Data modeling activities provide a vehicle for understanding young children's statistical problem solving, and research is needed in the use of data modeling as statistical problem solving with young children as they begin formal school.

The review underlines the importance of engaging young children in all aspects of statistical problem solving and identifies that literature addressing this with young children beginning school is limited. Existing literature on children's use of knowledge and reasoning processes in statistical problem solving were reviewed and identified. These include measurement as categorisation and classification, data representation and prediction, and children's meta-representational competence and intuitions, and areas of additional understanding that is needed are identified.

Data context and task context are identified from the literature review as pivotal to engagement with statistics and the use of knowledge and reasoning in statistical problem solving. Existing studies have not focused on the role of data context, or task context, individually or in combination, in young children's

statistical reasoning processes. Picture story books are identified as potentially fulfilling a unique role in integrating data and task context in statistical problem solving activities. There is a need to understand the characteristics of books used to contextualise statistical problems that interest young children and how knowledge gleaned from the picture story book is used by children in statistical reasoning when problem solving.

This review highlights the need to gain understanding of the intuitive and prior-to-school knowledge and reasoning skills young children possess when they begin school, and how, when, and under what conditions they engage knowledge and reasoning when making decisions to develop models during statistical problem solving. The following chapter presents the methodology that supports this exploratory study of the role of data context and task context in young children's statistical reasoning.

Chapter 3 METHODOLOGY

3.1 Introduction

This chapter presents the methodology and methods used to explore young children's statistical reasoning. An exploratory qualitative research design in an interpretative paradigm underpins this study. To answer the research questions (Chapter 1), educational design research informed by the Models and Modeling perspective (Lesh & Doerr, 2003) and the researcher's view of young children was utilised. The chapter first presents theoretical considerations, research orientations and methodology. This is followed by descriptions of the research methods, including the selection of participants, processes of data collection and data analysis. Finally, generalisability and trustworthiness, and ethical considerations for conducting research with young children are presented.

3.2 Theoretical Considerations

This study is informed and shaped by the theoretical influences of the Models and Modeling perspective (Lesh & Doerr, 2003) and perspectives on young children. Utilising different theoretical perspectives, known as "theoretical bricolage", positions the researcher, as a bricoleur. A bricoleur takes and adapt ideas from a range of theoretical sources to be used as tools to attend to questions that are of specific concern and interest (Cobb, 2007). A bricoleur approach in this study allowed theoretical perspectives presented in the following sections to be consciously chosen and defined to fit the specific purposes of the research investigation. Theoretical bricolage strengthens the rigour of a study and supports the development of a more distinctive research identity in the discipline of interest (Cobb, 2007), in this study, the discipline of statistics.

The researcher acknowledges the influences and choices made which invoked critical reflection by the researcher of the areas of theoretical co-existence and the competition that may exist between them (Cobb, 2007). Acknowledgement of the theoretical research framework provides structure for explaining and justifying the usefulness and appropriateness of a study, given the purpose and context of the study

(Lester, 2007). Accordingly, two major theoretical influences on this study are Models and Modeling and how it connects to statistical reasoning, and perspectives on young children and how these connect to the researcher's view of young children.

3.2.1 Connecting Models and Modeling with Statistical Reasoning

This study's exploration of statistical reasoning was informed by the Models and Modeling perspective [Models and Modeling] (Lesh & Doerr, 2003), which provided the principal theoretical research framework (Chapter 2), including the choice of methodology and the researcher's methodological choices. The Models and Modeling framework describes a "system of thinking about problems of mathematics learning" (Lester, 2005, p. 460), integrating various theoretical concepts including sociocultural theory and developmental psychology from multiple disciplines, and drawing from the work of Piaget, Vygotsky, Peirce, Holmes and Dewey (Lesh & Doerr, 2003). Lesh and Doerr describe the multiple theoretical influences in Models and Modeling as an acknowledgement and integration of "the best theories by the best theorists with the best practices of the best practitioners" (p. 533), used to develop sharable conceptual tools. The focus on "model" rather than "theory" in Models and Modeling emphasises that model development is not bound by a single theory (Lesh & Doerr). This study argues that Models and Modeling's integration of multiple theories is of itself a theoretical bricolage, used to address specific concerns and interests in mathematical learning through complex problem solving. The Models and Modeling framework reflects a broad theoretical view of a learner's conceptual development that takes the multidimensionality of young children's interpretation of their experiences into account when they engage in problem based modeling activities.

The task design of modeling activities plays a critical role in evoking processes in children's problem solving. Data modeling, as a specific element of Models and Modeling, is a particular type of problem modeling where statistical reasoning is enmeshed and can emerge (Lehrer & Schauble, 2003). Engaging in statistical problem solving, as data modeling, evokes working with disciplinary specific concepts and processes as data is handled and solutions found. These disciplinary specific processes have their own body of knowledge that are integral to making sense of the children's problem solving and, accordingly, are core to this

study. The capacity of Models and Modeling activities to trigger statistical reasoning, and for the statistical reasoning processes to be explored, documented and analysed, directly informed the conceptualisation, design and interpretation of the study.

3.2.2 The Researcher's View of Young Children.

A critical aspect of this study is the recognition by the researcher that research with young children is a means of constructing or reconstructing childhood (Kehily, 2004). Significant shifts to the social construction of childhood have occurred as the social conditions of contemporary childhood have changed (James & Prout, 1997; Prout, 2011). There is an increased acknowledgement of children's rights and experiences that have resulted in moves to position children as capable, expert and competent participants in their lives who have participatory rights (Early Childhood Australia, 2006; Graham & Fitzgerald, 2010; Mason & Danby, 2011). The view of the child as competent contrasts with prior research, including mathematics research, that has positioned children as passive participants in research who are on a developmental continuum of increasing competency as they move towards adulthood (De Corte & Verschaffel, 2007; Mason & Danby, 2011). As a result, research has been conducted *on* children to determine and analyse their current state of knowledge, developmental level or readiness to learn (Dockett & Perry, 2011; Ginsburg, Cannon, Eisenband, & Pappas, 2006), often with a focus on single concepts, and not underlying processes (Mulligan, 2011).

The shift in the construction of childhood has paralleled a shift in understanding young children's mathematical abilities. There is general consensus that young children's mathematical learning and knowledge between the ages of birth and 5 years stems informally from their quantitative experiences in the ordinary physical and social environment (Ginsburg, et al., 2006; Hunting, Mousley, & Perry, 2012). Young children "see mathematics as part of their everyday lives" (Perry, 2009, p. 659) and are capable problems solvers and thinkers, and yet existing capabilities and potential for accessing their mathematical knowledge and thinking for learning is largely underestimated (Clarke et al., 2006; Perry, 2009). There is, however, increased recognition that young children are capable of and should have opportunity to access "powerful mathematical ideas that are both relevant to their current lives and form a critical foundation for their future mathematical and other

learning" (Australian Association of Mathematics Teachers and Early Childhood Australia, 2006, p. 2). Research has begun to reflect the need to take into account children's prior informal mathematical knowledge and to investigate children's strategies for solutions in mathematical processes such as problem solving in contextually relevant problems (de Corte & Verschaffel, 2007; Papic, Mulligan, & Bobis, 2009), and that the interpretation of children's actions, experiences and thinking should be considered from the child's point of view (Clements, 2001). This study views young children as possessing diverse and powerful mathematical competencies that are accessible through research activities designed to provide stimulating, meaningful problem solving contexts for children.

This study took the perspective that the children are active, informed participants. Although the dichotomous sociocultural view of children can be problematic (Prout, 2011), the key elements are that a child is positioned as a competent individual who is capable of active agency and engagement with the world, and whose stage in life should not be considered preparatory, but significant in its own right (Dahlberg, Moss, & Pence, 1999; Woodrow & Press, 2007). The recognition of children's competency has implications for the research process for the child as research participant (Mason & Danby, 2011). Recognition of children's competency and agency affords the promise of realigning the way research involving children is approached, so that children are recognised as legitimate stakeholders with participatory rights in the research process (Danby & Farrell, 2004; Dockett, Einsdottir, & Perry, 2011). Viewing a child as a competent agent also determines that data made by the child in the research process is accepted as reliable, genuine and valid (Harcourt & Conroy, 2011).

This study aligns with the positions raised here in order to identify identifying perspectives and assumptions that impact on ethical and interpretative responsibilities and inform choices made in the techniques and practice of researching with young children (Dockett, Einsdottir, & Perry, 2011).

3.3 Research Orientation

3.3.1 Qualitative Perspective

The study employed a qualitative research perspective to address the research questions. The aim was to understand a range of participants' experiences in a natural setting (Creswell, 2008) and to enable all aspects of the phenomena under study to be considered in context (Goodwin & Goodwin, 1996). Qualitative research is broadly described as "a situated activity that locates the observer in the world" (Denzin & Lincoln, 2005, p. 3). The situated activity in this study focuses on participants' construction of their world, producing a variety of alternative views specific to a particular context (Fraenkel & Wallen, 2003). Accordingly, this orientation supported the aim of the study to investigate the knowledge and reasoning young children bring to statistical problem solving and the characteristics of the task context that engage children in statistical reasoning in a classroom setting. Qualitative research in naturalistic settings acknowledges that teaching and learning is content and context focused (Creswell, 2008).

In qualitative research, the world as a natural setting and the phenomena within it are "made visible" by the representations that result from research practices that collect and describe the routines and meanings in people's lives (Denzin & Lincoln, 2008). The classroom was the natural setting for the phenomenon under investigation in this study. The contextualised nature of the natural setting was central to the research questions and the type of research methods available for rendering children's thinking and reasoning "visible" in natural settings was of pivotal interest to both the theoretical and methodological underpinnings of the study (Creswell, 2008; Lesh & Doerr, 2003).

Qualitative methods are employed when exploring new areas of interest or concern (Strauss & Corbin, 1998) and so suit the exploratory nature of the study. Qualitative methods provide richer, fuller descriptions of the research context and complex phenomena under investigation that are not easily or able to be captured by quantitative methods (Kalinowski, Lai, Fidler, & Cumming, 2010). Multiple and varied methods of data collection provide an array of rich, descriptive, qualitative accounts that are important for identifying and addressing complex contexts, and also

provide flexibility to allow the researcher to follow unanticipated ideas and developments in the course of the research (Creswell, 2008; 2009). Consequently qualitative research methodology and methods were a prudent choice for this study that investigated the reasoning experiences and contexts of young children working with the complex phenomenon of statistics.

3.3.2 Interpretivist Perspective

The study employed an interpretivist perspective as a data inquiry approach. An interpretivist approach seeks to explain and understand the situated interpretations of social reality (Crotty, 1998), where the meanings of the data representations collected are interpreted in order to glean a better understanding of the phenomena being studied (Creswell, 2009). This study intended to explore and describe "terrain that was unfamiliar" and was suited to an interpretivist approach (Miles & Huberman, 1994). An interpretive methodology also works to expose the meanings, understandings and purposes that both individuals and groups attach to their activities in order to understand shared, socially constructed and negotiated meanings (Hughes, 2001). Adopting an interpretivist view of knowledge construction in this study enabled an understanding to be gained of the interaction between activities and meanings ascribed to these by young children in statistical problem solving.

3.4 Research Methodology

An educational design research study informed by the Models and Modeling theoretical framework was adopted in this study. This section provides a description of both educational design research and the relationship between the theoretical perspectives and the aims of the study.

3.4.1 Educational Design Research as a Methodology

Educational design research methodology is a new and evolving methodology in applied settings (diSessa & Cobb, 2004; Kelly, 2006). This section presents a brief discussion of its origins and aims, and distinguishing characteristics. The relevance of the characteristics is then connected to the specific methodological needs of this study.

3.4.1.1 Origins and aims.

The term *educational design research* is used consistently throughout this thesis to refer to the research methodology presented here. The use of educational design research reflects the term devised by McKenney and Reeves (2012) to denote design research in the field of education, as distinct from design research in other fields. Design-based research (Design-Based Research Collective, 2003) is one term among a range of methodological approaches broadly considered to be design research (van den Akker, Gravemeijer, McKenney, & Nieveen, 2006) that share common aims and characteristics (Wang & Hannafin, 2005). Other terms within this collective include "design research" (Cobb, Stephan, McClain, & Gravemeijer, 2001; Collins, Joseph, & Bielaczyc, 2004; Edelson, 2002), "design experiments", (Brown, 1992; Collins, 1992), and "development research" (van den Akker, 1999) (see further discussion in Herrington, McKenney, Reeves, & Oliver, 2007; van den Akker, Gravemeijer, McKenny, & Nieveen, 2006; Wang & Hannafin, 2005).

Educational design research is "a genre of inquiry" (McKenney & Reeves, 2012, p. 7) that move towards "a more intimate definition of learning" (Kelly, 2006, p. 114) where instructional design and research is interdependent (Cobb & Gravemeijer, 2008). Theoretical research origins lie in multiple disciplines including psychology and sociology, and its design aspects originate in multiple fields such as computer science, engineering and curriculum theory (Sandoval & Bell, 2004). Educational design research in education has its historical roots in the work of Brown (1992) and Collins (1992) and arose from an impetus to study learning differently because there was a perceived need for research to consider both the theories and approaches to learning in context (Collins, Joseph, & Bielaczyc, 2004). The initial motivation was to move away from the "incomplete understanding" that was argued to occur when educational variables are studied in a laboratory or "impoverished" contexts (Brown, 1992, p. 1). Studies outside of the context in which learning takes place create a gap between theory so created and practice that takes place in "messy" classroom contexts (Brown, 1992).

Educational design research is an applied methodology (Barab & Squire, 2004, p. 2) used to explicitly exploit design as a means of understanding contextualised teaching, learning and systems. This can occur if the boundary

between design and research is eliminated (Edelson, 2002). Educational design researchers are considered to be "applied researchers" (Barab & Squire, 2004, p.8) with a principal aim of increasing the relevancy between learning research and learning practice (Reimann, 2011). The aim of research generated outcomes is to either advance or generate learning theory and to develop applied design knowledge that is sharable and impacts on pedagogical practice (Design-Based Research Collective, 2003). The relevance of educational design research to pedagogical practice has led to it being described as socially responsible research (Reeves, 2000). Educational design research was a suitable methodological choice for this study due to the focus of inquiry to understanding the relationship between young children's knowledge and reasoning and task design in statistical problem solving.

Educational design research focuses on the characteristics of a design that has a specific purpose within a context (McKenney & Reeves, 2012). Data are collected to inform how and why an intervention functioned in a particular context in order to produce theoretical and pedagogical knowledge that is useful to others (Kelly, 2007). Consequently, educational design research engineers an innovative educational environment around particular forms of learning and simultaneously conducts research on the learning (Wang & Hannafin, 2005). The engineered research design aims to facilitate developmental change and investigate the resulting construction of basic conceptual constructs that are occurring (Lesh & Kelly, 2000). For this study, educational design research was a methodology that facilitated the engineering of a classroom environment to stimulate statistical reasoning and enabled the function of the design to be examined.

3.4.1.2 Distinguishing characteristics.

Educational design research differs from most educational research as it does not examine what exists, but what could be in a modified context, and so has an *exploratory* aim (Schwartz, Chang, & Martin, 2008). Educational design research chooses to work in the 'context of discovery' rather than the 'context of verification' (Schickore & Steinle, 2002 in Kelly, 2006, p.114). As such, it is a valuable and appropriate research approach where a starting point is needed to address an educational problem where little research or guidelines exist for how to structure and support activities to address the problem (Cobb & Gravemeijer, 2008; Plomp &

Nieveen, 2007) as is currently the situation with young children's statistical reasoning.

The grounding of the design and implementation of an instructional innovation or artefact in current, explicit theory is a *pragmatic* aim of educational design research (Burkhardt & Schoenfeld, 2003). The innovation or artefact must be workable, modifiable and transportable to other environments (Gorard & Taylor, 2004) and aim to improve teaching and learning outcomes. Prior research and literature, however, provide the basis for the initial development and design principles of an intervention for studying the phenomena of interest (McKenney & Reeves, 2012; Plomp & Nieveen, 2007). For this study, given existing available research and theoretical understanding, modeling activities using design principles from the Models and Modeling perspective were evaluated as viable instructional innovations for accessing children's statistical reasoning.

Educational design research assumes that learning is situated in *natural settings* and there is a need to understand learning as it occurs naturally (McKenney & Reeves, 2012). The designed innovations or artefacts that engineer the environment are a lever for studying contexts and learning in the setting in which they occur (Sandoval, 2004). Research is positioned as being done *in* rather than *on*, classrooms (English, 2003a) because context is "central to its conceptual terrain" (Kelly, 2006, p. 113). The aim for educational design research is to deal with messy contextual situations involving multiple variables (Kelly, 2006; Lamberg & Middleton, 2009). This study's concern was to research young children in the classroom setting, and educational design research supported this concern.

Educational design research monitors *conditions of change*, through the identification and scrutiny of the multiplicity and complexity of variables in the environment, some of which may emerge as the research progresses (McKenney & Reeves, 2012). Examining conditions of change provides an opportunity to better understand the systems in play in the context in which they are operating (Barab, 2006). Researchers initiate the design of the artefact or innovation through conjectures about how to support learning in the classroom context that are also based on theoretical conjectures on how learning occurs. Both design and theory are further developed as the iterative nature of the research continues to develop and test

the design (English, 2003a; Sandoval, 2004). This was a core area of consideration for this study where the research interest was in changes in learning and the conditions that support these changes (Lehrer & Schauble, 2004).

Educational design research actively *collaborates with practitioners* in the activities and stages of the research process (Van den Akker, 1999). This approach requires commitment by the researcher to develop an effective, trusting, working relationship in order to understand the context and to be open to the influence and input of the practitioner in research decisions (McKenney & Reeves, 2012). Effective collaboration with the practitioner is considered to increase the chance of a successful design and implementation of an intervention that will be relevant and useable but also engage the practitioner in professional development (Plomp, 2007). The importance of the practitioner-researcher relationship also impacted on the participant practitioner selection for the study (section 3.5.2.1, p. 81).

The distinguishing characteristics of educational design research presented in these sections influenced the choice of educational design research as the methodology for this study. The alignment between educational design research and the study purpose is now addressed.

3.4.2 Educational Design Research and Young Children's Statistical Reasoning

Educational design research provided a "point of entry" choice for the researcher (Kelly, 2006, p. 115) due to its "abiding interest in understanding children's thinking" (Confrey, 2006, p.137). Researchers using educational design research analyse the core ideas in the domain of interest to help provide relevant or useful goals that may not be those currently in place in curriculum or the like (Gravemeijer & Cobb, 2006). In this study, the core domain idea was statistical reasoning. Lehrer and Romberg (1996) note that it is difficult to capture children's reasoning processes using traditional word problem tasks. Educational design research attempts, through the use of specifically designed tasks to engineer the learning environment and "track the evolution of children's thinking" (p. 71). In this study, the use of educational design research enabled a focus to be placed on statistical process. Instructional innovations as data modeling activities, designed to

reflect real-world situations were used to enable statistical reasoning to be traced through understanding patterns of thinking and reasoning in groups and individuals (Shavelson, Phillips, Towne, & Feuer, 2003).

Educational design research approach to research is of particular value when there is an area of learning that may be investigated with participants who do not usually learn it and where little knowledge is available about development and thinking in the area (Lehrer & Schauble, 2004). Educational design research aligns with investigating young children's statistical reasoning as little is currently known about the knowledge and reasoning young children bring to statistical problem solving or the task context conditions that impact on this.

Educational design research is valuable when the researcher's interest is not in what thinking and development typically occurs, "but in what can occur under good, but not highly unusual circumstances" (Lehrer & Schauble, 2004, p. 640). Criteria for an intervention to establish "good" circumstances or conditions include being relevant, practical and effective (Nieveen, 1999). For this study, educational design research provided a methodological vehicle for developing an intervention for creating good conditions for researching young children's statistical reasoning. The modeling activities designed for the study were relevant to the area of learning studies, informed, and realistically useable in the classroom setting.

This study's inquiry focus fell within broad educational design research guidelines (Shavelson, et al., 2003). Educational design research's dual aims are in theory and practice. The aims are to understand the "how" and "why" questions about the characteristics of designed instructional innovation that support children's learning in everyday contexts, in addition to gleaning theoretical insights into learning (Bell, 2004; Edelson, 2002). This study investigated the how and why, as children brought their knowledge and reasoning skills to their engagement with statistical problem solving. The research questions also sought to address the question of what characterised the task context for activities that engage young children in statistical reasoning. The methodology rendered the statistical reasoning and context characteristics visible to the researcher and provided an appropriate methodological toolkit to track children's use of knowledge and reasoning.

3.4.3 Educational Design Research and Mathematics Research

Educational design research is often situated within a domain-specific theory that provides a structure and theoretical guide to the instructional activities (Kelly, 2006; Cobb & Gravemeijer, 2008). The role of theoretical understanding in the design, inquiry framework and generation of tested findings is important to the forms of theoretical understanding and practical contributions made by studies (McKenney & Reeves, 2012). The relationship between mathematics research and educational design research is a symbiotic one, and the nature and strength of this relationship is well documented and growing (e.g., Kelly, Lesh, & Baek, 2008). Recently, there has been some clarification of research methodologies that are distinctive to mathematics education, and educational design research is one such methodology (English et al., 2008). Educational design studies support mathematics research by tracking and documenting participants evolving ways of thinking as they engage with thought-revealing designs, and provide shared products (theoretical and practical) that should be auditable and persuasive to practitioners (English et al., 2008).

Models and Modeling and educational design research reflect parallel structures of thinking about and examining learning that is stimulated by design interventions. Both Models and Modeling and educational design research are interested in producing meaningful change in educational contexts. Models and Modeling task design (reviewed in sections 2.4.2, p. 38 and 2.4.3, p. 41) is intrinsically concerned with the design of the problems (in this study, a data modeling problem being worked to a solution), the learning that is generated as during the problem solving, and the learning context in which learning occurs. The link between the children's statistical reasoning, including the use of data context knowledge during problem solving, and the design of the task context as integral to the children's learning environment is a central tenet of this study. In this study, Models and Modeling, and specifically data modeling, was the dominant theoretical base used to design the instructional innovations for the study. The instructional innovations posed problems designed to expose the children's statistical reasoning and use of knowledge, including their engagement with the data context as part of the task context within the classroom. As the principal theoretical framework that

informed the learning theory and methods for this study, Models and Modeling was supported by the aims and characteristics in educational design research.

3.5 Research Methods

3.5.1 Participant Recruitment

The recruited school was a State government primary school situated in the north east of Adelaide, with an Index of Educational Disadvantage [IED] (Department of Education and Child Development [DECD], 2010) rating at the time of data collection of category 6, with category 7 being the least disadvantaged and category 1 the most disadvantaged. The IED is a socio-economic index that is calculated using a combination of Australian Bureau of Statistics and DECD data and used by the DECD to allocate resources to schools in relation to their socio-economic status (DECD, 2012). The school has approximately 400 children enrolled from pre-school to year 7 drawn from the surrounding suburban district, predominantly from English speaking backgrounds.

The principal and staff at the school had a strong interest in, and focus on, student mathematics and science development and a specified aim to further develop student and educator's confidence, interest, knowledge and skills in mathematics. The school was supportive of the research aims and methodology and, over the course of the researcher's attendance at the school, accepted the researcher as a member of the school community, providing resources and practical support for the research process.

3.5.2 Study Participants

The participants were members of one class of 14 children, comprising five girls and nine boys aged from 5 years to 5 years 3 months (mean age 5 years 2 months) in their first term of their first year of formal schooling ("Reception"), and their teacher.

3.5.2.1 The teacher.

The class teacher was a qualified and registered early childhood teacher. In the three years prior to the data collection, the teacher had worked as a contract tutor at a South Australian University for the first six months of each year. In the second

six months of each year, he had worked at the participant primary school as a contract teacher, teaching classes formed for children beginning their formal schooling in mid-year intakes. As a consequence, the teacher had experience teaching young children beginning school. The teacher had a pedagogical interest in collaborative inquiry teaching and was familiar with, and supportive of, creating classroom expectations of children's participation and contribution. These types of classroom expectations were a feature of the instructional innovations for the study, and so the teacher was able to provide micro-culture support for the instructional sequences (Gravemeijer, 2004).

The researcher and the teacher had worked at the same University teaching environment in the three years prior to the study and had a pre-existing professional working relationship. As the establishment of an effective and trusting working relationship with the practitioner is considered to increase the chance of successful educational design research outcome (Plomp, 2007), the pre-existing relationship helped shape a 'co-learning agreement' between the researcher and teacher (McKenney & Reeves, 2012). Although three schools were approached as potential participant schools following the requisite ethics approval, the teacher's opportune availability with a class of children commencing full-time school resulted in a purposeful selection of both the participant school and participant teacher.

3.5.2.2 The children and commencing school in South Australia.

In South Australia at the time of data collection in 2010, the DECD specified children's school enrolment entitlements for public schools. Children were eligible and accepted for enrolment at a government primary school from their fifth birthday. Reception is the name given to the first formal year of full time schooling in South Australia. Children in a Reception class usually range from five to six years of age. South Australia has four school terms a year, each approximately 10 weeks long.

Most children in South Australia attend four terms of preschool or kindergarten, and then begin primary school in the school term following their fifth birthday. This results in an increase in student numbers in Reception classes each term of the school year as children turn five years of age and enrol. There were fourteen children due to enrol and commence at the participant school in the July

2010 at the commencement of Term 3 of the four term school year. The participant school Principal made a decision to create a new class at the commencement of Term 3 to accommodate the fourteen children and the class that resulted from this decision was the class recruited for this study. Table 3.1 details the pseudonym names and ages of the children at the commencement of the school term in July 2010.

Table 3.1
Ages of participating children

Child (Pseudonym)	**Age at 1 July 2010** **Years: months**
Blake	5 : 2
Bryce	5 : 2
Carl	5 : 1
Chris	5 : 2
Eliot	5 : 2
Gina	5 : 3
Isabel	5 : 2
Jade	5 : 1
Kyra	5 : 2
Lee	5 : 1
Mia	5 : 0
Ted	5 : 1
Toby	5 : 1
Sam	5 : 2

Thirteen of the 14 children in the participant class had attended the school's on-site purpose built pre-school (kindergarten). Part of the pre-school program for children transitioning into primary school is to undertake five weeks of transition visits to the primary school in the term prior to their beginning full time attendance. Transition visits consist of the children walking from the pre-school as a group to attend weekly sessions of two hours in an existing Reception at the primary school. Ordinarily, these visits would be to the classroom and teacher that the children would join when they commenced school. The participant class however was newly established for the third term. As a result, 14 children who participated in this study did not have transition visits therefore prior to commencing school.

The classroom space was a converted storage area and hallway in the main building. Partition screens were used to shield the space visually from the two neighbouring open plan classrooms; however, the noise from both these classrooms was considerable. Tables and chairs were provided to seat 26 students, as there were 12 new children due to start school in the class in fourth term. The 12 pre-school children who would join the class in fourth term commenced transition visits for three hours each Thursday from the third week of the data collection term.

3.5.3 Data Collection - Early Tasks and Activities

Table 3.2 provides a description of the data collection timeline and principal activities and tasks completed over the ten week school term commencing July, 2010. The modeling activities highlighted in bold in Table 3.2 are those from which the principal data was collected.

Table 3.2
Timeline of research tasks and data collection activities

Term week 2010	Description of data collection activities and research tasks
1	Introduction of the research and researcher to the children and parents
2	Consent/assent forms sent home to parents
3	Consent/assent forms returned
4	Selection of groups for modeling activities
5	Filming class activities begins. **Class discussions on recycling, reuse and throw away terms.**
6	**Baxter Brown Modeling Activity implemented**
7	**Michael Recycle Modeling Activity implemented**
8	**Litterbug Doug and Charlie and Lola Modeling Activities implemented**
9	Predicting, collecting, sorting, categorising rubbish collected in the classroom
10	Predicting, collecting, sorting, categorising rubbish collected in adjoining classroom, tree planting in school grounds.

Details of the preliminary activities listed in weeks one to five in Table 3.2 are presented in the following sections.

3.5.3.1 Researcher classroom participation.

The researcher began attending the class at the same time the participant children commenced school in July 2010, although the primary data collection with the modeling activities was not until week five. As a result, the researcher was presented to the children with the support of the classroom teacher as a participant researcher and classroom helper. The teacher and researcher conferred continually to work for consistent approaches in daily interactions with the children.

The researcher was conscious of her temporary involvement in the classroom, and the ongoing role and relationship between the teacher and children once the research involvement in the classroom ceased. A total of 164 hours of classroom attendance on various days and for various times were logged by the researcher over the 10 weeks of data collection. To raise the children's awareness of the temporary nature of the researcher's presence in the classroom, the children were reminded regularly through conversation that the researcher's attendance would vary from day to day and would be for one school term only. The children were advised each day when the researcher would next be joining the class, and for how long.

The researcher's classroom attendance had a number of aims that included: making initial classroom observations, supporting and engaging the teacher in preliminary adaption of the modeling activities, determining a realistic time frame for the development of the instructional innovation and instructional sessions, observing the engagement, levels and types of interaction demonstrated by the children to inform the selection of children for the small groups for the modeling activities and determining the effective positioning of the video cameras and audio equipment for recording of the modeling activities.

3.5.3.2 Researching with children and gaining assent.

A full account of the ethics requirements and decisions are found at section 3.7, p. 102. The researcher's class participation from the commencement of the school term was undertaken to develop a working relationship with the children (Harcourt & Conroy, 2011) and to establish trusting relationships with the parents

and children. Developing trust with the participants was needed to support gaining informed consent from parents/guardians and freely chosen "assent" from the children for their participation in the research (Smith, 2011). The participant children had an average age of 5 years, and consent for participation from each child's legal guardian was mandatory. Working from a view that children are active agents and participants in the research (Coady, 2001), the researcher also sought and gained child agreement to participate.

The researcher sought to actively engage the children in the research process with a view to gaining and maintaining their initial and ongoing assent to the research. The researcher endeavoured to explain the research process truthfully to the children and to answer honestly any questions the children asked about the research process, such as "how does the camera work?" and "who will read the story about what we did?" The recording equipment for data collection (section 3.5.5.1. p. 91), and how the camera and microphone worked, were explained and demonstrated. The children's ongoing interest in, familiarity with, the equipment was demonstrated when the children in one group turned the camera off on two occasions during filming with a consequent loss of data. It is not known whether this was curiosity or withdrawn assent to the filming on that day.

Children's assent was gained by the researcher establishing trusting relationships with the children and actively engaging with children with the intention of forming a shared meaning about the purpose of the research. These aims were achieved through supporting the children's understanding of their role and responsibilities, explaining how data would be collected, and who would share or access it (Conroy & Harcourt, 2009). Engaging children for the purpose of assent considers the intersubjectivity of the relationship between the child and researcher, and the need to explain the research process within the child's 'sphere of understandings' (Conroy & Harcourt, 2009, p. 161). The researcher must be conscious that assent is ongoing and that there may be times when children choose to withdraw and/or re-enter the research process (Smith, 2011). The researcher's interactions were designed to build trust with the children and, over time, the children revealed that they felt safe and at ease with her presence. This was evidenced through the children's initiation of conversations with her, sharing

interests and concerns, and actively seeking her support with respect to daily classroom routines and activities.

3.5.3.3 Selecting groups for the data modeling activities.

The modeling activities required the children to work collaboratively at times in teacher-assigned groups of three children. Three children in a group are considered by researchers to be an optimum number for engaging in modeling activities (Lesh & Kelly, 2000). Following receipt of consent forms, the children were grouped into two groups of three children and two groups of four children. The composition of the four groups was stable throughout the data collection for the tasks where small group work was required. The groups comprised the following children: Group 1 - Isabel, Toby and Carl; Group 2 – Eliot, Jade and Sam; Group 3 – Gina, Ted, Lee and Blake; Group 4 – Bryce, Kyra, Mia and Chris. The grouping was initially based on twelve children where there was full informed consent given by both the adult caregiver and the child. Four children formed one group where consent was not full. Of these four children, two were children who had provided assent, and consent was provided by the adult caregiver for participation in the activities, but not for video-taping the children. One child was due to leave for an extended overseas holiday three weeks into the data collection, and the fourth member was a fully consenting child. None of the four children in this group was videoed in the small group work or during whole class discussions. The remaining ten children with full consent and assent for video and audio taping were placed in two groups of three and one group of four. The group compositions were selected to ensure that there was a mix of boys and girls and to observe peer compatibility and purposeful communication among the children.

3.5.3.4 Supporting reasoning and collaboration through dialogue.

The importance of the social dimensions of learning, such as communication between learners in learning environments, highlighted in both the Models and Modeling perspective (Lesh & Doerr, 2003) and statistics literature, led the researcher to draw more deeply from theory that addresses the role of dialogue in learning. In this study it was important to create and build expectations with the children to listen to each other and provide explanations for their ideas and decisions.

As a result, one of the early tasks in the classroom was the implementation of six lessons adapted from speaking and listening activities to support communication skills (Dawes & Sams, 2004. These lessons were implemented in weeks one to five (Table 3.2, p.84).

The learning objectives for the lessons were to raise children's awareness and purposes of talk to provide information, consider alternative points of view and make decisions together in a group (Dawes & Sams, 2004). The lessons used a three part structure of whole class-small group-whole class activities that mirrored the structure for the modeling activities the children would be engaging in for the principal data collection for the study. The lessons aimed to provide practice for the children in the practicalities of whole class and small group collaborative discussion they would experience in the modeling activities.

3.5.3.5 Words and symbols in the modeling activities.

The terms "reuse", "recycle" and "throw away" are consistently used in the modeling activities at the core of the study, including being assigned categories for the children to work with in the first modeling activity. Prior to the implementation of the modeling activities, the children discussed the terms in three separate whole class discussion times, each of approximately 10 minutes in weeks 4 and 5 of the data collection period. Each term was consecutively discussed, one for each discussion session, presented as a written word and a symbol combined on a card (Figure 3.1).

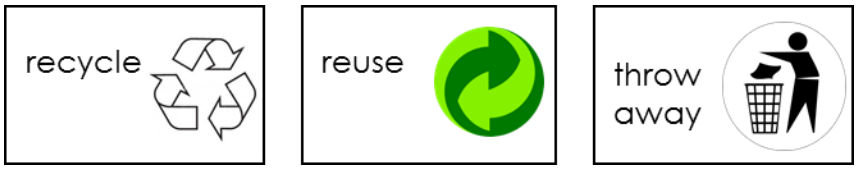


Figure 3.1 Words and symbols for classroom use.

Twelve of the fourteen children actively contributed to the three discussions that totalled approximately 22 minutes. The children were encouraged to think about what the words' meanings and they had opportunities to say what they thought each of the words meant.

3.5.4 Data Collection – Modeling Activities

3.5.4.1 Overview of the modeling activities.

The data modeling activities were implemented as part of the children's science and mathematics curriculum planning to allow for flexibility in timetabling. A series of activities, comprising data modeling problems were developed from the Models and Modeling perspective (Appendices A, B, C, & D). These were drawn from the work of English (2009b) available through a Wiki established for the Australian Research Council Project (DP 0984178) [ARC: Chief Investigators - L.D. English and R. Lesh] that investigated statistical reasoning in the early school years. These modeling activities were adapted to the context of the participating class. The names of the activities, the title and publication details of the supporting literature and the broad purpose of the activity from a Models and Modeling perspective are set out in Table 3.3.

Table 3.3

Modeling activities as instructional innovations

Activity No.	Activity Name	Supporting Literature	Activity Purpose
1	Baxter Brown's Messy Room	Baxter Brown's Messy Room by L.D. English.	Data attributes and representation
2	Michael Recycle	Michael Recycle by Ellie Bethel, Worthwhile Books, 2008.	Data representation
3	Litterbug Doug	Litterbug Doug by Ellie Bethel, Meadowside Children's Books, 2009.	Data prediction
4	Charlie and Lola	Charlie and Lola: Look after your planet by Lauren Child, Penguin, 2009.	Using data to answer a question

The children's picture story books, as supporting literature that underpinned the activities, were purposefully written (English, 2009a, Activity 1) or selected from

commercially available children's picture story books (Bethel, 2008, 2009; Child, 2009, Activities 2, 3 and 4) for exploration and discussion of data modeling and model-eliciting concepts.

3.5.4.2 Overview of the implementation of the modeling activities.

The four modeling activities were implemented consecutively in weeks six to eight of the 10 week school term (Table 3.2, p. 84).

Each of the four modeling activities comprised four tasks:

Task 1 - a warm-up activity where the picture story book was read to the whole class;

Task 2 - a warm-up activity to familiarise the children with the context of the model-eliciting activity, conducted with the whole class;

Task 3 - a model-eliciting activity where a problem was posed to be worked to a solution, conducted in small groups of three to four children;

Task 4 - a presentation-discussion activity, where the model developed in the small groups was brought to the whole class for presentation and discussion.

Task 1 was repeated for each modeling activity to allow the picture story book to be read twice. The first Task 1 reading enabled the children to focus on enjoying the picture story book as literature (Hunsader, 2004) and capture the children's spontaneous responses to and questions and comments about the picture story book. A second reading occurred at the beginning of each Task 2. This reading re-presented the picture story book as a warm-up for the modeling problem. Task 3 in each modeling activity presented a modeling problem for the children to work to a solution in small groups of three and the solutions were reported in Task 4. Following each fully completed modeling activity there was a short period to conduct data analysis and instructional redesign. Full details of the content, design, implementation and children's models produced as solutions to the problems are presented in Chapter 4.

The use of four tasks for each modeling activity provided flexibility in implementing the tasks that were responsive to the children's engagement, could

scaffold the children into structured tasks and could be implemented over more than one session if required. Further, due to the emerging nature of the research design and the modeling approach, the time required to complete the implementation of the modeling activities required a degree of flexibility within the setting.

3.5.5 Data Collection – Capturing Data

In keeping with the purposes of the educational design research, data were collected to document the children's reasoning and knowledge over the instructional period, and the implementation of the modeling activities (Cobb, Stephan, McCain, & Gravemeijer, 2001). The data collection was guided by the working structure of the modeling activities. Data were collected as the children worked in both whole class tasks and independently in small groups of three to four children. Accordingly, varieties of data were sourced from observations and documentation of all communications and products of both the whole class tasks and small group tasks. Engaging a range of data accommodated the multiple variables in the real life settings (McMahon & Oliver, 2004). Data were collected from multiple sources to provide richer, more detailed and extensive understandings and opportunities to look for processes and relationships that were evolving or developing (Creswell, 2007; Neuman, 2003). Repeated and multiple sources of data collection within the study also provided broader measures of evidence to support the development of converging lines of inquiry, adding to the reliability of the research findings (Patton, 2002). Details of the data collection methods are presented next.

3.5.5.1 Videotaping and audiotaping: children and teacher.

Digital videotaping captured and collected data in the classroom. Episodes were transcribed from the audio recordings that were embedded in the video recording and included descriptions of visual information gleaned from the video. In this section, the data collection method is described and the usefulness of these methods to capture data is provided.

Three digital video cameras and three digital audio recording devices were employed in the classroom. The audio recording devices were Bluetooth microphones, each physically separate and digitally connected to the video-cameras, with an audio coverage radius of approximately one metre. The researcher used one

video camera as a handheld video camera to follow whole class interaction, such as teacher instruction, presentations by the children, and 'critical events' such as a group or individual engaged in a specific aspect of a problem (English & Watters, 2005, p. 63). During the small group work for the modeling activities, all three cameras were mounted on small, portable, table stands. One microphone was placed in the centre of the working area for each small group table to capture the physical and verbal communication and action of the groups of fully consenting children. During the course of the filming, three small group sessions with one group were lost. Twice, one or more of the children manually switched off the video-camera during small group work, and the software failed once during downloading the video onto the computer. This rendered limited data for the consenting group of four children, named Group 3 in the study. The video recordings were downloaded and stored on an external, password protected hard-drive.

Videotaping is increasingly used in data collection as it has the advantage of being able to be repeatedly reviewed for more diverse interpretations (Robson, 2011), able to capture nonverbal behaviours and reduce the demands on taking field notes (Wiersman & Jurs, 2005). The data are preserved as a record and employed to make sense of what is happening (Hammersley, 2010). Using video to collect data with young children provided an opportunity to see children's multiple ways of communicating meaning through a method that would cause minimum disruption to the participants (Flewitt, 2006). The use of video in this study enabled aspects of the children's interaction that were anticipated as being important to be captured, such as the children's work in independent groups while developing their models, facial expressions and body movements (Lesh & Lehrer, 2000). As the use of language and co-construction of models in problem-solving by children during small group work were of specific interest to the study, video recording with heightened audio recording support was reasoned to be an appropriate collection method that would also support multilevel analysis and triangulation of emerging findings in the data.

All audio recordings were transcribed in full by the researcher. Transcription is a constructed tool that involves multiple decisions as to what to select to transcribe, how to represent it, and whether to include gesture, silences and other non-verbal communications (Hammersely, 2010). Transcription decisions were made

by the researcher to include and accurately describe communications believed to be relevant to understanding what was going on. Such descriptions included children's gestures accompanying reasoning, vocal emphasis during speaking, body movement and facial expressions during co-construction of models and disruptive events during activities.

3.5.5.2 Children's representational media.

Copies of original representational media constructed by the children in the study during the modeling activities were collected, as they are integral to the Models and Modeling perspective's view of the role of representational media in revealing the children's conceptual models (Lesh & Doerr, 2003). Copies were recorded electronically to alleviate the need for physical storage or difficulties in timely returning of children's work to them.

3.5.5.3 Teacher-researcher meetings and conversations.

During the 10 week data collection phase, the teacher and researcher met at the end of each modeling activity implementation session, and at numerous other times, to discuss the children's responses to the activities, to review the teacher's and the researcher's interpretations of the children's responses, and to review and adapt activities based on the discussions held. These meetings and conversations were recorded in field notes by the researcher. Following completion of the data collection phase and the transcription of the audio taping, the researcher and teacher maintained ongoing contact during retrospective data analysis to discuss the emerging themes in the data.

3.5.5.4 Researcher journal and field notes.

The researcher recorded personal reactions and reflections to the data collection process to support the ongoing evaluation of the data collection process and future analysis (Neuman, 2003). A summary of the data collection methods, aims and purposes is set out in Table 3.4.

Table 3.4

Summary of data collection methods, aims and purposes (adapted from Flewitt, 2006 and Silverman, 2000)

Data Collection Method	Aim	Purpose
Early classroom participation for observation	Extend the period of contact with the learning environment and participants	Become familiar with learning environment and participants, providing teacher support for instructional innovations, building trusting relationships with the children
Audio and video recordings	Record multiple modes of communication	Gain insight into individual and group interaction during reasoning processes. Support identification of the design characteristics and its implementation that impacted on its use by the children.
Children's products	Collect "auditable trails of documentation" of conceptual models produced by the children during problem-solving	Gain insight into the children's use of external media to clarify, modify or revise their statistical thinking
Teacher-researcher meetings and conversations	Record meetings and conversations during data collection	Gain insights into teacher's perspectives of the children's learning responses to inform instructional design changes and implementation
Researcher journal and field notes	Record details of interactions and comments from observations and reflection	Supplement video-audio data, documents thoughts, identify emerging themes

3.6 Data Analysis

The analysis approach was interpretivist, which provided an inductive path to ways in which to describe and explain patterns of relationships in the data (Miles & Huberman, 1994), allowing an interplay between the researcher and data (Strauss & Corbin, 1998). An interpretivist approach enabled insight to be gained into young children's reasoning with statistical context when solving data modeling problems and into how the contextualised modeling activities and learning context affected conditions for statistical reasoning and statistical learning when working to a problem solution.

An interpretivist approach allowed important dimensions to emerge from patterns found in the data, an employed inductive and deductive analysis. Deductive

analysis was informed by theoretical knowledge of statistical processes and concepts that informed the research questions and enabled theoretical properties to be examined in the data and comparisons to be made. The use of inductive and deductive analysis enabled data to be reduced and core meanings that were theoretically based or emerged inductively from patterns or themes in the data to be identified. Analysis commenced with equal attention being given to all data that was then telescoped into analysis of selected data as patterns, themes and theoretical properties emerged. Observer notes (as journal and field notes), teacher-researcher meetings and conversations, transcripts and video transcription and viewing were used. Video-backtracking was employed, where video segments were viewed multiple times from multiple perspectives. Collectively, analysis of these data were used to establish a framework for interpretation that aimed to reduce concealed biases (Lesh & Lehrer, 2000). Simultaneous and retrospective analysis was undertaken, and details of the analysis process and gerneralisability and trustworthiness are provided in sections 3.6.1 – 3.6.6.

3.6.1 Design Based Methodology Consideration for Data Analysis

The use of educational design research placed obligations on the researcher in terms of the contribution that this methodology seeks to make, and how analysis works to achieve this. These aspects are now considered.

The use of educational design research in complex and messy classroom settings requires researchers to articulate their "argumentative grammar" (Kelly, 2004; Cobb & Gravemeijer, 2008); that is, "the logic that guides the use of a method and that supports reasoning about its data" (Kelly, 2004, p. 118). The logic, or grammar, a feature of the research method, is the means by which data analysis, claims and assertions are linked (Cobb & Gravemeijer, 2008). Cross study findings can be compared and the contribution of studies evaluated, a process similar to qualitative research in general in this regard (Reimann, 2011). On this interpretation, data analysis in educational design research is about making sense of the data through documented procedures that, as far as possible, thoroughly and systematically represent the design process (Edelson, 2002) and fully and truthfully represent the processes of collection (Patton, 2002).

Educational design research aims to provide conclusions able to address the practical and theoretical results of an innovation's implementation (Plomp & Nieveen, 2007). Analysis therefore should reflect the how and why of the functioning of the innovation in the context of the study, and the study conclusions should reflect the intended outcomes of the designed innovation, given the context and conditions in which it was implemented. The problem for this study was how young children can be supported into reasoning statistically. The design of the data modeling activities were characterised by initiation through picture story books, and aimed to engage and activate children's use of statistical reasoning as they worked a problem to a solution. Therefore the design of the data modeling activities aimed to provide conditions for examining the essential features of the practices that triggered the phenomenon in question; statistical reasoning. As a small individual study, the aim of this study was to contribute theoretical building blocks, or 'humble theory' (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003), and make a practical contribution to educational products and processes that support statistical learning (McKenney & Reeves, 2012).

3.6.2 Simultaneous and Retrospective Analysis

Simultaneous analysis occurred as ongoing changes were made to the modeling activities that formed the core of the data collection. Given the children's responses to the modeling activities, this analysis was informed by emerging ideas by the researcher and participant teacher about children's learning at that particular point in time. Short meetings in person or by phone were held between the researcher and teacher following a modeling activity session. The context of these discussions informed ongoing changes to the modeling activities, providing minicycles of design and analysis. Details of the design changes during data collection are presented in Chapter 4.

Retrospective analysis of the data was employed as a situated, retrospective explanation to account for the statistical reasoning that occurred by systematically working through the data (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003). This enabled "evidenced-based claims and results to be examined in concert with the underlying design theory" (Wang & Hannafin, 2008, p. 11), and the details of this are presented next.

3.6.3 Approaching the Data - the Analytic Lens

As stated in section 3.2 (p. 69), the principal theory informing this study was the Models and Modeling Perspective (Lesh & Doerr, 2003). The study was also informed by theoretical understanding with respect to young children. These theories therefore framed the inquiry process and subsequent data analysis (McKenney & Reeves, 2012). In addition, the study was situated within the domain of statistics, and the structure of the domain knowledge acted as a further theoretical guide (Kelly, 2006). As an interpretive study that has used theory to shape its development, the study can be considered to be theory bound (Jungwirth, 2008).

3.6.4 The Analysis Process

Data analysis in educational design research is typically inferential, interpretative and cyclical (Reimann, 2011). This approach was reflected in the structure the analytic process. Both inductive and deductive approaches to data analysis were employed. A deductive approach was used because the research questions were determined deductively and so based on explicit theoretical frameworks underpinning and informing the study, the data analysis employed a partially deductive framework (Patton, 2002). From this perspective, the data were analysed deductively according to existing theoretical frameworks, which acted as 'sensitising concepts'; categories or references that originated in the research literature and were brought by the researcher to direct data exploration (Patton, 2002, p. 456). For example, as the theoretical framework for the study reasoned that the instructional innovations would trigger statistical reasoning and learning, data evidencing these processes was actively sought.

The study focus was the exploration of statistical reasoning through the models created by the children as they worked the modeling problem to a solution. The study was interested in the characteristics of the task contexts and the data contexts the children drew from as they engaged with the modeling tasks and developed their models. Accordingly, data analysis strove to reveal the substance of the contextual use and reasoning employed by the children (that is, what contextual knowledge they drew from and what reasoning they used). The theoretical framework used to approach the analysis validated targeting the specific

identification of the models developed by the children during the modeling activities. Data analysis strove to reveal the impact of key elements of the task contexts, that is, determine which elements of the design of the modeling activities impacted the children's use of knowledge and reasoning to solve the statistical problem. The children's use of contextual knowledge when engaging with data based reasoning were actively sought, as was evidence of the role of the design characteristics of the modeling activities on statistical reasoning processes and their development.

Data analysis also employed an inductive process, where important dimensions were allowed to emerge from the patterns found in the data. The use of both inductive and deductive approaches helped organise and explain the data and find concepts to help make sense of and present the data (Miles & Huberman, 1994). For example, inductive analysis found patterns of difference in the children's use of picture story book knowledge when reasoning between the design and analysis systems in data modeling and patterns of more abstract reasoning in task contexts with certain characteristics. Analysis repeatedly moved from verification to discovery, through deductive and inductive processes, as themes or categories for specific statistical processes such as instances of inductive reasoning were established and tested (Patton, 2002).

Data were initially analysed chronologically. Repeated reading of the transcripts and viewing of the videotaping enabled the researcher to gain an understanding of the data as a whole and to develop sensitivity to the data. Iterative refinement cycles for videotape analyses of conceptual change were a key tool. This technique enabled data interpretations to be validated through being repeatedly tested, refined and extended and to develop an adequate framework for interpretation that endeavoured to reduce bias (Lesh & Lehrer, 2000). Initial and subsequent impressions were noted and diagrammed for logical ways to select sessions for closer analysis, in conjunction with data collected through other methods, including ongoing collaboration with the participant teacher.

A content analysis was applied to the data, as a means of reducing and making sense of it and to identify core meanings that were theoretically based or emerging as patterns or themes (Patton, 2002). In conjunction with the interpretative framework already developed, content analysis provided usable units of analysis for

categorisation into emerging themes (Denscombe, 1998) which were described and summarised for more focused coding (Miles & Huberman, 1994). A provisional 'start list' of codes drawn from analysis at the time of data collection, based on the conceptual framework along with the research questions, also informed this. Topic coding (Richards, 2009) enabled a focus on construct validation through seeking agreement as to categories through other interpretations generated from other sources, and to avoid a tendency to view data through narrow or limited theoretical windows. The coding process itself was inherently subjective, however, sensitivity to context and theory were sought to bring balance to the process (Patton, 2002).

Data contributing to the research questions were progressively reviewed, and examined for patterns and trends using constant comparative strategies (Strauss & Corbin, 1990). Common themes through multiple perspectives were identified and refined through systematic comparison of similarities and differences between concepts to bring out possible properties and dimensions not otherwise evident (Strauss & Corbin, 1998). These themes were grouped for analytic coding to engage in contextualised interpretation (Richards, 2009) with recursive testing and affirming between the data and coding occurring for codes that did not fit the data until verification of the analysis could be met. The themes reinforced many of the key categories proposed through the theoretical framework such as the children's use of the picture story context in data based reasoning and inductive reasoning during data analysis, suggesting the conceptual framework as an acceptable model (Saldana, 2007).

3.6.5 Managing the Data

The large amounts of data (video, photographs and audio transcription) were partially managed using the computer software NVivo9, selected due to its ease of use, data input capacities and analysis features (Bazeley, 2007). NVivo9 provided assistance in helping store and organise data, search for and locate data associated with codes or themes, make comparisons among codes and supported conceptualising alternative levels of analysis abstraction (Creswell, 2007).

Nodes based on the themes and codes developed from the data were created using the multiple data sources. The data were re-coded and transferred, which

assisted with the mechanical aspects of management and analysis. However, due to constraints in learning to use the wide potential of the NVivo9 software, some coding and management was achieved through manual methods, including visual mapping of themes and codes, and annotation and colour coding of printed transcripts of audio, conversational and journal entries.

3.6.6 Generalisability and Trustworthiness

As for many types of qualitative research, the issues of generalisability and trustworthiness require special attention (Cobb, 2000; Simon, 2000). Reflective of this were two key concerns for data analysis arising from educational design research generally, namely representativeness as generalisability and trustworthiness. These key concerns involve how well the data represents the problem, the context and the participants, and how valid and reliable the data is (McKenney & Reeves, 2012).

Trustworthiness goes to the heart of credibility of analysis and "is concerned with reasonableness and justifiability of inferences and assertions that result from retrospective analysis" (Cobb & Gravemeijer, 2008, p. 87). The researcher initially sought trustworthiness by ensuring that the collection and analyses of data were "both systematic and thorough", with all phases of the analysis documented (Cobb, 2000, p.328). The data collection followed recommended guidelines for optimising the collection of quality data (Richards, 2009) and aimed for useful, contexted data to capture available and pertinent information with detail, accuracy. This was achieved through the reviewing and checking of events and transcriptions. The role of the teacher was acknowledged in collaboratively constructing the data and in simultaneous and retrospective analysis. The teacher was engaged in cycles of independent and collaborative analysis of the data which served to support the evaluation, negotiation and consensus with respect to emerging interpretations. This method strengthens the credibility of the analyses and enhances the dependability of the research (Lincoln & Guba, 1985; Roth, 2005).

Throughout the analysis process, a variation of the constant comparative method of analysis was used, contesting inferences made about the data and coding. The data were worked through chronologically and systematically using data management that allowed the data to be retraced. In addition, multiple aspects of the

study supported the trustworthiness of the study. Inductive analysis that classified data due to existing theory (such Models and Modeling and statistical learning) was employed, as data was explored for emergent patterns. A full description of all stages of the study, including the instructional innovations and their implementation was provided. The explicit conceptual framework and structure of the study design was set out to provide the underlying rationale and links between research, theory, questions, design analysis and conclusions. These actions meet guidelines provided to encourage academic rigor, and credible, trustworthy and plausible designs in educational design research (McKenney, Nieveen, & van den Akker, 2006).

The study also employed the process of triangulation, which draws together and uses multiple sources of data as independent measures to find agreement and clarification about the meaning of data. Triangulation is achieved through the repetition of analyses across the data (Design-Based Research Collective, 2003; Miles & Huberman, 1994) and allows multiple independent verifications to help guard against possible researcher bias (Patton, 2002). Importantly, triangulation supports the reliability of findings and meets the need for systematic documentation, analysis, reflection and a strong chain of reasoning (Design-Based Research Collective, 2003; Miles & Huberman, 1994; Plomp, 2007). In the analysis process in this study, data were drawn from multiplicity of collection methods, types and sources set out in Table 3.4 (p. 94) which were collated and cross-referenced. Constant comparative methods of analysis and the use of iterative refinement cycles, particularly of the video and audiotaping, were used to refine and test interpretative frameworks.

With respect to generalisability, both Cobb (2000) and Simon (2000) argue that it is the treatment of classroom activities and events as exemplars or prototypes that give rise to generalisability. This is albeit not in the traditional sense, but in terms of what is found about the pedagogical products that will be useful to others in other settings (Rasmussen & Stephan, 2008). The educational design research approach assumes that "the mathematical practices and associate patterns of learning documented during a (design) experiment can emerge when the instructional sequence is enacted in other classrooms" (Cobb, Stephan, McClain, & Gravemeijer, 2001, p. 152). Educational design research therefore does not aim for context free

generalisations but for analytic generalisation about knowledge of whether and why an intervention works in a particular context (Plomp, 2007). Heuristic statements that emerge strive to support generalisability of the design principles as a working hypothesis (Plomp, 2007). For this study, the modeling activities, designed using Models and Modeling principles and incorporating children's picture story books to contextualise the statistical problem, engaged young children in data-based statistical reasoning that drew on data context in working to find a solution. A generalised heuristic statement is that statistical reasoning can be expected to occur, given the learning conditions described in this study, and the implementation of a designed intervention in the manner set out in the study.

This study has provided evidence of processes put in place to compensate for potential conflicts of interest and challenges to the trustworthiness and generalisability of the study. These include:

- a shift to being a critical researcher in later phases of the study;
- treating each part of the research design as equally important in order to develop a strong chain of reasoning;
- engaging in triangulation through theory and the use of multiple data sources;
- systematic design, documentation, analysis and reflection at all stages of the research; and
- using the collaborative teacher and colleagues as critical friends to develop observer and analytic reliability.

3.7 Ethical Considerations

This section identifies the ethical considerations of the study, including informed consent for the participants, anonymity and confidentiality. Ethics approval for this study was sought and obtained from the Queensland University of Technology Human Research Ethics Committee (Approval number 1000000536) and the South Australian Department of Education and Children's Development (Approval number DECS CS/10/251-2.2). Approval from these organisations was dependent on meeting criteria with respect to the conduct of the study.

3.7.1 Informed Consent

3.7.1.1 Children and legal guardians.

Steps were taken to gain children's assent and parental/guardian consent to the research. A prepared brochure (Appendix E) written as a story with illustrations, was sent home with the parent/guardian consent forms with a request that parents read the story with their child. The children were invited to give permission to be participants with a child's Consent Form (Appendix F), in addition to the parent/guardian consent form. The parent/guardian consent form detailed the participation expectations, expected benefits, and stated any anticipated risks, how confidentiality would be achieved and contact details for the researcher and participating organisation. The process complied with organisational ethical criteria to inform the participants of the nature and possible consequences of the research so that they were positioned to make an informed choice (Christians, 2005). Parents were informed through an initial introductory letter (Appendix G) and through information in the consent package documentation that the researcher was available in person or through email or phone contact should they have any questions or concerns about the research and their child's involvement. The researcher was available most mornings over the 10 week data collection period when the children were coming into the classroom with their parents or caregivers.

A package was prepared and given to parents in the second week of the school term. The package contained:

- letter to the parents from the researcher, explaining the research procedures and requesting their child's participation; (Appendix H)
- QUT Participant Information for QUT Research Project (Parent/Caregivers); (Appendix I)
- QUT Consent Form for QUT Research project (Parent/Caregiver); (Appendix J)
- QUT Consent Form for QUT Research project (Child/Student); (Appendix F)

- brochure that parents or caregivers were invited to read with their children to explain the research and to seek the child's assent to his or her participation in the study (Appendix E).

The forms and letters provided information for the parent/guardian to support and inform their understanding of:

- the child's participation was by choice and the child could be withdrawn at any time without detriment;
- the role that his or her child would have in the research; and
- what would happen to the data collected from his or her child, where the results may be published and who would have access to this.

Of the 14 children in the class, two parents/guardians gave consent for participation but not for videotaping, and one child left in week four for an extended overseas trip. Along with one other fully consenting child, these four children formed a group during small group work that was not videotaped, and every effort was made during whole class discussions, as the video was not fixed but hand held, to selectively pause the picture or focus the camera elsewhere when necessary.

3.7.1.2 Participating teacher.

Informed consent was obtained from the participating teacher who provided a written undertaking to agree to all confidentiality and anonymity procedures put in place for the study. A completed QUT Participant Information Form for QUT Research Project (Teacher) is at Appendix K and the Consent Form (Teacher) is at Appendix L.

3.7.2 Anonymity and Confidentiality, Including Data Storage and Handling

The conceptual framework underpinning a study informs the ethics processes such that issues of confidentiality are dependent on the nature of the data to be collected (Eynon, Fry, & Schroder, 2008). Confidentiality is of particular concern with visual material, such as video and young children as participants (Robson, 2011). In the Consent Form Parents/Caregivers, permission was sought for visual images of the children to be used in publications and teaching materials, and an option provided for permission to be given, but for facial images to be blurred. Three

of the twelve fully consenting parents asked for this option to be implemented. Full consent for use of the visual materials for its stated purpose was obtained, however, the researcher is mindful of confidentiality and the degree of detail needed for the research claim being supported (Flewitt, 2005). Pictures of the participants for presentation of analysis and findings in this study have been selected with confidentiality in mind.

Anonymity, along with confidentiality, protects participants' identity and reduces risks of sensitive issues being disclosed (Christians, 2005). Anonymity and confidentiality were provided by identifying the educational setting with pseudonym and individual participants by code. The key to the code was stored separately from the data and pseudonyms ere used to report the study. All electronic data is stored on a password-protected external hard drive and on disc backup copies secured in locked filing cabinets, along with all hard copies of data, such as printed copies of audio transcripts, working copies of documents and master lists of data, in accordance with the National Statement on Ethical Conduct in Human Research (National Health and Medical Research Council, Australian Research Council & Australian Vice-Chancellors' Committee, 2007). Viewing all data has been and continues to be restricted to the researcher, participating teacher and the supervisors authorised by the approving Ethics committee.

3.8 Chapter Summary

The study aimed to explore the role of the task context and the role of data context in how young children engaged context knowledge and reasoning as they found solutions to statistical problems, where the problems were contextualised by a picture story book. Theoretical considerations in developing the design of the study included the Models and Modeling perspective (Lesh & Doerr, 2003) and perspectives on young children.

A qualitative and interpretivist research orientation was chosen to best support the naturalistic setting and exploratory nature of the study. The distinguishing characteristics of the methodology, educational design research, sat well with the chosen orientation theoretical underpinnings of the study. Educational

design research was utilised to actively gain insight into the characteristics of effective task design for engaging statistical reasoning.

The research methods were presented, including the methods for participant recruitment of the teacher and children. The practical implementations of ethically obtaining young children's assent to research involvement were outlined. Data collection, including early tasks and activities that were introduced to support the children's engagement with the modeling activities were presented. A broad overview of the data collection of the modeling activities and methods of data collection were provided. The underpinning theoretical basis and analysis processes were described, and source triangulation, trustworthiness and generalisability of the study addressed. Lastly, the ethical considerations of the study, including participant informed consent, and anonymity and confidentiality were presented.

The following chapter attends to a full description of the implementation of the four modeling activities and the models the children developed. In accordance with design based research methodology, documentation of all stages of the research is required for the trustworthiness and generalisability of the study (Plomp, 2007). The implementation of the four activities provided the principal data analysed for the findings and discussion presented in the subsequent Chapters 5, 6, & 7.

Chapter 4 MODELING ACTIVITIES: Implementation and Children's Models

4.1 Introduction

This chapter presents the content, implementation and models developed by the children for the four modeling activities *Baxter Brown*, *Michael Recycle*, *Litterbug Doug* and *Charlie and Lola*. The four activities were implemented consecutively between week five and week eight of data collection. This chapter expands on the overview of the modeling activities provided in section 3.5.4, p. 89.

Each of the four modeling activities are presented separately, and the content and implementation of each activity is addressed. First, the four tasks that comprised each modeling activity are described. Second, the implementation of each modeling activity in the classroom is specified. Third, the children's models that were developed to find a solution to the modeling problems are presented. Finally, the chapter is summarised and subsequent chapters introduced. Changes made to activities as a result of simultaneous analysis during data collection are noted.

The next three chapters (Chapters 5, 6, and 7), present and discuss the findings that emerged from analysis of the data collected during the implementation of the four modeling activities described in this chapter. Chapter 5 presents and discusses findings from the analysis of the children's responses to reading the picture story book in Task 1 in each modeling activity. Chapter 6 and Chapter 7 present and discuss findings from analysis of the children's use of knowledge and reasoning as they found solutions to the data modeling activities.

4.2 Modeling Activity 1: Baxter Brown Data Modeling Activity

Baxter Brown was the first modeling activity implemented in week six of the data collection. The focus for the Baxter Brown modeling activity was the generation and selection of attributes and the organising, displaying and representation of data. Each of the four tasks that comprised Baxter Brown (Figure 4.1) and their implementation is presented next.

1. BAXTER BROWN
Task 1. Whole class picture book reading
Task 2. Whole class warm –up: classifying real objects into categories
Task 3. Small group data modeling problem
Task 4. Whole class reporting of modeling solution

Figure 4.1 Component tasks for modeling activity 1, Baxter Brown.

4.2.1 Task 1: Warm-up – Reading the Picture Story Book

Task 1 was a whole class warm-up activity designed to familiarise the children with the problem context for Baxter Brown Tasks 2 & 3. The picture story book, *Baxter Brown's Messy Room* (English, 2009a) was a purpose written story for the data modeling problem in Task 3. The story was read to the class by the teacher. Immediately following the reading the children were invited to offer questions and comments about the story. Next, the children were invited to respond to any questions that were posed.

4.2.2 Task 2: Warm-up – Sorting Objects According to Attributes

Task 2 was a whole class warm-up designed to introduce sorting objects according to attributes that the children determined. The activity began with the picture story book read a second time. Next, the data modeling problem that had been introduced in the picture story book was presented to the children: Baxter Brown must clean up his room. To help Baxter Brown clean up his room, the children were asked to sort real objects into pre-determined task categories of recycle, reuse and throw away.

Ten different objects of differing quantities replicating those in the picture story book were provided for the children to manipulate and explore: 7 apple cores, 5 plastic bags, 6 old toys, 9 empty drink cans, 7 cereal packets, 8 dog biscuits, 8 dog bones, 4 old shoes, 5 newspaper and 6 milk cartons. The objects were introduced by the teacher into the activity, counted, and placed on a low table.

Three hoops were placed on the floor in a row (Figure 4.2). Each hoop had a category label card (Figure 4.3) above it for reuse, recycle or throw away.

Figure 4.2 Three labelled hoops.

Figure 4.3 Category label cards.

The labels had been introduced previously (section 3.5.3.5, p. 88). The children sat in a semi-circle next to the hoops and took turns to choose and place an object in a category hoop. The children were asked to choose an object and place it in the hoop representing the category they had chosen. They were asked to explain the attribute they had used to determine the classification for the object.

4.2.3 Task 3: Data Modeling Problem – Finding a Solution

Task 3 was a small group work activity where the data modeling problem was posed again to the children: Baxter Brown needed help to clean up his room. To help

Baxter Brown, the children needed to work out what objects in his messy room could be recycled, or reused or what could be thrown away. The children worked to find a solution to the data modeling problem using pictorial representations of the objects from the story. Before the small group work began, the children were shown a chart with pictures of the objects found in Baxter Brown's room (Figure 4.4).

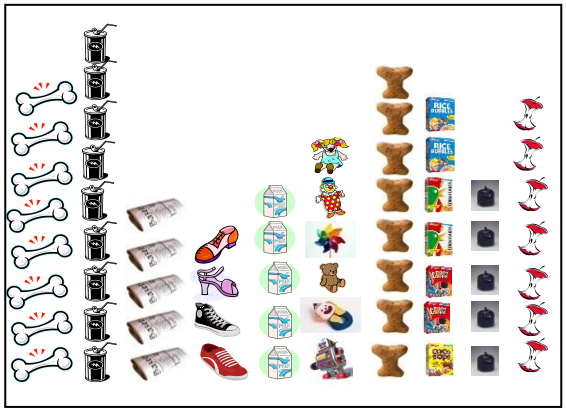


Figure 4.4 Pictorial chart of objects represented in the story.

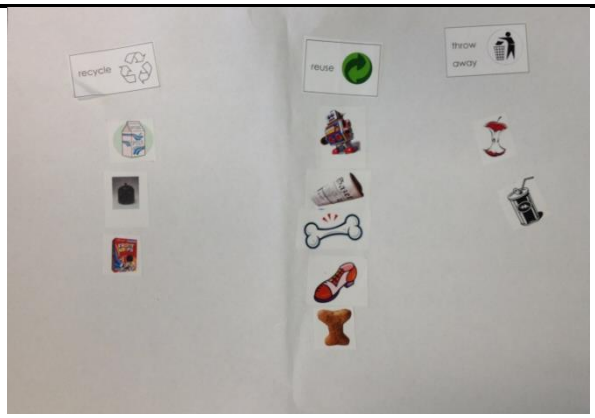
The teacher named and counted each object in a group, for example, "shoes: one, two three four shoes" and many of the children joined in the counting. The number of each type of object depicted in the chart replicated the number of objects depicted in the picture story book. Each small group was provided with a packet of ten cut out pictures from the chart, representing one of each type of object: one each of the apple core, plastic bag, old toy, empty drink can, cereal packet, dog biscuit, dog bone, old shoe, newspaper and milk carton (object pictures). The teacher explained that each packet had one picture of each type of object from Baxter Brown's room (category pictures) and three category label pictures (recycle, reuse, throw away) (Figure 4.3, p. 109). In addition, each group was provided with a blank sheet of A3 paper, and had access to pencils, scissors and glue sticks on the desks. The children worked at tables in small teacher assigned groups of three or four. The children were asked to sort the pictures and organise and display the classifications of the pictures in any way they liked. The teacher instructed the children to say *why* a picture was to be sorted into recycle, reuse or throw away as they worked together.

4.2.4 Task 4 – Small Group Reporting

Task 4 was a whole class task where the children reported each small group's organisation and representation of the data modeling problem solution. A member of each small group went to the front of the class and placed their group's data representation on the white board to report their modeling solution.

4.2.5 Children's Models

Each of the four data models developed by the four groups is shown as a photograph and a diagram in Figure 4.5, Figure 4.6, Figure 4.7 and Figure 4.8.



Recycle	**Reuse**	**throw away**
milk carton	Toy	apple core
rubbish bag	Newspaper	drink can
cereal packet	Bone	
	Shoe	
	dog biscuit	

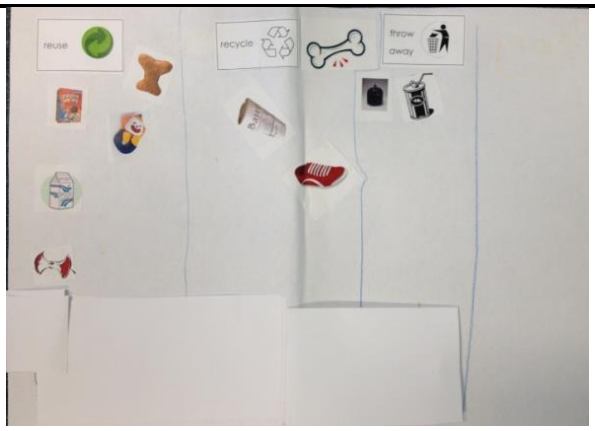
Figure 4.5 Baxter Brown data model for Group 1.

Recycle	**Reuse**	**throw away**
Bone	Toy	apple core
dog biscuit	rubbish bag	cereal packet
drink can	Shoe	
milk carton		
Newspaper		

Figure 4.6 Baxter Brown data model for Group 2.

Recycle	**Reuse**	**throw away**
drink can	cereal packet	Bone
apple core	Shoe	Toy
milk carton	newspaper	Dog biscuit
rubbish bag		
Newspaper		

Figure 4.7 Baxter Brown data model for Group 3.



Recycle	**Reuse**	**throw away**
cereal packet	bone	rubbish bag
dog biscuit	newspaper	drink can
milk carton	shoe	Dog biscuit
Toy		
apple core		

Figure 4.8 Baxter Brown data model for Group 4.

There were similarities between the organisation and display of the data. All four groups used columns to organise the representation of the categories and columns were labelled using the category pictures. All four groups used the paper in landscape position. Differences in the displays were:

- Two groups, Groups 1 (Figure 4.5) and Group 3 (Figure 4.7) positioned the object pictures under each other.
- One group, Group 4, (Figure 4.8) drew vertical lines between the columns and glued the object pictures within the columns

One group, Group 2 (Figure 4.6) clustered the column in the bottom left hand quadrant of the paper.

4.3 Modeling Activity 2: Michael Recycle Data Modeling Activity

Michael Recycle was the second modeling activity and was implemented in week seven of the data collection. The focus for the Michael Recycle modeling activity was identifying and displaying pictorial data in a more abstract form. Each of the four tasks that comprised Michael Recycle (Figure 4.9) and their implementation is presented next.

2. MICHAEL RECYCLE

Task 1. Whole class picture book reading

Task 2. Whole class warm –up: drawing pictures of objects

Task 3. Small group data modeling problem

Task 4. Whole class reporting of modeling solution

Figure 4.9 Component tasks for modeling activity 2, Michael Recycle.

4.3.1 Task 1: Warm-up – Reading the Picture Story Book

Task 1 was a whole class warm-up designed to familiarise the children with the problem context for Michael Recycle Task 2 and 3. The picture story book, *Michael Recycle* (Bethel, 2008) was a commercially available book. The picture story book was read to the class by the teacher. Immediately following the reading, the children were invited to offer questions and comments about the story. Next, the children were invited to respond to any questions that were posed.

4.3.2 Task 2: Warm –Up – Creating Pictorial Representations

Task 2 was a whole class warm-up designed to create the pictorial representations of objects for use in Michael Recycle Task 3. The task began with a re-reading of the picture story book from Task 1. Next, the data modeling problem was posed. A group of real objects were presented to the children as having been found by Michael Recycle and the problem was that he needed help to sort the objects. The task required the children to draw pictures of the objects on sticky notes that would be sorted into categories in Task 3.

Nine real objects were distributed across three tables where the children sat to draw their pictures. Next to each object was a printed card with the name of the object. The grouping of the objects on each table was informed by the children's sorting decisions in the Baxter Brown modeling activity. For example, types of objects similar to those that had been classified as "throw away" in Baxter Brown were placed on Table 1: orange peel, old bread and an empty snack food packet. Type of objects that were similar to those classified as reuse or throw away in Baxter Brown were placed on Table 2 and 3. Table 2 had a paper bag, a cardboard box, and an empty drink can and Table 3 had an empty plastic bottle, a glass jar and a cereal packet. One child from each of the four groups formed for small group work for the study (section 3.5.3.3, p. 87) was selected to work at each table of objects. This ensured that each group for Task 3 would have drawings of a variety of objects for use. The children were each provided with two 12.5 x 7.5 cm sticky notes. They were asked to choose two objects to draw, one on each sticky note, and to write the name of the object if they wished to. Coloured pencils were available to the children in pencil caddies on each table.

4.3.3 Task 3: Data Modeling Problem – Finding a Solution

This small group task presented the data modeling problem. The children were asked to help Michael Recycle sort out the objects he had found, using the pictures they had drawn.

Each child in a group had drawn two objects they had selected from those on the tables in Task 2. For groups with three children, there were six pictures to sort and represent, for groups of four children there were eight pictures to sort and

represent. A cardboard cut-out of the character Michael Recycle from the picture story book was placed on each group's table. The children were asked to sort and display the pictures in a way that would make it easy for Michael Recycle to see how the objects had been sorted. During the task, Carl from Group 1 asked for the terms *recycle*, *reuse* and *throw away* to be written on the electronic whiteboard. All groups used the terms to label their categories. The list written by the teacher is shown in Figure 4.10.

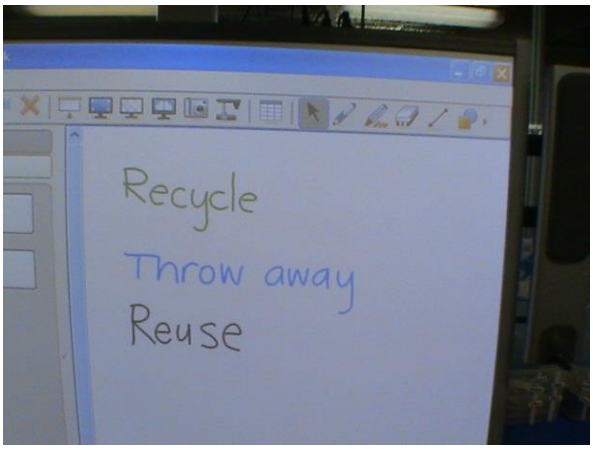


Figure 4.10 List of words requested by Group 1.

4.3.4 Task 4: Small Group Reporting

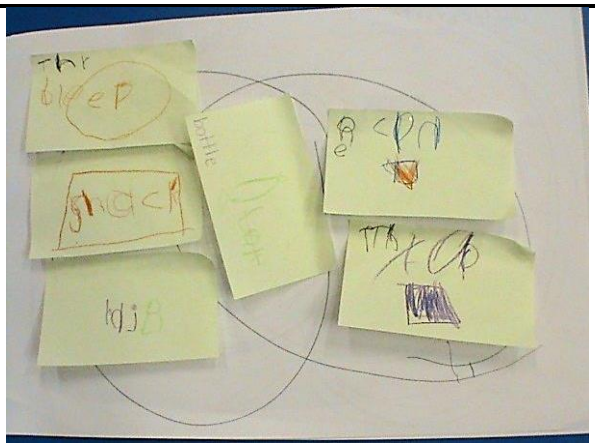
Task 4 was a whole class task where the children reported each small group's organisation and representation of the data modeling problem solution. Children sat on the floor in a circle with the teacher. The group reporters spoke from their places in the circle and used the data model the group had developed to report the group's solution.

4.3.5 Children's Models

Each of the three data models developed by three of the groups is shown as a photograph and a diagram in Figure 4.11, Figure 4.12 and Figure 4.13. The fourth group's model was developed while a school support officer unexpectedly engaged with the children and was not used as she influenced the children's models. The children labelled all of the pictures they drew with the name of the object. Two types of models were identified on the basis of the organisation, display and representation of the pictorial data.

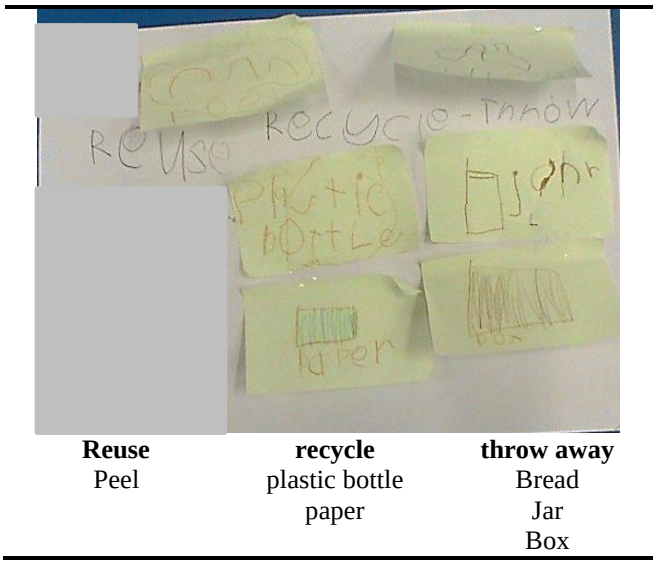
Recycle	**reuse**	**throw away**
Box	paper	Snack
	jar	cereal box
		Peel

Figure 4.11 Michael Recycle data model for Group 1.



throw away	**recycle and throw away**	**Recycle**
Peel	bottle	Can
Snack		Box
Jar		

Figure 4.12 Michael Recycle data model for Group 2.



Reuse	**recycle**	**throw away**
Peel	plastic bottle	Bread
	paper	Jar
		Box

Figure 4.13 Michael Recycle data model for Group 3.

Model 1. This model was created by Group 1 (Figure 4.11) and Group 3 (Figure 4.13). The model addressed the three categories, *recycle*, *reuse* and *throw away*. The pictorial data were displayed in columns with written category labels at the head of each column.

Model 2. Group 2 (Figure 4.12) addressed two categories, *recycle* and *throw away*. The pictorial data were displayed in two overlapping Venn diagram circles. Drawings for each category were grouped together in each circle. One drawing was placed in the intersection of the circles. The group members attempted to label the categories on drawings in each circle.

4.4 Modeling Activity 3: Litterbug Doug Data Modeling Activity

Litterbug Doug was the third modeling activity, and was implemented in week seven of the data collection. The focus for the Litterbug Doug modeling activity was reading, interpreting and extending data represented in an abstract format to make predictions. Each of the four tasks that comprised Litterbug Doug (Figure 4.14) and their implementation is presented next.

3. LITTERBUG DOUG

Task 1. Whole class picture book reading

Task 2. Whole class warm –up: introducing reading data tables

Task 3. Small group data modeling problem

Task 4. Whole class reporting of modeling solution

Figure 4.14 Component tasks for modeling activity 3, Litterbug Doug.

4.4.1 Task 1: Warm-Up – Reading the Picture Story Book

Task 1 was a whole class warm-up designed to familiarise the children with the problem context for Litterbug Doug Tasks 2 and 3. The picture story book, *Litterbug Doug* (Bethel, 2009) was a commercially available book. The picture story book was read to the class by the teacher. Immediately following the reading, the children were invited to offer questions and comments about the story. Next, the children were invited to respond to any questions that were posed.

4.4.2 Task 2: Warm-Up Activity – Introducing the Data Table

Task 2 was a whole class warm-up designed to introduce reading and interpreting the data table for Task 3 (Figure 4.15).

What Litterbug Doug collected	Monday	Tuesday	Wednesday	Thursday
	2	5	4	
	4	3	2	
	2	6	3	
	1	4	2	
	2	3	0	

Figure 4.15 Litterbug Doug data table.

The task began with a re-reading of the picture story book from Task 1. Next, the data table that contextualised information for the data modeling problem was introduced. In the picture story book for the task, Litterbug Doug was a lazy, messy

character who did not recycle until Michael Recycle arrived to teach him how and to clean him up. As a result, as the story ended, Litterbug Doug became a Litter Policeman. In the data modeling problem, Litterbug Doug was in his new role as the Litter Police, and he had tidied up the town by collecting rubbish in the park. The data table represented how much rubbish Litterbug Doug had collected in the town's park on three days; Monday, Tuesday and Wednesday. The data modeling problem (to be worked to a solution in Task 3), asked the children to predict what Litterbug Doug collected on the fourth day, the Thursday. The Thursday column in the data table was left blank.

Reading the data table was scaffolded through a series of table representations introduced on the electronic interactive white board. The first image, seen in Figure 4.16, was an illustration of Litterbug Doug in his role as a Litter Policeman taken from the final page of the picture story book read in Task 1.

Figure 4.16 Electronic white board introduced in task 2.

The second image, seen in Figure 4.17, introduced and presented two columns visually.

Figure 4.17 Introducing columns of objects.

The left hand column displayed pictures of individual objects and the right hand column portrayed multiples of the same objects. The objects depicted were: apple cores, tin cans, newspapers, banana peel and pieces of cheese. The teacher named the objects. He then explained that the pictures of objects in the right hand column represented how many objects Litterbug Doug, working as the Litter Police, had collected on Monday in the park. Next, the teacher asked; "how can we work out what it means?" The teacher introduced the words *data table* and *columns*, and gestured up and down the columns with his hands.

The third image, seen in Figure 4.18, introduced recording quantities of objects with numerals.

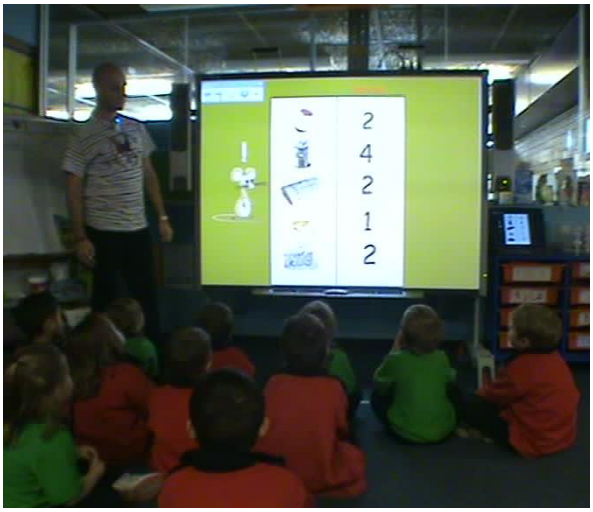


Figure 4.18 Introducing column labels, row labels, and numbers.

The teacher presented two columns. The left hand column displayed pictures of the same individual objects displayed in Figure 4.17 (p. 120). The right hand column presented numerals in place of the pictures of multiple objects previously portrayed in the right hand column in Figure 4.17 (p. 120). In addition, the head of the right hand column was labelled with the word “Monday” in red.

The next three figures illustrate how reading the table was modelled by the teacher. These figures depict the teacher as he named each object in the left hand column and read the corresponding number in the right hand column. The teacher used hand gestures to move from object to numeral across the row and then down the column. An example of this is depicted in Figure 4.19. The teacher is standing to the right of the table. He said, “we can see that on Monday” and touched the word Monday at the top of the column.

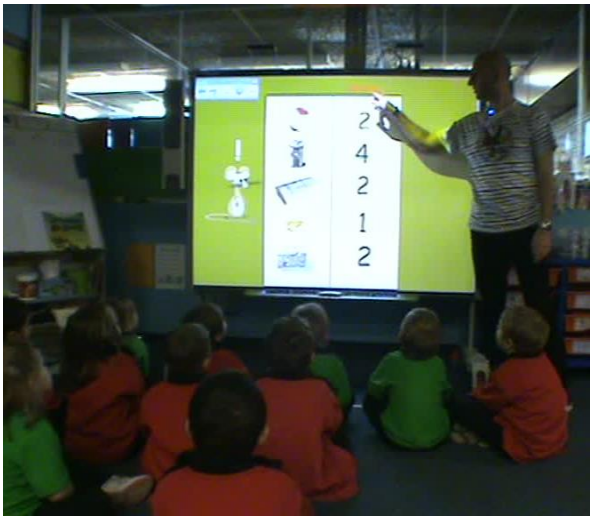


Figure 4.19 "On Monday..."

Next, as seen in Figure 4.20, he continued and stated, “Litterbug Doug collected 2 apple cores” and touched the picture of the apple core.

Figure 4.20 "Litterbug Doug collected...".

Finally, as shown in Figure 4.21, he touched the picture of the apple core and moved his hand across to touch the numeral two in the apple core row. The word *row* was the introduced by the teacher to describe his action.

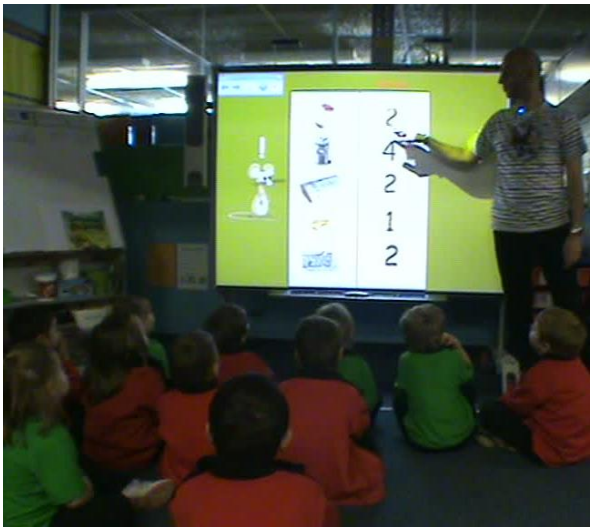


Figure 4.21 "Two apple cores...".

The two columns depicted in Figure 4.21 replicated the first two columns of the completed data table seen in Figure 4.15 (p. 118). The teacher described the data table as an organised way for Litterbug Doug to record what things he had collected, how many of each thing he collected and on what day he had collected them.

Next, an A3-sized paper data table (Figure 4.15, p. 118) was introduced that represented Litterbug Doug's rubbish collection over three days on Monday, Tuesday and Wednesday. Data values for the number of objects collected were provided for each of these days. The teacher repeated the process of using hand gesture and language to name each object in the left hand column and the corresponding numeral in the row to the right of the object. This is depicted in Figure 4.22.

Figure 4.22 Introducing the data table for task 3.

The teacher used this process to work down each column for Monday, Tuesday and Wednesday. Next, the teacher posed a question to the whole class asking what they noticed about the numbers on the different days.

4.4.3 Task 3: Model-Eliciting Activity – Finding Solutions

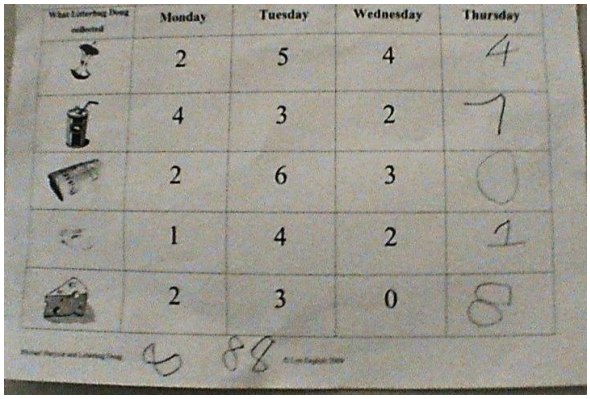
This small group task presented the data modeling problem. It was implemented immediately following Task 2, as the children had shown enthusiasm for the activity. The children were asked to talk in their groups about how the numbers of things *Litterbug Doug* collected have changed over the three days and to look at the blank Thursday and work out how many different things they thought Litterbug Doug might have collected on Thursday, the fourth day and say why they thought that amount would have been collected. Each group was provided with an A4-sized data table (Figure 4.15, p. 118). The Thursday column in the data table was blank. The children were encouraged to represent the predicted values for Thursday in any way they liked, for example, by drawing pictures or writing numbers. Each group had access to pencils on the tables.

4.4.4 Task 4 : Small Group Reporting

Task 4 was a whole class task where the children reported each small group's organisation and representation of the data modeling problem solution. The children were asked to explain their group's decision about how many of each sort of rubbish they predicted Litterbug Doug would collect on Thursday, and why. Children sat on the floor in a circle with the teacher. The reporter for each group spoke from the circle and used the data model the group had developed to report the group's solution.

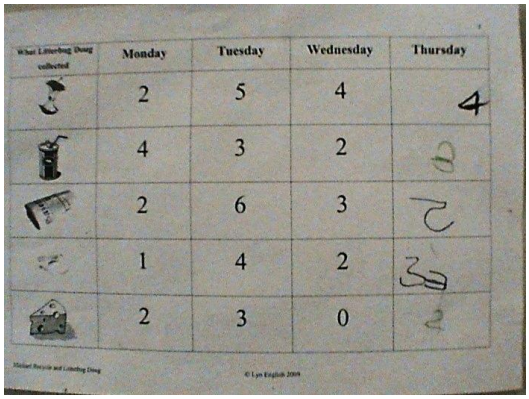
4.4.5 Children's Models

Each of the four data models developed by the four groups is shown as a photograph and a diagram in Figure 4.23, Figure 4.24, Figure 4.25 and Figure 4.26.



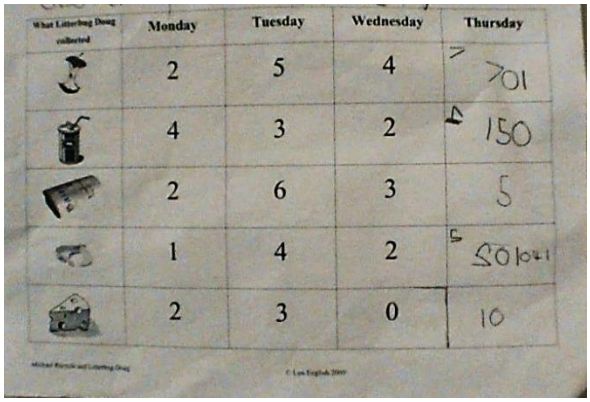
	M	T	W	Th
	2	5	4	4
	4	3	2	7
	2	6	3	0
	1	4	2	1
	2	3	0	8
	8	88		

Figure 4.23 Litterbug Doug data model group for Group 1.



	M	T	W	Th
	2	5	4	4
	4	3	2	3
	2	6	3	5
	1	4	2	3
	2	3	0	2

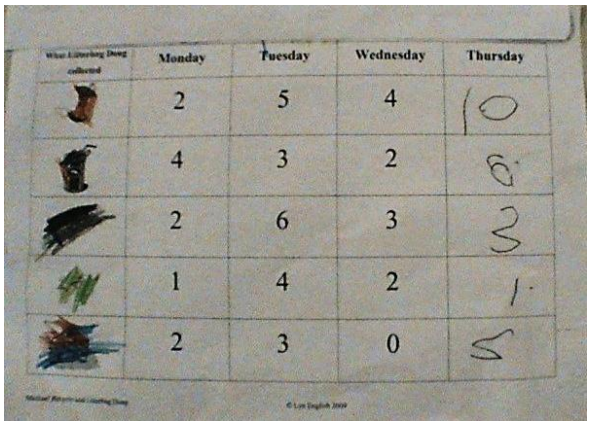
Figure 4.24 Litterbug Doug data model for Group 2.



	M	T	W	Th	Th*
	2	5	4	7	701
	4	3	2	1	150
	2	6	3	5	5
	1	4	2	2	201041
	2	3	0	10	10

*represents the altered numbers

Figure 4.25 Litterbug Doug data model for Group 3.



	M	T	W	Th
	2	5	4	10
	4	3	2	6
	2	6	3	3
	1	4	2	1
	2	3	0	5

Figure 4.26 Litterbug Doug data model for Group 4.

All groups recorded a prediction for each of the missing values for Thursday. All predicted values were represented as numerals and all the values recorded were between zero and ten. No group replicated a complete column of existing numbers in the table. Three of Group 3's original recorded predicted values were altered by one group member, who re-wrote the original value in the top left hand corner of each box after the numbers were altered.

4.5 Modeling Activity 4: Charlie and Lola Modeling Activity

The fourth and final activity, Charlie and Lola, was designed to engage the children in reading and considering given data in a table in order to discuss and find a solution to a problem posed as a *question*. Each of the four activities that comprised Charlie and Lola (Figure 4.27) and their implementation is now presented.

4. CHARLIE AND LOLA

Task 1. Whole class picture book reading

Task 2. Whole class warm –up: reading complex data tables

Task 3. Small group modeling eliciting problem

Task 4. Whole class reporting of modeling solution

Figure 4.27 Component tasks for modeling activity 4, Charlie and Lola.

4.5.1 Task 1: Warm-Up – Reading the Picture Story Book

Task 1 was a whole class warm-up designed to familiarise the children with the problem context for Charlie and Lola Tasks 2 and 3. The picture story book, Charlie and Lola: Look After Your Planet (Child, 2009) was a commercially available book. Following the picture story book being read, the children were asked the following five questions;

1. Who can tell me who Lola's friends are in the story?
2. What did they have to do to get a tree of their own?
3. Why is recycling a good thing?
4. To be a good recycler, what do you have to do?
5. Do you think Lola is a good recycler? Why or why not?

4.5.2 Task 2: Warm Up – Introducing and Reading the Data Table

Task 2 was a whole class warm-up designed to introduce reading and interpreting the data table the children would work with in Task 3. In the story read in Charlie and Lola Task 1, Lola learned about recycling. She inspired her classmates to enter a recycling competition to win a tree for the school. To win the tree, Lola and her classmates had to collect one hundred recyclable objects and fill a tree poster with leaves to represent each object.

The characters and plot from the story provided the basis for the problem introduced in Task 2 and worked to a solution in Task 3. The problem posed the following scenario: Lola's teacher had been so impressed with Lola and her classmates recycling that she asked Lola to be the judge for a school recycling competition. For the competition, five children (all characters who featured in the picture story book) had kept a record of the recyclable objects they had collected in a week. Two model-eliciting problems were posed as questions. The first question was "Do you agree that all of the items can be recycled?" The second question was "Who do you think is the best recycler and why?"

A data table (Figure 4.28) was introduced to the children that represented how many of each object had been collected by each of the five children in the competition; Charlie, Marv, Moreton, Marty and Lotta.

	Lotta	Charlie	Marty	Moreton	Marv
plastic bottles	5	5	4	7	7
glass jars	0	4	5	7	4
broken plates	5	0	2	4	3
food scraps	9	2	1	0	0
old books	1	7	7	2	0
how many for each person?	**20**	**18**	**19**	**20**	**14**

Figure 4.28 Data table for Charlie and Lola.

The children were beginning readers, so pictures of the objects were placed at the row headers, pictures of the characters from the book were placed at the column headers, and the columns were coloured to provide visual cues for reading the row and column information. A total values row, with larger bolder numerals, was inserted across the bottom of the table.

The data table was introduced as an image on the classroom electronic interactive white board. The teacher named each character in the table as he touched each picture at the head of each column. Next, the teacher named each object as he touched each picture at the head of each row. The children were then asked a series of questions about reading the data in the table that had been designed for the task. The questions were:

1. What items did Lola and her friends recycle?
2. How many things did Lotta recycle?
3. How many things did Charlie recycle?
4. How many things did Marty recycle?
5. How many things did Moreton recycle?

6. How many things did Marv recycle?
7. How many glass jars did Charlie recycle?
8. How many food scraps did Marty recycle?
9. How many food scraps did Lotta recycle?
10. Who recycled two old books?
11. Who recycled three broken plates?

The children responded to the questions using the table on the classroom interactive white board to demonstrate their responses.

4.5.3 Task 3: Model-Eliciting Activity – Finding Solutions

In Task 3 the children worked in small groups to find a solution to the model-eliciting problem posed as questions. Each group was provided with an A4 size data table (Figure 4.28, p. 128) and had access to pencils on the tables. The first question was "Do you agree that all of the items can be recycled. The children worked to find a solution to the problem using the data table. The model solution was reported in Task 4. The second question was "Who do you think is the best recycler and why?" The children worked to find a solution to the problem using the data table. The model solution was reported in Task 4.

4.5.4 Task 4: Small Group Reporting

Task 4 was a whole class activity where the children reported each small group's organisation and representation of the data modeling problem solution. The children were asked to explain their group's decision for each of the questions. Children sat on the floor in a circle with the teacher. The reporter for each group spoke from the circle and used the data table to report the group's solution.

4.5.5 Children's Models

A summary of each of the four groups' decisions for Task 3 is displayed in Table 4.1.

Table 4.1

Summary of models for questions 1 and 2 in Charlie and Lola task 3.

Question 1: Do you agree all the objects can be recycled?	
Group number	**Objects determined as not being recyclable**
Group 1	books, broken plates, food scraps
Group 2	food scraps, broken plates
Group 3	food scraps (disputed)
Group 4	Books, plates and food scraps
Question 2: Who do you think is the best recycler and why?	
Group number	**Reasons stated within the group**
Group 1	Character's final column value is higher than final column value of another character with an equivalent maximum total value Absence of zeros in the character's column
Group 2	Character gave items to recycle and helped others Total value in the character's column, Characteristic of being good
Group 3	Character's column values and total value
Group 4	Character's total value and maximum value in the column

All groups were consistent in their solutions to Question 1. Each group reported a decision that not all items could be recycled, although there was not necessarily consensus about the decision. All groups reported excluding at least one item from the object category as objects that were not recyclable, and all groups excluded food scraps.

In contrast, the groups were not consistent in their solutions to Question 2. The table displays solutions expressed by individual children. The majority of children in all groups relied on the data table values to reach a solution. Members of Groups 1 and 2 selected one character, Marty, on the basis of the range of data values, reasoning that there were no zeros in his column. Three groups, Groups 1, 3 and 4, had members who considered the total and range of the data values in a

character's column to reach a solution. Two characters with the highest total values, Lotta and Moreton, were considered under these criterions. The total amount collected by a character was also a tentative criterion for a member of Group 2 in reaching a solution that Lotta was the best recycler.

The characters and plot in the picture story book were considered by two members to reach a solution, and the characteristics of "helpfulness" and "goodness" featured in their reasoning.

4.6 Chapter Summary

In this chapter, the content of the four modeling activities was described and implementation of each activity was presented. The chapter presented the models that were developed by the children to find solutions to the data modeling problems. The following chapter presents the findings from the analysis of the children's responses to reading the picture story book in Task 1 in each modeling activity.

Chapter 5 DISCUSSION AND FINDINGS: Initiating Interest in the Data Context: The Role of Picture Story Books

5.1 Introduction

This chapter presents and then discusses findings that emerged from the thematic analysis of Task 1 for each of the four modeling activities, *Baxter Brown, Michael Recycle, Litterbug Doug and Charlie and Lola*. Task 1 introduced the picture story book that initiated each modeling activity. Each activity provided an opportunity for the children to respond to and pose questions about the story. The chapter is in two parts. First, findings for the children's responses to each picture story book are presented. Second, the findings for all four picture story book responses are discussed.

Each picture story book used in the modeling activities fulfilled two contextual roles. First, each book fulfilled the role of *data context*. The data context stimulated the statistical problem and bound the data used to solve the problem. The picture story book used in each modeling activity contextualised the problem to be solved and so the narrative and picture content had the potential to influence the knowledge the children drew from and the reasoning they used. Second, as an integral part of the *task context*, the picture story book initiated the children into the modeling activity and had the potential to influence the children's interest in, and connection to, the modeling problem to be solved. Therefore, a concern for this study was to find what characteristics of picture story books supported the children's interest *in* and reasoning *with* the modeling problem.

5.2 Introducing the Picture Story Book and Inviting the Children's Response

The four modeling activities implemented in the study were named by the title of the initiating picture story book. The four books are:

1. *Baxter Brown's Messy Room*, a purpose written story (English, 2009a).
2. *Michael Recycle,* a commercial publication (Bethel, 2008).

3. *Litterbug Doug*, a commercial publication (Bethel, 2009).
4. *Charlie and Lola: Look After Your Planet*, a commercial publication (Child, 2009).

In Task 1, the picture story book was read by the classroom teacher to the whole class. The children were grouped informally seated on the carpeted floor. The teacher sat on a low chair and read the book, pausing to display the pictures by slowly moving the book in a horizontal arc before proceeding to the next page. The teacher read with an animated voice, gave emphasis to words and phrases and changed his voice tone for different characters as reading the book progressed. The teacher did not say anything about what was being read, ask questions or make remarks.

As the picture story book was read, the children responded spontaneously with comments. Immediately following the reading, with the exception of the Charlie and Lola modeling activity, the children were invited to ask questions or to provide comments about the story. Questions or comments were written onto the classroom white board with the name of the child who proposed the question or comment noted next to it. The children were then invited to answer any questions that had been raised. The findings that emerged from the thematic analysis of Task 1 for each of the four modeling activities are presented next.

5.3 Baxter Brown's Messy Room

5.3.1 Summary of the Picture Story Book Plot

Baxter Brown is a white fluffy dog with a room that is so messy from all the rubbish he has collected that he is lost in it. What should he do? (Full story: Appendix M).

5.3.2 Children's Spontaneous Responses to the Picture Story Book

The children demonstrated consistent, sustained and attentive listening as the picture story book was read. During the story reading, the children's spontaneous reactions were seen as the children asked questions, pointed to the illustrations, laughed as the plot unfolded, and used gestures such as bringing a hand to the mouth during a moment of tension in the story.

The picture story book was written in a style reminiscent of familiar children's "lift the flap" books, for example, the "Spot the Dog" series (Hill, 1983, 1994, 2003). In lift the flap books, a question is posed in the book about where a character may be hiding and the picture answer is found when a paper flap is lifted. The children reacted spontaneously as a group to the questions posed in Baxter Brown as demonstrated in the following example:

Teacher:	*One morning, Mr and Mrs Brown noticed that Baxter Brown was missing.*
	Is he sleeping in the washing machine?
Children:	(laughing) no!
Teacher:	*Is he outside in the bushes?*
Children:	(laughing) no!

There were unanimous responses to the questions posed in the story, and the children appeared to enjoy the improbability of the suggested hiding places.

As a group, the children revealed that they enjoyed some of the intricacies of the plot. For example, Baxter Brown was barely able to move because of the position and amount of rubbish he had managed to accumulate and the children responded:

Teacher:	*Baxter Brown has collected so many of these different things that he can hardly move in his bedroom*
Children:	(laughing and pointing to the picture)
Teacher:	*He has…empty packets, biscuits, cans, apple cores everywhere on his floor, in his bed, on his chair, on his bookshelves and in his cupboards.*
Children:	(laughing loudly).

As the plot unfolded and Baxter Brown's owners searched for him, there was disquiet voiced amongst the children about where Baxter Brown might be, as they sat very quietly listening. Toby asked anxiously, "do you know where he is?" The children appeared to enjoy the eventual discovery of Baxter Brown's whereabouts, illustrated in the following:

Teacher:	*It was a tail! Was it Baxter Brown's tail? It looks like we have to wade through all this junk to find out, thought Mr and Mrs Brown. They stepped over bones, apple cores, newspapers,*

cereal packets, old toys, biscuits, old shoes, empty drink cans, milk cartons and plastic bags. All that junk! Finally, Mr and Mrs Brown reached the long, thick, white tail that was waving above the rubbish. Is that you Baxter Brown?

Ted: (gasps audibly and quickly points) aah! Yes it is!

Teacher: *The tail kept swaying, we have to remove some of this rubbish to see if it is him!*

Blake: (kneels up) it is!

Lee: (looks at Blake) yes or no?

Jade: (shakes her head) it's not him! (pauses, smiles).

Ted and Blake seemed relieved and excited that the tail was Baxter Brown's (Figure 5.1).

Figure 5.1 Responding to discovering the main character.

Lee looked for reassurance from Blake, but Jade's initial response indicated that she was unconvinced that it was Baxter Brown, and she may have enjoyed refuting Blake's discovery, knowing that the character had been found. These examples suggest that the children were concerned about the whereabouts of the character and were relieved when he was found. The children enjoyed the mystery and discovery that accompanied these aspects of the plot.

When the children were invited to ask questions or give comments about the story, their responses focused on the problem revealed in the plot. These findings are presented in the next section.

5.3.3 Children's Questions and Comments About the Picture Story Book

When invited to offer questions or comments about the picture story book, the children's responses demonstrated sustained interest in Baxter Brown's dilemma, how it arose and how it might be resolved. The children spent over seven minutes asking questions and offering responses to those questions that were offered. The children raised their hands enthusiastically to offer solutions and responses to questions other children had asked (Figure 5.2) until all questions had been resolved.

Figure 5.2 Children continue to offer responses to questions.

The children were troubled that Baxter Brown had created the problem by collecting rubbish and that this had consequences for him. This unease was evident in the questions and comments the children put forward. Several children explored the logical consequences of Baxter Brown getting into the problem in the first place. Isabel commented, "why did he, I know why he didn't clean up, because um, he just didn't think he might get lost in it". Isabel's response suggested that Baxter Brown had not reasoned that collecting rubbish would cause him a problem. Carl continued the logic of Isabel's thinking. Immediately following her comment he provided a logical analysis of Baxter Brown's situation, and said, "ah, if he didn't clean up he'll get lost and if he cleans up, he, he won't get lost!" Similarly, Eliot recounted the plot and highlighted the consequences of failing to clean up and stated, "they cleaned up

because he couldn't move and he got lost". Finally, Blake explained, "if he did clean up all that rubbish then he wouldn't get lost". Each of these examples demonstrated that the children had connected two events, collecting rubbish and getting lost. They saw one as the consequence of the other, that is, Baxter Brown being lost was a consequence of Baxter Brown failing to clean up his room.

Other comments illustrated that several children attempted to explain why Baxter Brown might have been lost. Some children were perplexed by the situation. Ted said quizzically, "he just left his room all messy", while Lee asked, "why did he want to hide in his bed?" indicating that Baxter Brown's actions could be a source of mystery. Mia said, "maybe he was going to have a real rest then he forgot that he had all that rubbish". Gina speculated that "he was just stuck in his bed because of all that rubbish that's why um he couldn't get up". These responses suggested that Mia and Gina were hypothesising to explain why Baxter Brown had not acted to get himself out of the dilemma he was in.

The question of what Baxter Brown should do to solve the problem was posed at the end of the story. Baxter Brown asked at the end of the story, "What should I do?" and the narrator asked of the reader "What do you think Baxter Brown should do?" The children responded to the questions. Jade exclaimed, "he should throw it away!", and Mia declared "he has to clean his room up!" Lee suggested, "he should put all the stuff in the bin". These replies introduced the children's predicted solutions to Baxter Brown's problem. Toby was intrigued as to how Baxter Brown himself had anticipated the question of what should he do as the story came to an end:

Toby:	Um, (pause) why di…why did he want, why did he guess the question that he wanted to clean up his room?
Teacher:	So why did he guess that that was the question?
Toby:	Yeah.

In summary, the children's attentiveness to the story was revealed in their physical and verbal reactions to the picture story book as it was read. The children enjoyed the narrative style of the story and the descriptions, mystery and discovery experienced in the plot. The questions and comments offered by the children showed

sustained interest in the problem revealed in the plot. Individual children expressed concern and interest in the circumstances and consequences of Baxter Brown's problem and how it might be resolved.

5.4 Michael Recycle

5.4.1 Summary of the Picture Story Book Plot

Michael Recycle is a caped superhero whose mission is to save planet earth. He flies into towns that are messy and teaches the people about recycling so they can clean up where they live. The story is written in rhyme (Full story Appendix N).

5.4.2 Children's Spontaneous Responses to the Picture Story Book

The children listened quietly as the picture story book was read, although a few children began to fiddle with their clothing and turn their head to noise distractions. No child responded with pointing, laughter or body movements that might indicate interest, such as moving forward or leaning towards the book. Some children began to lie back or roll to their side as the story came to an end.

The only spontaneous responses evidenced were as the picture story book was introduced and the title read. Many children repeated the words and then Gina commented, "They rhyme. Michael Recycle!"

5.4.3 Children's Questions and Comments About the Picture Story Book

When invited to offer questions or comments about the picture story book, the children's responses demonstrated interest in the character. The children spent over ten minutes asking questions and offering responses to questions other children had posed.

Three children asked questions or commented about the character Michael Recycle's altruistic behaviour. Sam stated, "he helps people", while Chris asked, "how come he tries to, um how come he helps people?" Gina queried, "um, why did she, why did she help people?" Sam, Chris and Gina's responses indicated an interest in the "goodness" of the character, and what might motivate him to help people. Gina's question however used the personal pronoun *she*. This immediately generated debate among the children about the sex of the main character, Michael Recycle.

The teacher asked first who thought Michael Recycle was a boy and why, and second, who thought Michael Recycle was a girl and why. During the discussion, many children became physically animated, moving to point to the book, rising up on their knees and leaning forward to listen and put forward their ideas, as seen in Figure 5.3.

Figure 5.3 Responding to the identity of the main character.

Some children relied on the illustrations in the book for reasons to support their opinion. Eliot said, “he doesn’t have any lipstick on”, and Toby stated as he pointed to the book, “he has a little medal thing, ‘cause boys sometimes get medals”. Eliot and Toby’s provided these reasons to support Michael Recycle being male. To support his view that Michael Recycle was a girl, Sam gestured from his head to his neck and said, “because there’s hair on the back of him and it goes right down to there” as he indicated his shoulder. Isabel stated, “because um, girls have more bigger eyelashes than boys” and Jade proposed that “it has um, it has um, blond hair”. The reasons put forward by the children demonstrate how the children used details they had observed in the illustrations in the book to come to their decision about the sex of the character. It may also reveal that the character’s identity was a mystery or problem that the children were motivated to solve. The discussion about the sex of the character was ignited by the publically stated view of one child, and indicated that the children were attentive to and prepared to justify their views about an alternative idea.

In summary, the children’s physical and verbal reactions to the picture story book revealed limited response to or interest in the plot or character in the picture

story book as it was read. The questions and comments offered by the children showed limited interest in Michael Recycle's motivation or effectiveness in helping people. The principal interest shown was in determining the sex of the main character.

5.5 Litterbug Doug

5.5.1 Summary of the Picture Story Book Plot

Litterbug Doug is a lazy, messy character who does not recycle and has rats for friends. His enormous, smelly piles of rubbish are upsetting the town folk, until Michael Recycle arrives to teach him how to recycle and clean himself up. As a result, on the last page of the story, Litterbug Doug becomes the Litter Police (Full story Appendix O).

5.5.2 Children's Spontaneous Responses to the Picture Story Book

The children listened quietly and calmly during much of the reading of the book. The children's spontaneous responses heard throughout as the reading focused on the description of the objects Litterbug Doug had collected. The reactions included disgust and enjoyment, evidenced through responses such as "yuk" and "ooh!" to the pictures of the rubbish piles. The sight of a toilet in the rubbish pile brought laughter from most children, and Jade, Ted, Gina, Toby and Blake pointed at the page and said, "toilet!"

The character Michael Recycle was immediately recognised when he appeared in the plot and illustrations, and several children pointed excitedly with extended arms, shuffled forward, and the pitch of their voice rose as they called out "Michael Recycle!" The following example as the teacher read, illustrates the response:

Teacher:	*But then something happened, that none could explain, it wasn't a bird and it wasn't a plane. A green caped crusader stupendously swooped, descending to earth with a great loop the loop.*
Children:	(unanimous statements) Michael, Michael Recycle!
Mia:	(pointing to the book) there's Michael Recycle!
Ted:	Coming to tell him.

Ted's response suggested that he had anticipated Michael Recycle's role in the plot, and that his arrival signalled that Litterbug Doug would be told to clean up and recycle. The children's interest in the arrival of Michael Recycle contrasted with their disinterested response to the reading earlier that week of the Michael Recycle picture story book. The excitement may be explained by recognition of what was now a familiar character and the character's anticipated role in the story.

There was a spontaneous empathetic comment when a question was posed by the character Litterbug Doug. The character asked through the narrative whether it was too late to have real friends rather than rats as friends. Carl responded as follows:

Teacher:	*they do give me fleas and they nibble my toes, they make quite a racket, their hygiene's not great, I'd love some real friends but is it too late?*
Carl:	No
Teacher:	(commenting on the illustration) oh, look at those rats, nibbling his toes
Carl:	(in a quiet voice) it's never too late you know.

Carl's comment suggests concern for the character's situation and insight into his belief that circumstances can change.

5.5.3 Children's Questions and Comments About the Picture Story Book

When invited to offer questions or comments about the picture story book, the children's responses demonstrated interest in resolution of Litterbug Doug's rubbish problem and in his personal characteristics. Two children commented how Litterbug Doug had changed after Michael Recycle had intervened. Jade said, "um he didn't, um because then he was clean, he was messy and then he was clean". Similarly, Toby explained, "Michael Recycle is so clean, so he made him clean and I, I saw at the end when he was having a bath I saw Michael Recycle in the window". These examples indicate the children were satisfied with the resolution to Litterbug Doug's problem and they had knowledge of the resolution from the story narrative and the illustrations.

Some children appeared initially curious about how Litterbug Doug had got into the problem he had and how he was reformed. Four children asked the following questions. Sam asked, “why did he, didn’t he clean up his rubbish?”, Blake queried, “how did he get all that rubbish?” and Ted said, “how come he was all dirty?”. Sam, Blake and Ted’s questions reflected on the actions that led Litterbug Doug to have his rubbish problem in the first place. Eliot asked, “how did he like, um, how did he be good in the end?” Eliot’s question reflected on what transformed Litterbug Doug into someone who was “good”. All four children’s questions indicate that they were interested in what leads to a problem and how it is resolved.

The children were eager to offer responses to the questions that Sam, Blake, Ted and Eliot had posed. Figure 5.4 shows Eliot responding to one of the questions posed, while two other children waited for an opportunity to talk.

Figure 5.4 Responding to a question in Litterbug Doug.

To explain how Litterbug Doug had accumulated rubbish and failed to clean it up Toby offered, “because he was a messy boy”. Chris suggested that it was “because Michael Recycle didn’t help him and he was too tired”. Similarly, Lee said, “he were too tired to do it”. Blake submitted that, “he doesn’t clean up his room and he doesn’t like cleaning up his house and he likes being messy”. Jade stated that it was “because he was lazy and too tired because he was, he needed help”. Finally Mia suggested, “I think he didn’t do it because he keeps forgetting”. The responses provided by the children revealed they had reasoned that Litterbug Doug’s rubbish problem was the result of personal characteristics such as laziness, forgetfulness and tiredness. Chris and Jade’s responses indicated that Litterbug Doug would need assistance to act to

resolve his problem. Litterbug Doug's personal characteristics are qualities the children had extrapolated and inferred from the story.

The children's interest in the role that helping and learning might play in resolving Litterbug Doug's problem were also evident in their responses to Eliot's question, "How did he be good in the end?" Several children reasoned that Litterbug Doug was able to "become good" because he learned how to. Jade explained "because he finded out how to do it, he founded out how to be good, Michael Recycle helped him to do it and ah, that's my idea". Jade's explanation suggested that finding out how to be "good" occurred when Litterbug Doug was helped by Michael Recycle. Carl's suggestion extended Jade's explanation. He suggested that:

> I think how he be good at the end, um, Michael Recycle helped him learn to recycle and also, also, I think he also had a bath and the mouse helped him to have a bath and he had a bath in the sink.

Carl's suggestion was that learning to recycle and being clean by having a bath was a defining attribute for "being good". The theme of goodness resulted from learning was continued by Gina who said, "because at the end, Michael Recycle taught him how to tidy up so now he knows how to tidy up and that's why he's the Litter Police". Gina's response indicated that she saw good as a consequence of learning how to be tidy from Michael Recycle, and that being good was rewarded by the responsibility of becoming a litter policeman. Sam also supported the idea of learning as a key attribute for being good, as shown in the following exchange:

Sam:	I, because ah, um, Michael Recycle um, telled him what to do and he learned.
Teacher:	So you agree with Gina that Michael Recycle taught him how to do it
Sam:	And telled him how to learn
Teacher:	Taught him how to learn how to recycle?
Sam:	(nods).

Sam's explanation indicated that he viewed being "told" as a precursor to learning, and that Michael Recycle was able to teach Litterbug Doug by telling him how to recycle. The responses by Jade, Carl, Gina and Sam support an ongoing concern by the children with the goodness of the character: his failure to be good and his coming

good. This may be a reflection of the subplot of the story that concerns Litterbug Doug's failure to have friends other than rats and cats. By becoming good, Litterbug Doug may now be able to have friends that are "real".

In summary, the children's spontaneous responses to the picture story book focused on recognition of the character Michael Recycle and the objects described in the story. The questions and comments offered by the children elicited two questions that generated multiple and detailed explanations of both the cause and hypothesised resolution of Litterbug Doug's litter problem. The children's explanations focused on the goodness of the character, including that his problem was the result of character traits such as laziness and forgetfulness. It was suggested that he had been reformed through learning.

5.6 Charlie and Lola

5.6.1 Summary of the Picture Story Book

Lola wants to clean up her bedroom so that it does not get as smelly and messy as Marty's bedroom. Charlie tells Lola that she should recycle her things and explains to her what recycling is and why it's important. Lola gets her classmates to join her in recycling so they can win a tree for their school (Full story Appendix P).

5.6.2 Children's Spontaneous Responses to the Picture Story Book

The children listened attentively as the picture story book was read. The children's spontaneous responses to the book revealed two areas of interest. First, many children recognised the characters Charlie and Lola from their own experiences, clapping and laughing as they recognised them. Second, there were some spontaneous laughter at the description of the character Marty's smelly room, and comments on the accuracy of illustrations. For example, Sam and Eliot responded to a picture of an enormous pile of rubbish bags, Sam said "daah!" and Eliot stated "That's not real!" Sam's response indicates disbelief, which was stated openly by Eliot. There was not an opportunity to invite the children to offer comments or questions immediately following the story reading because the model-eliciting questions (section 4.5.3, p. 126) were posed.

5.7 Discussion

5.7.1 Introduction

This section discusses the findings that emerged from the thematic analysis of Task 1 for each of the four modeling activities. The findings presented the children's spontaneous responses to the reading of the picture story book and the questions and comments that were posed following the reading. These findings revealed the characteristics of affective and cognitive interest to the children.

The characteristics of a picture story book used to contextualise a statistical problem are critical to young children's statistical reasoning. This is because, from the perspective of statistics learning, familiarity with the context of a problem is known to influence data analysis and interpretation (Gal, 2005) and knowledge of the context is known to support determining the relevance of data in problem solving (Pfannkuch & Wild, 2004). The ability to connect to a personally meaningful, understandable, contextualised problem is an important aspect of bringing children into statistical problem solving. Further, stimulating interest in a problem is an expressed aim of designing modeling activities and begins with initiation into the modeling task (Lesh & Doerr, 2003). As described in Chapter 2, in Models and Modeling, effective use of the design principles of personal meaningfulness, and model construction are pivotal for initiating a modeling activity (Lesh & Doerr, 2003). Initiating tasks are designed to encourage children to make sense of the situation based on their personal knowledge and experiences and stimulate the need for a model to be constructed, modified or refined (Lesh & Harel, 2003). In this study, stimulating interest in the modeling activities was achieved by reading picture story books.

Picture story books used to contextualise statistical problems play a crucial role in statistical reasoning as an aspect of task design for engaging children in statistical reasoning and as a potential source of data knowledge for children to use in statistical reasoning. In the absence of research on the role of picture story books in statistical learning, the findings in this study fill this gap in the current literature. The next section discusses classification of picture story books used in statistical learning and research.

5.7.2 Classifying Picture Story Books Used to Contextualise Statistical Problem

The research focus for this study was on statistical reasoning within the Models and Modeling theoretical framework (Lesh & Doerr, 2003). From a Models and Modeling perspective, and therefore a task context perspective, the picture story book provided a realistic context used to authenticate and frame the modeling activity tasks, including the data modeling problem (Mousoulides, Sriraman, & Christou, 2007), and motivated and interested the children in expressing their statistical understanding (Doerr & English, 2003). In the modeling activities in this study, a picture story book acted to stimulate and contextualise the data modeling problem the children would engage with. The design of the data modeling problem embedded a need for the children to manage and make statistical sense of the problem, that is, the statistical idea to be worked, such as prediction or representing data, was integral to solving the problem (English, 2006). Knowledge needed for solving the problem included knowledge of the data context provided by the picture story book.

In addition to initiating and stimulating modeling, the picture story books used in this study fulfilled the role of providing the data context for the modeling problem to be solved. The data context in statistical problems is defined by Pfannkuch (2011) as "the context of the real-world situation from which the problem arose (which is) inextricably linked to resolving the problem or learning more about the situation" (p. 28). The picture story book provided the real-world situation that gave rise to the data modeling problem. From a task context and data context perspective, the learning *purpose* for a picture story book in this study differed from a picture story book that might be chosen for specific instruction in mathematics, such as learning about shapes or number.

Examining characteristics of books that fulfill a statistical learning purpose was approached using existing classification frameworks for selecting books for mathematics instruction provide. Marston's (2010) framework provides criteria for assessing mathematical content, including content that is incidental or unintentional, but still offers opportunities for "mathematical problem solving and reasoning" (p. 387). On face value, the three commercially available picture story books, *Michael*

Recycle (Bethel, 2008), *Litterbug Doug* (Bethel, 2009) and *Charlie and Lola* (Child, 2009) offer no discernible mathematical content. Any statistical content in the story is incidental or unintentional to the book's primary purpose of entertaining. The three books provide a story plot that, given the children's knowledge and experiences, encouraged them to make sense of a problem solving situation and moved them to recognise the need for a model to be developed to solve the problem (Lesh & Doerr, 2003). Classifying a story under Marston's framework as affording problem solving and reasoning opportunities then is compatible with the Models and Modeling design intent, namely, the story initiate and stimulates a modeling problem for the children to work to a solution. The fourth picture story book, *Baxter Brown's Messy Room* (English, 2009a) differed from the other three books in that it was written specifically to initiate a data modeling problem. The statistical problem to be solved was embedded in the narrative content of the story. Using Marston's (2010) framework, *Baxter Brown's Messy Room* can be classified as having content specific to the development of a mathematical concept, in this case, a statistical concept.

Although helpful, the unique role of picture story books in contextualising statistical problems is not accommodated by existing classification schemes. Finding support for determining picture story characteristics from comparable research is equally problematic for two reasons. First, with the exception of English (2009; 2010; 2011), children's picture story books have not been used to initiate modeling activities for statistical problems solving with young children. Second, young children's response to the characteristics of a picture story book that initiate and contextualise *statistical* problem solving has not been researched.

Capturing the children's spontaneous and subsequent responses a picture story book in this study enabled characteristics of interest that support statistical reasoning to be explored. Prior studies on the role of picture story books in domain-specific mathematics learning, examined differences in categories of cognitive engagement of children's spontaneous responses to fiction and non-fiction books (Moschovaki & Meadows, 2005) and child-initiated utterances as reactions to domain-specific mathematical phenomena in a book (Van den Heuvel-Panhuizen & van den Boogaard, 2008). This study proceeded on the same assumptions as the studies conducted by Moschovaki and Meadows (2005) and Van den Heuvel-

Panhuizen and van den Boogaard's (2008). This study used similar methods to these studies to capture children's spontaneous responses, and the picture story books were read without pre-empted questioning or probing by the teacher reading the story.

On the other hand, this study is distinguished in two ways from studies conducted by Moschovaki and Meadows (2005) and Van den Heuvel-Panhuizen and van den Boogaard's (2008). First, the children's responses were extended beyond their initial spontaneous comments or questions, to include questions or comments the children initiated immediately following the book reading. Second, this study sought to identify whether the characteristics that were of interest to the children were used as they subsequently engaged in statistical reasoning in the modeling activities (presented in Chapters 6 and 7). Discussion of the children's responses to the picture story book is next.

5.7.3 Limited and Misdirected Interest

The children's interest in the picture story book *Michael Recycle* (Bethel, 2008) was limited, and interest that was evident was misdirected from the story content that supported the modeling problem. These findings contrast with interest generated by the other three picture story books used in the study. Michael Recycle stimulated limited interest for the children in this study and the children's only spontaneous response when Michael Recycle was read was to the rhyming in the book title. The children's disinterested responses were demonstrated in their physical responses and lack of spontaneous comments as the book was read. The lack of spontaneous responses suggests that the story did not stimulate mental processing (Moschovaki & Meadows, 2005; Van den Heuvel-Panhuizen & Boogaard, 2008) or provide information that was interesting or personally meaningful to engage the children's attention (De Young & Monroe, 1996). The story had a predictable story line and lacked mystery and it is possible that this failed to provide an authentic connection for the children (Nesmith & Cooper, 2010).

Misdirected interest in the story was revealed in the children's comments and questions following the initial book reading. The book character Michael Recycle prompted animated debate about whether he was male or female due to the children's perceived ambiguity observed in the book's illustrations. Illustrations are part of the

whole picture book and can represent story-related components, so they have the potential to cognitively engage and interest children (Elia et al., 2010). In the book Michael Recycle, the children's interest in the characters sex can be interpreted as a mystery to be solved or as tapping into core questions of gender identity for young children. The children's responses highlight the importance of combining text and illustration of a similar content for books used to contextualise statistical problems. Ambiguity between text and illustration may be a useful tool for stimulating discussion however, as a characteristic for stimulating interest in model development to solve a statistical problem this study found that ambiguity in the illustrations served to misdirect or distract the children's attention away from other elements of the story, such the problem in the plot used to frame the modeling problem.

The picture story book Michael Recycle failed to generate any responses in the children to indicate enjoyment of the storyline, a liking for the character or interest in the problem in the story. The plot in the story reached a climax that was fully resolved by the characters within the story itself; Michael Recycle cleaned up the village successfully, and without fuss. The limited and misdirected interest by the children, particularly with respect to the plot may be explained by the findings of interest in the other three picture story books which are discussed next.

5.7.4 Capturing Interest: Mystery and Uncertainty

The findings from the children's responses to *Baxter Brown's Messy Room* (English, 2009) were that they enjoyed the element of mystery through discovery present in the story and that this element of mystery was not present in the other three picture story books. The children showed concern when Baxter Brown was lost, and relief and excitement when he was discovered. The children's enjoyment in the mystery of Baxter Brown's whereabouts and his subsequent discovery was evident in the children's responses to the story reading, through gesture, facial expressions, and body movements. Interest was conveyed through physical responses that provided information not expressed in speech (Broaders, Cook, Mitchell, & Goldin-Meadow, 2007). The findings indicate that that the children enjoyed the uncertainty of not knowing where Baxter Brown was and are in keeping with mystery and uncertainty being elements of an interesting and engaging story (De Young & Monroe, 1996).

Interest is also supported when a child identifies with a character, so that personalising a storyline to connect to the audience's prior knowledge makes it engaging and enjoyable (De Young & Monroe, 1996). Baxter Brown elicited personal connections with the children by experiencing a problem that is a common one for young children; a love of collecting objects that leads to a need to tidy one's room. The children enjoyed the descriptions of the dog character Baxter Brown and the amount and types of items that he collected. *Baxter Brown's Messy Room* (English, 2009) therefore combined the elements of mystery, uncertainty and personal connections for the children in a way that stimulated interest.

5.7.5 Capturing Interest: The Unresolved Problem, Uncertainty and Prediction

The study found that the children's response to an unresolved problem generated interest observed as prediction and hypotheses by the children about how to resolve the uncertainty of the problem presented in the story. Interest as prediction was only found in the children's responses to *Baxter Brown's Messy Room* (English, 2009). The children spontaneously responded to the problem in the plot and their questions and comments made predictions about possible solutions to Baxter Brown's problem and expressed logical connections between his problem and his actions as they explained the consequences of collecting too much rubbish. The children's interest was in how the dog character was lost, and how his problem of being lost was partially, but not fully resolved when he was found. The other three picture story book used in the modeling activities in this study, *Michael Recycle* (Bethel, 2008); *Litterbug Doug* (Bethel, 2009); and *Charlie and Lola: Look After Your Planet* (Child, 2009), did not generate prediction responses by the children. Events in a good narrative story have the power to impact affective responses and stimulate mental acts such as guessing and supposing (Fisher, 1999) and stories with elements such as uncertainty, (for example, not knowing how a story will end) achieve interest through the cognitive challenges in prediction or anticipation that is created by uncertainty (De Young & Monroe, 1996). This finding indicates that the children were sensitive to and responded to the cognitive challenge brought by uncertainty and generated predictions.

Uncertainty was embedded in the plot in Baxter Brown's Messy Room (English, 2009a), which reached an unresolved climax at the end of the story when Baxter Brown needed help to clean up his room to prevent him becoming lost again. Baxter Brown's rubbish problem generated the data modeling problem posed for the children, that is, the children were challenged: how could Baxter Brown's problem be *resolved*? The children were specifically asked by the narrator in the story, "What do you think Baxter Brown should do?" The presence of conflict in a story has been described as essential or, more specifically, conflict that moves to a climax and resolution (Pacis, 2011). However, for Baxter Brown, this element of storytelling is contravened, and the problem in the plot was presented as one left hanging at the end of the story itself, inviting the children to solve it. The significance of the findings of the children's responses to the problem in the plot lies in the requirement for a picture story book that initiates a modeling activity to stimulate the development and expressed representation of a model to describe, explain or solve a contextualised problem (Lesh & Harel, 2003). The findings for Baxter Brown, in contrast to findings for the other three picture story book used in the study, suggest that a picture story book that arouses spontaneous interest in the problem in the plot that then becomes the modeling problem to be solved may be best placed to stimulate model development. Further, generating the question to be resolved from within the story may strengthen how the modeling problem is contextualised and this is an area for further research.

Prediction responses by children during a story reading indicate active cognitive engagement that can be facilitated by a familiar story format that engages prediction and analysis of the storyline (Moschovaki & Meadows, 2005). The finding for prediction responses during the reading of *Baxter Brown's Messy Room* (English, 2009) is consistent with Moschovaki and Meadows' findings, as the book used a "lift-the-flap" genre in the narrative. Lift the flap stories are familiar to many children from popular stories such as Eric Hill's 'Spot the dog' series. Familiarity that supported prediction responses may have come also from the children liking and connecting to the story character and plot. Renninger and Hidi (2011) characterise interest as a motivational psychological state of engagement that includes both affective and cognitive components that guides attention which is observable. The

affective component typically describes positive emotions, often expressed as "liking" and can be triggered by meaningfulness and involvement when situated in classrooms (Renninger & Hidi, 2011). The findings suggest that Baxter Brown was a meaningful story for the children. Ainley (2006) points to the prominence in younger children of a range of affective emotional interest responses such as enjoyment and concern that help form coordinated relationship between interest as affect, motivation and cognition. The findings of prediction responses to *Baxter Brown's Messy Room* may therefore be explained as a combination of the affective components of the children's enjoyment of and familiarity with the style of narrative and the cognitive components stimulated by uncertainty presented in the plot as an unresolved problem that stimulated cognitive challenge.

The role of problem resolution in the story as a characteristic of interest is further contrasted with findings of interest in the unresolved problems found in the other picture story books used in this study, which are discussed next.

5.7.6 Capturing Interest: The Resolved Problem and the Role of the Character

In contrast to Baxter Brown, the children did not spontaneously respond to the resolved problems presented in the three picture story books, *Litterbug Doug* (Bethel, 2009), *Michael Recycle* (Bethel, 2008) or *Charlie and Lola: Look After Your Planet* (Child, 2009). These three picture story books differed in the way that the problem in the plot was presented and resolved. In each story, the plot reached a climax that was fully resolved by the characters within the story itself; Michael Recycle cleaned up the village successfully, Litterbug Doug was reformed and became a litter policeman, and Lola creatively recycled enough rubbish to win a tree to plant in the school. The resolution of a dilemma or problem within the story is in keeping with the core elements of a fictional story for engaging young children (De Young & Monroe, 1996). Although a fictional story may resolve the problem by the last page, this may not be a feature that best fits a picture story book that initiates a modeling problem, where interest in developing a model to solve a problem is critical. The children's failure to find interest in a resolved problem however, was alleviated by their interest in how a problem *was* resolved, particularly when the character affected by the problem was of interest. These findings are discussed next.

The children demonstrated some interest with familiar characters in illustrations in the picture story books *Litterbug Doug* (Bethel, 2009) and *Charlie and Lola: Look After Your Planet* (Child, 2009) and illustrations. These findings are in contrast to the limited and misdirected interest in the picture story book *Michael Recycle* (Bethel, 2008), including the problem presented in the plot already discussed (section 5.7.3, p. 146). Litterbug Doug and Charlie and Lola generated spontaneous responses as the book was read and the children showed enjoyment and attention to the illustrations, for example the toilets and piles of rubbish, and the character Michael Recycle was recognised with enthusiasm and Carl showed empathy towards Litterbug Doug wanting real friends instead of the rats he was pictured with. Similarly, the children's spontaneous responses to Charlie and Lola revealed interest in recognising familiar characters in the illustrations and several children questioned what they were seeing in the illustrations. The children's responses to the illustrations affirms the pleasurable role of visual images in books for children (Nesmith & Cooper, 2010), and the capacity of illustrations to capture children's interest (Elia et al., 2010).

A significant finding from the numerous children's responses to *Litterbug Doug* (Bethel, 2009) revealed that he was a worrisome character for them. Many of the children determined that Litterbug Doug was messy, lazy and forgetful, and needed to be taught how to "be good". The children did not respond to Litterbug Doug's reformed role as the litter police but focused on the characteristics that concerned and interested them. Their concern was twofold; first, for the problematic behaviour that had led him to be living in piles of rubbish with rats for friends and second, how he was reformed in the story. The children directed their attention to ask questions to find out more about Litterbug Doug, to work out how his problem had been solved. They reasoned that Litterbug Doug's rubbish problem was the result of his own actions. The children had ongoing concern for the "goodness" of Litterbug Doug's character: his failure to be good, his "coming good" and the consequences for both. Characterisation is an element of engaging stories identified by De Young and Monroe (1996), the findings of the children concerns for Litterbug Doug indicate that the children identified with the character, as one they could care about and follow through the story. The focus on the moral dimension of the character is

important, and ties to research on the moral concerns of young children (Nucci, 2001). This element of the picture story book appears to have tapped into matters that children care deeply about. Their concern for Litterbug Doug's reform, as a problem resolved within the story, contrasted with the interest in the unresolved problem that was generated by Baxter Brown. Unlike Baxter Brown where problem resolutions were predicted, the resolution of Litterbug Doug's problem was explained within the story. The children's responses indicate that their interest was in how resolution had *occurred.* Interest in the worrisome Litterbug Doug's problem resolution contrasts further with the children's lack of interest in the virtuous Michael Recycle, who as an "already good" super hero, flew in and reformed Litterbug Doug into a litter policeman. Both the picture story books Litterbug Doug and Michael Recycle had the plot problem resolved in the story. The difference in the children's interest between the two books appears to be determined by whether the problem is one that involves a character of interest.

5.8 Chapter Summary

The emergent findings in this chapter are from observed interest demonstrated by young children when picture story books were read to initiate statistical problem solving as data modeling problems. Interest was revealed through the children's spontaneous responses and questions and comments about the picture story books. The findings address research Question 2: What characterises task contexts in data modeling activities that engage young children in statistical reasoning?

The findings add to existing work by suggesting that the four picture story books used in the study can be classified under existing frameworks for selecting books for promoting mathematical development. Existing classification frameworks however, do not accommodate selecting picture story books whose specific purpose is to initiate and provide the data context for a modeling problem that engages statistical problem solving. Gaining knowledge of characteristics of picture story books used to contextualise modeling problems that are of interest to young children can inform selecting picture story books used for this purpose.

The children were interested in characteristics that stimulated positive emotions and cognitive responses. Interest was found in picture story books with familiar elements, such as the book's genre, recognisable characters, and in books that create mystery. Picture story books that were personally meaningful generated interest, found in stories that generated concern for a character, or where a character's behaviour was familiar. Interest was also found in amusing illustrations or those that depict familiar characters, although ambiguous illustrations can direct attention away from elements of the storyline that are important to the modeling problem.

A key finding was that children responded to the uncertainty created by an unresolved problem in the story, which can stimulate affective and cognitive responses to generate predictions by the children about how to resolve the problem. A further finding was that problems that resolved in the story did not generate spontaneous prediction responses and could limit interest in a picture story book. Interest in a resolved problem can be stimulated however, if how the problem was resolved, and the personal characteristics of the character involved in the problem, are of concern to the children. While preliminary, the findings suggest that while a number of characteristics of the picture story books generated interest, there are important differences in interest responses based on how problems are presented in a story. Either a picture story book that arouses spontaneous interest in an unresolved problem in the plot, or a story where the problem is resolved, but the character and the resolution of the problem in the story is of concern to the children, may be best placed to stimulate model development.

The picture story book used to initiate the children into each modeling problem in the study formed part of the *task context* of the modeling activity. In doing so, it also provided the *data context* that stimulated the modeling problem and contextualised and bound the data used to solve the problem. Each picture story book therefore had the potential to influence the statistical reasoning used by the children to work the modeling problem to a solution. Findings of the children's use of knowledge drawn from the picture story book to solve a modeling problem are presented and discussed in Chapters 6 and 7.

Chapter 6 DISCUSSION AND FINDINGS: Children's Reasoning about Attributes and Data Representation

6.1 Introduction

In this chapter, the findings that emerged from the theoretical and thematic analysis of two modeling activities, *Baxter Brown* and *Michael Recycle*, are presented and then discussed.

The principal theoretical and methodological vehicle used to examine statistical reasoning in this study was the Models and Modeling framework (Lesh & Doerr, 2003), specifically data modeling. Data modeling comprises two related systems of activity, design and analysis. The first, *design,* is where the nature of variables and their measurement are identified (Lehrer & Schauble, 2007a). The two modeling activities addressed in this chapter focused on the components of the design system of activity found in data modeling. Findings from themes that arose from analysis are therefore situated under headings for the components in the design system of data modeling (Lehrer & Schauble, 2003; Lehrer et al., 2007). The component headings are: generating, selecting and measuring attributes, and organising, displaying and representing data.

This chapter is in two parts. First, findings for the children's use of knowledge and reasoning as they generated, selected and measured attributes are presented, and then discussed. Second, findings for the children's use of knowledge and reasoning as they organised, displayed and represented data are presented and then discussed.

6.2 Findings: Generating, Selecting and Measuring Attributes

The generation, selection and measuring of attributes was a specific focus of the Baxter Brown and Michael Recycle modeling activities. These two activities were implemented consecutively in weeks 6 and 7 of the data collection. Brief

descriptions of the component task for each modeling activity and the data analysed for this chapter are found in Figure 6.1.

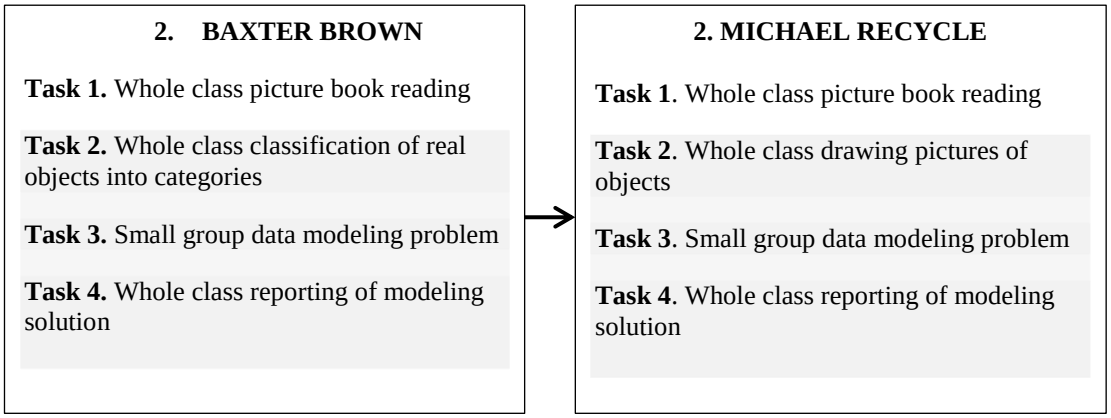


Figure 6.1 Summary of the tasks drawn on for analysis in Chapter 6.

For the purpose of this study, as stated in section 2.4.4.1, p. 45, generating and selecting attributes occurred when the children selected qualities of an object that were used as criteria for constructing categories (Lehrer & Schauble, 2007). Measuring attributes occurred when objects were classified by the children into those categories (Lehrer & Schauble, 2007). Three categories, *recycle*, *reuse* and *throw away* were core to the design of the modeling activities. The categories were initially discussed with the children prior to the implementation of the two modeling activities. The findings for this initiating discussion and tasks 2, 3 and 4 for the two modeling activities are presented in the following sections.

6.2.1 Generating and Selecting Attributes When Discussing Categories

The children generated and selected attributes for categories during a preliminary whole class discussion. In week 5 of the data collection, prior to the implementation of the modeling activities, the children engaged in whole class discussion about the meaning of the categories *recycle*, *reuse* and *throw away*, providing initial insight into attributes they were selecting and generating as criteria for the categories.

Attributes the children provided were criteria for acts of recycling, reusing and throwing away, such as placing objects in specific bins for recycling, giving old or unwanted objects away that could be reused, and taking large, broken items to the

"dump" or putting them in a rubbish bin to throw them away. The children gave examples of the consequences of such actions, such as receiving money for recycled objects through community cash deposit systems and being able to play again with reusable objects. These examples indicated that the children had prior knowledge from everyday experiences involving the acts and consequences of recycling, reusing and throwing away objects that they connected to the categories during discussion. The children's sources of knowledge revealed in their responses were consistent with the research that before school learning and knowledge stems from children's physical and social interactions (Ginsburg et. al., 2006).

The children's discussion exposed abstract attributes they held about recycling and reusing that focused attention on whether objects could be returned and in what condition. Distinctions were drawn between recycling and reuse. When *recycling* was discussed, Gina explained that this meant returning an object to the recycling bin and said, "If you return it, it means you don't get it back again, if you put the cans in the recycling bin, and they go in there and you want them back you can't get them back". Gina's comment indicated that once an object is deposited in a recycling bin, it is not recoverable by whoever placed it. Kayla initiated an explanation as to why an object placed in a recycling bin might not be recoverable:

> You put it in the recycling bin and somebody takes it and putted it in another bin and then they come and do some work on it and make more stuff and then it goes to a shop and they sell it all over again.

Kayla's account demonstrates knowledge of recycling processes and suggests that an object can be modified and made available again. Both Gina and Kayla's explanations introduced an object's *returnability* as an attribute, that is, whether the object could come back to you. Kayla extended this to include whether the object had physically altered when recycled and therefore made available again in a changed form.

When ideas were offered for what *reuse* might mean, Bryce, Jade, Sam and Lee gave examples of toys, such as a soccer ball, which they suggested could be reused for playing, either by giving it away to someone else to use or receiving someone else's to enjoy. Their suggestions reflected that they considered an object reusable if it could be returned in some way. Eliot explained further that in addition

to being returnable, toys could only be reused "if they're still not broken". Isabel agreed that an object's physical condition for its original purpose must be maintained in order for it to be reusable, saying "you can reuse um wear um clothes again, like T-shirts and pants and stuff". Gina, Isabel and Bryce proposed ways that objects such as boxes, could be reused to make cubby houses or to "keep stuff in". Similarly, cans could be reused "to fill 'em up with more things". These statements implied that an object's purpose could be changed as long as the original form was maintained. Much later in the whole class discussion, when asked what the differences between recycling and reuse might be, Carl pointed out that "if you reuse you get it back, and if you recycle it, it's gone, you can't get it back". For Carl in particular, the returnability of the object was a defining attribute that differentiated between the two categories.

A whole class discussion about the meaning of the categories also occurred at the beginning of the first implemented modeling activity, Baxter Brown during Task 3. Similarly, the returnability of an object and its potential to change into something different surfaced were the *only* defining attributes offered by the children for the categories of recycle and reuse. When the category of *reuse* was discussed, Jade said that reuse, "means …you um… it means if you have toys or things, they will just come back", followed by Kayla who stated, "you can reuse stuff and it comes back to ya" and Toby who reported, "you get it back". These explanations indicated that for an object to be reused, it needs to be returned and in its original form. Returnability also featured as an attribute for the category *recycle*. Chris stated, "ah, we, you don't get it back", a view supported by Toby when he said that, "you don't ever get it back". Both children affirmed that a recyclable object is not returned, although it is not clear as to whether the children believed that it would never be returned in its original form or at all. Isabel affirmed that two attributes for recycling were returnability and change of form, " Recycle means…everything that…you can get back because it melt, it gets melted down, then it get mackened into something new". Isabel's underlying factual understanding of the recycling process that appeared to have influenced her belief that a recycled object will be returned and in a different form. Isabel continued to explain this view during the subsequent small group work in Baxter Brown Task 3 with Toby and Carl.

The examples provided by the children in both whole class discussions provided insight into the knowledge they relied on for generating and selecting attributes for the categories recycling, reusing and throwing away. A distinguishing element of findings for the children's generation and selection of attributes in the preliminary whole class discussion and the whole class discussion at the beginning of Baxter Brown Task 3, is that the children were *not* involved in using the attributes as measures to classify objects or pictures of objects. The discussion engaged the children in generating and selecting attributes, but not in using these attributes to classify objects. The attributes generated in these discussions were defined by criteria that were general and abstract in nature, and focused on whether an object could be returned or not, and whether the form of the objects could be changed.

In each of the two modeling activities, the children would generate and select attributes for categories and then use these attributes to classify objects into those categories. The modeling activities that used objects (as pictures or real objects) therefore moved the children from *thinking* about generating and selecting attributes for categories in whole class discussion to *applying* those attributes as a measure to classify an object into a category. The findings for the two modeling activities revealed differences in the children's use of knowledge to reason about attributes when working with pictures and when working with real objects, which are discussed in the next two sections.

6.2.2 Generating, Selecting and Measuring Attributes With Pictures

The children used knowledge of actions with objects made by family members to generate and select and measure attributes when working with *pictures* in Baxter Brown Task 3. Attributes of returnability and original or changed form of an object dominated attribute discussion and decisions in Baxter Brown Task 3 as the children worked with *pictures* of objects to find a solution to the data modeling problem. Isabel in Group 1 classified shoes into the category of reuse on the basis that "someone else might need it" indicating that returnability in its original form were selected attributes. A picture of a milk carton was classified into recycling; "because with recycling, you can get stuff back" suggesting that returnability was the selected attribute. Toby immediately reacted by challenging Isabel's classification, saying; "no you can't! That one does" (pointing to the reuse symbol on the paper).

Toby's challenging of "you get stuff back" highlights the importance he placed on the "returnability" attribute. Toby qualified his definition of the returnability attribute explaining that reuse is when, "you use it for something else", implying that the object is returnable, but in its original form. Toby's explanation is consistent with the attributes for reuse and recycle he had previously raised in the preliminary whole class discussion (section 6.2.1, p. 157). These examples illustrated a consistency existed in the children's attributes for the reuse and recycle categories. The determining attribute that differentiated between the categories was whether or not the form of the object could or should be changed.

Similarly, in Baxter Brown Task 3, Sam (Group 2) alluded to object returnability as he worked to explain why he would recycle a cereal packet, saying, "because it come, it come back when it was, when it was, when it was, I don't know". Sam appeared to be working to articulate whether an object can be returned as an attribute to consider for recycling. Sam's focus on the importance of returnability as a category attribute was also visible when he reported his group's model solution to the whole class in Baxter Brown Task 4. The explanation Sam gave for classifying newspaper into reuse was that "the people, the newspaper…and the people can read it again". This example reaffirms Sam's consistent application of returnability as a defining attribute for recycle and reuse. During the group reporting in Baxter Brown Task 4, additional examples were provided that demonstrated that an object's returnability and potential to change form were attributes worthy of the children's attention. Carl reported on behalf of his group (with Toby and Isabel) and provided additional reasons for classifying objects that were canvassed during their group discussion when he said "so we'd get it back and back and it would reuse, and the bone in reuse so we get it back, and dogs like to…to er, chew them". Carl's explanations reaffirmed the importance of an object being returned and in its original form as core attributes for the category of reuse.

The attributes that were applied by the children to classifying pictures of objects across the small group work in Baxter Brown Task 3 were returnability and change of form. These two attributes are consistent with those raised by the children in the whole class discussions. In those discussions, the children did not *use* the attributes to classify as they did in Baxter Brown Task 3, however, the attributes used

in the whole class discussions, and the small group work using picture data, are the same.

The attributes of returnability and change of form of an object were not visible when the children worked with picture data in Michael Recycle Task 3.The contrast between the children's model development in Baxter Brown and Michael Recycle is significant, because the children did not reveal any attributes as they developed their models. Across all groups, the children names categories (recycle, reuse or throw away) as they classified pictures into them, but they did so without providing explanations. As a result, the attributes the children attributed to the categories was unknown. Some instances of picture data classification occurred when a category was named but no explanation was offered for the attributes being relied on to classify the object. For example, in Group 1, Toby said, "I think the paper goes in recycle" and Isabel suggested, "I think jars are recycle". In Group 2, Jade stated "I think this one goes in um the recycling" whereas Sam proposed, "I think this one goes in the throw away". In Group 3, Gina said, "I think the paper should be recycled" and Blake claimed, "I think this goes in throw away".

In other examples, the category was not named and classification explanations were incomplete or not provided. This is illustrated in Group 2, when incomplete explanations were offered by Eliot who said, "I think that one goes in there 'cause", and Jade, who stated "I think that one goes on there for a reason. Because". Sam did not provide an explanation when he said, "I think this one goes in both" as he placed his bottle drawing on the paper. These examples illustrate that when the children were classifying the pictures into categories and representing the categories as they placed the pictures on paper, they did not provide auditable evidence of the knowledge that was being drawn on to determine attributes for each category.

The group reporting in Michael Recycle Task 4 provided some explanations of attributes the children relied on to classify the picture data. The children used knowledge of actions with objects made by family members to generate and select attributes, with family members specifically named. Isabel (Group 1) explained that she had placed the drawing of her jar into the reuse category "because I see my mum reuse jars" and her cereal box drawing into throw away "because I see my mum

throw away those". Similarly, Jade (Group 2) reasoned that she had placed a can in recycle because "um, I saw my mum put it in there". When Group 3 reported, the teacher asked Blake about why his peel drawing had gone into reuse, and Blake explained "'cause I seen my mum do it". Gina reported that her paper drawing was in recycling "ah, because I seen my mummy do it". These examples illustrate that specific experience of family members' actions was drawn on to generate and select attributes that were used for classification.

These findings in Michael Recycle are that discussion about attributes by the children was not present as the children developed their models in small group work in Task 3, and that the few attributes that were revealed in Task 4 made direct reference to family experiences. This contrasts with the children's work with pictorial data as they developed their models in Baxter Brown Task 3 (section 6.2.2, p. 160). In Task 3, the children discussed and provided reasons for the attributes they used to make classification decisions. In addition, the children predominantly relied on the attributes of returnability and change of form. The Baxter Brown modeling activity however, had a different design focus to the Michael Recycle modeling activity. In Baxter Brown Task 3, the children were provided with pictures of the objects and categories, and the categories they were to work with (recycle, reuse and throw away) were pre-assigned. For Michael Recycle Task 3, the children created their own pictures drawn from real objects and chose their own categories, providing different task demands between the two modeling activities for both the creation and organisation of the picture data. A possible link to the use of real objects to generate picture data in Michael Recycle, and attributes that draw on knowledge of family experiences is reflected in the findings presented in the next section.

6.2.3 Generating, Selecting and Measuring Attributes With Real Objects

The children used knowledge of actions with objects made by family members to generate and select and measure attributes when working with *real* objects in Baxter Brown Task 2. During the whole class Baxter Brown Task 2, the children sorted real objects into the three categories; recycle, reuse and throw away. The attributes generated by the children were drawn from knowledge of actions taken to recycle, reuse or throw away. The children's use of this knowledge corresponded to findings of knowledge drawn on to generate attributes in the

preliminary whole class discussion (section 6.2.1, p. 157). However, in contrast to those findings, the children's explanations for the attributes for all three categories were explicitly linked to known or observed actions by family members at home, who were named. For example, classification of toys into *reuse* was explained when Kayla said, "because it's what my mum does", Mia stated, "because, um, my mum never gives away toys" or as Indiana explained, "I seen my mummy and daddy put newspaper in the reuse". Jade reported reusing newspapers, "because that's what my mum does". For the category *recycling,* Gina explained that cans are recycled "because my mum puts cans in recycling" and for Ted, milk cartons were recycled because "my mum put 'em in there". For the category *throw away,* Chris offered that, "um, my dad puts the drinks in the bin" which paralleled Bryce's idea when he stated, "I seen my dad throw cartons in the bin". The children drew from their home experiences of seeing or knowing a family member's action with a similar object to reason about attributes for the categories and to classify objects. Common nouns for their family members, such as "mum" and "daddy", were consistently used to denote who had performed the actions the children relied on.

The findings indicate that the knowledge the children relied on to generate and select attributes for the three categories when working with real objects appeared to be influenced by the task requirements. The knowledge the children relied on differed between tasks that that required classification of *real* objects, and tasks that did not require classification at all (categories were only discussed) or required classification of abstract representations of objects as *pictures*. Tasks that did *not* require attributes to be used to classify real objects generated and selected the abstract attributes of returnability and change of form. In tasks that *did* require classifying real objects, including drawing pictures from real objects, attributes were generated and selected that relied on observed family actions with objects. The varying explanations provided by the children across all tasks however, support a general finding that children actively connected to and relied on their real world knowledge when generating and selecting attributes for all three categories of recycle, reuse and throw away.

A distinct contrast to the reliance on family experiences for classifying real objects however was found when there was a perceived connection by the children

between the object for classification and the picture story book, and this is presented next.

6.2.4 Connecting Attributes to the Picture Story Book

Some attributes generated and selected by children for the category of reuse relied on knowledge from the picture story book. This was found when three children each classified object with an accompanying explanation that linked to their knowledge of the dog character Baxter Brown. Toby, who had earlier commented on how much rubbish Baxter Brown had, thought that the dog biscuits should be reused "because dogs eat biscuits". Toby's explanation appeared mindful of the needs of the dog character from the story. Next, when the old toys were being categorised, Bryce explained that a toy ball should be reused because "I think Baxter Brown might like it again", and was immediately supported with verbal agreement from three other children. Bryce's comment explicitly linked the category attribute for "reuse" to Baxter Brown and his ability to enjoy the toy again, which prompted peer contribution. Both Toby and Bryce's explanations reveal that they had formed a connection to the picture story book that prompted them to think of what the dog character might like. Finally, when Eliot considered where to classify an old robot toy, he said "um, I think er, reuse, 'cause my dog at home…we never um, give away toys". Eliot's reasoning alludes to a connection between the character Baxter Brown (who needed to clean up his room), the toy to be classified, and Eliot's home experiences. At Eliot's home, dog toys are always kept. All three comments drew on attributes for reuse raised by the children in prior whole class discussions. If a defining attribute of reuse is returning an object in its original form for someone else to use, then classifying toys or dog biscuits as reuse would allow Baxter Brown have the objects to enjoy as they are.

The three examples from Toby, Bryce and Eliot provide implied and direct connections to Baxter Brown and to objects a dog might use. The examples support the finding that a perceived connection by the children between the object for classification and the picture story book was used to make sense of the data. In addition, the attributes generated and selected by the children supported classification of the object into *reuse*, hypothetically maintaining the object in its original form. The use of returnability and original form attributes is consistent with attributes

found in the whole class discussions of categories (section 6.2.1, p. 157) and when working with pictures (section 6.2.2, p. 160). It is in direct contrast to the children's classification of the other real objects in Baxter Brown Task 2, where experiences of family members' actions were relied on. Further, the *only references* to the picture story book made by the children in *either* of the two modeling activities (Baxter Brown and Michael Recycle) was when the children worked with real objects in Baxter Brown Task 2.

6.2.5 Contrasts Between Modeling Activities When Working With Attributes

The findings presented in section 6.2 reveal significant differences between the two modeling activities in the generating and selecting attributes for categories and using these attributes to classify pictures or real objects into those categories. In Baxter Brown, the children discussed and explained the attributes they generated, selected and used to classify of data. The children's model development in Baxter Brown was therefore focused on organising the data, as category and classification decisions using the attributes were made. Limited time was spent on discussion and actions to display and represent data. In contrast, across all of the tasks comprising Michael Recycle, there was limited discussion or explanation by the children about what they relied on to generate, select or measure attributes used to organise data. The children's model development was focused on displaying and representing data.

These findings may be explained by the task design. In Baxter Brown, the modeling activity was designed to focus attention on generating and selecting attributes (section 4.2, p. 107). In Michael Recycle the modeling activity was designed to focus attention on identifying and displaying data (section 4.3, p. 113). The design distinction between the two modeling activities was evident in the children's models developed to display and represent data. These findings are presented and discussed in section 6.3.6, (p. 176) of this Chapter.

6.2.6 Section Summary

The children's generation and selection of attributes in tasks engaging whole class discussion and classification of picture representations of objects relied on knowledge of potential actions and consequences for objects such as returnability and change of form. In tasks where attributes were generated and applied to

classifying real objects, or pictures drawn by the children from real objects, the children relied on knowledge from directly observable experiences of actions by family members. The picture story book was openly referred to when some objects were classified in the Baxter Brown modeling activity.

6.3 Discussion: Generating, Selecting and Measuring Attributes

6.3.1 Introduction: Determining Categories and Classification When Working With Attributes

In this section, the findings presented in 6.2 are discussed. Throughout the discussion knowledge and reasoning that engaged the data context and task context findings are addressed, and implications for future research and practice are signposted.

The children generated and selected attributes to begin the progressive selection needed to construct data (Lehrer & Schauble, 2002) and find solutions to the data modeling problems. The attributes were used by the children as a measure to classify objects. During the generation and selection process, the children made decisions about what to observe and how to measure it. Selecting attributes involves "seeing things in a particular way, as a collection of qualities rather than intact objects" (Lehrer & Schauble, 2007, p. 154). Accordingly, the process of generating, selecting and measuring attributes provided insight into the knowledge and reasoning the children drew on to construct attributes for categories and measure objects through classification as members of that category. The reasoning and knowledge used by the children as they generated, selected and measured with attributes across the two modeling activities, and how these were used to reason statistically and make sense of the data, are now discussed.

6.3.2 Reasoning About Attributes

The children used both inductive and deductive reasoning to reason about attributes and find solutions to the modeling tasks. Inductive reasoning involves making "mental connections between something that we already believe is true and something we believe connects to it in some way" (Chiasson, 2005, p. 215), a process that constructs generalisations by connecting to known examples as a means of filling "gaps in our knowledge" (Goswami, 2011, p. 282). Inductive reasoning

occurs as data or existing knowledge are used to reason to a general conclusion (Lavigne & Lajoie, 2006). This process of induction was found in the children's reasoning about attributes. The repeated processes in generating and selecting attributes for categories relied on inductive reasoning using specific knowledge the children held from past experiences to reason to generalisations. Categorising requires moving from known examples to make reasonable but uncertain connections to new or novel information (Gelman & Meyer, 2011; Goswami & Bryant, 2007). For example, in considering the category of recycling, the children's specific knowledge or beliefs was used to generate generalised attributes to represent that category. Knowledge that was used to generate attributes included actions by family members to recycle particular objects, knowledge of recycling processes, such as melting something to change its form, and the consequences of recycling, such as objects being returned in some way but not in the objects original form.

In contrast to the inductive processes used to generate and select attributes for categories, using the attributes to classify objects relied predominantly on the children's deductive reasoning. Deductive reasoning moves from the general to the specific (Goswami, 2011), where a specific statement is accepted or proved as a consequence of information found in established, generalised statements (Tarski, 1995). In an inquiry, deduction is a logical conclusion that tests the validity of the evidence found in the generalisation, which may be a hypothesis, law or theory (Lavigne & Lajoie, 2006). Classifications are judgments of membership of a category that are criterion dependent (Lipman, 2003). Attributes selected for categories are used to deductively determine a specific conclusion about whether an object meets the attribute criterion (the generalisation) and must therefore be classified into that category. For example, if an object that can be melted is recyclable (attribute criterion for a category) and an object can be melted, it must be classified as recyclable. When the children drew from the picture story book to classify an object, they combined their specific knowledge or beliefs about what dogs like with knowledge from the picture story book and used this in conjunction with attributes for the category reuse in order to return toys and biscuits to the dog character Baxter Brown.

Using inductive reasoning to generate and select attributes for categories engages a core statistical characteristic defined in this study. Participation in modeling practices creates a dynamic relationship between modeling and meaning, where definitions are negotiated which resemble the processes of statistical reasoning (Lehrer & Schauble, 2007a). In data modeling this includes "deciding which aspects of the world are relevant to the conceptual model and how best to measure them" (Lehrer & Schauble, 2007a, p. 150). Findings that inductive reasoning was used to generate and select attributes reveals that inference, which is, moving from specific instances to generalisations, was a central reasoning process in the children deciding what aspects of the data they were handling were relevant to developing their conceptual models. The findings of this study support the research of Nisbett, Krantz, Jepson, and Kunda (1983) who examined the use of "statistical heuristics", described as "intuitive, rule-of-thumb inferential procedures that resemble formal statistical procedures" (p. 345) that are used when reasoning inductively about everyday problems. They concluded that the use of statistical heuristics is related to the development and application of causal understanding, and includes the inductive application of "moving from particular observations to general propositions" (p. 342). Statistical heuristics were visible in the children's generation and selection of attributes when the children used inferential processes to drawn on their existing knowledge and generate and select attributes to make sense of the data. Reasoning in statistical inquiry requires statistical reasoning, because sense must be made of the data based on inferences made using whatever statistical knowledge is available (Lavigne & Lajoie, 2006). The findings suggest that the children used their existing knowledge to reason about generating, and selecting attributes for categories that made sense of the data. Those attributes were the used as a measure to classify data into categories. In doing so, the children revealed their application of statistical knowledge and statistical reasoning.

6.3.3 Reasoning About Attributes and Variation

The findings suggest that the children reasoned with variation when making decisions about attributes for categories, and classifying objects using those attributes as a measure. Variation is one of the "big ideas" in statistics that affects every aspect of statistical problem solving (Moore, 1990; Pfannkuch, 2005). It is argued in this

study that young children should be given the opportunity to explicitly engage with variation as they begin statistical learning. Thinking about variation begins with awareness of it in a real situation (Pfannkuch, 2005). Prior modeling studies with children (Grades 3-6) who had previous modeling experience, have examined children's development of mathematical accounts of variation in measurement that impacts statistical distribution (Lehrer, 2007; Lehrer & Schauble, 2004, 2011; Lehrer, Kim, & Kornold, 2010; Lehrer et al., 2007). In these studies, variation was defined in the context of the description or measurement of those characteristics that affect statistical distribution. In contrast, in this study variation is considered from the perspective of variability, that is, something that is inherent in the perceptual characteristics of the data (objects and pictures of objects) the children handled (Reading & Shaughnessy, 2004). For young children, variability as "observable reality" (Wild & Pfannkuch, 1999, p. 235) underpinned categorisation and classification decisions the children made to generate, select and measure attributes. Variation, as measuring or describing that characteristic (Reading & Shaughnessy), is then revealed in the organisation and representation of the data visible in the representations found in the children's models (discussed in section 6.5, p. 186).

The findings suggest that the children were aware of the variability inherent in an object and that this impacted their use of attributes to determine category membership. The repeated comparison of objects (as real objects or pictorial representations of objects) against the attributes the children had determined for the categories resulted in differences of opinions about where objects should be classified. Children challenged each other as to how attributes should be applied to objects, and some children acknowledged and recorded that an object could be classified in different ways. For example, an object such as a milk carton could be reused or recycled, but this was determined by how it would be returned, in it's original form or in a changed form. The findings support Lehrer and Kim's (2009) view that variability is "merely difference until it has been cognitively and materially transformed" (p. 119) when structure is imposed on it for a purpose. Findings of children's engagement with variability and variation are indicated, and they support suggestions found in Watson's (2002) work with 6 year olds that an intuitive appreciation for variation develops early. Given the critical importance of variation

in statistical reasoning and thinking (Moore, 1990; Shaughnessy, 2007; Watson, 2006) the role of variability and variation in children's work with attributes needs more attention.

Engaging variability when developing and applying attributes incorporates decisions about similarity and difference. Young children have a propensity to categorise and classify (Goswami, 2007) when they make decisions about whether something is similar or different to something else. Lipman (2003) argues that the ability to determine similarity and difference underpins all reasoning. Assessing similarity and difference between objects is about considering the variability inherent in the object. At the perceptual level, analysis of difference between objects could be considering attributes such as shape, colour, size or texture. The findings from this study are that the children did not use perceptual features of objects to determine their attributes, but used more abstract features such as knowing or believing that particular processes could apply to some objects and not to others. For example, an object that could be melted and change its form could be recycled, and an object that could keep the same form could be reused.

In this study, the findings indicate that when reasoning about category attributes, the children's attention was on differences between objects, and when determining classification of an object, the focus of attention was on similarities between the object and the attribute selected for a category. Awareness and acknowledgement of variation and variability is critical to reasoning statistically about measurement and connections between data, data samples and data distribution (Shaughnessy, 2007). Research is needed that supports and extends children's inductive capacity to consider variation as variability when they reason about attributes as they classify and categorise.

6.3.4 Using Real World Knowledge to Generate and Select Attributes for Categories

The children used real world knowledge to generate and select attributes for categories. Categories (recycle, reuse, throw away) were provided as part of the task design in the Baxter Brown modeling activity. The provision of specific categories afforded categorisation opportunities that differed from those usually accessible to

young children in two ways. First, the children did not create categories for themselves but constructed attributes for categories that were already allocated. This differs from typical categorisation activities for young children where they determine categories for themselves by grouping objects based on the perceived attributes such as colour, shape or size (Hanner, James, & Rohlfing 2002). Second, the allocated categories of recycle, reuse and throw away referred to events or actions, so potential attributes for the categories were not visible or perceivable from the object stimuli provided. The combined effect of these two design features was that children were required to look beyond the perceptual features of the objects in order to generate and select attributes for specific categories. Unless the children had knowledge of the recycling processes for example, there was nothing inherent in an object they had that would support determining attributes for a category it could belong to. Attributes for the assigned categories were not therefore physically perceivable and required the children to look beyond immediately apparent, physical properties to generate and select attributes.

This study found that the children used prior knowledge from various sources and initiated an active search for connections and distinctions in their experiences in order to generate and select attributes for the assigned event categories of recycle, reuse and throw away. Young children's determination of category attributes has featured in prior data modeling studies. Lehrer and Schauble's (2000) study of Grade 1 and 2 children (average age 7 years 1 month) examined the attributes developed to assess self-portraits, where perceptual stimuli was available to the children. They found that the children initially gave evaluative comments, and relied on adult assistance to develop more descriptive statements for attributes over several iterations of model development. In contrast, the findings in this study are that in the absence of perceptual stimuli to support generating category attributes, the children immediately initiated descriptive statements without adult assistance. The children generated and selected complex attributes that were based on and described known actions, such as giving unwanted objects away that could be reused, and the consequences of actions, such as being able to play again with reusable objects. Other attributes described observed or known interactions with objects that known from actions by family members, such as a child observing his or her mother place

cans in the recycling bin at home. Children's descriptions of attributes made use of different kinds of informational sources including how others actions with objects and how objects are used (Gelman, 2009) in addition to their own observations and knowledge. This confirms that children learn from evidence of direct experiences and indirectly through information provided by other people (Kushnir, Vrendenburgh, & Schneider, 2013).

The children drew from their knowledge of recycling processes to generate and select attributes using unobservable facts that went beyond first-hand experiences. These attributes took into account whether an object could be processed and change its form by being made into something different, whether it could be used again in its original form and whether the object would be available for use again, that is, its returnability. The findings support English's (2010) data modeling research. English (2010) found that children (mean age 6 years 8 months) provided with an event or action category, generated attributes that used unobservable facts, including melting, keeping and composting objects. The perception of objects, particularly correlations and associations between features, can affect children's construction and use of categories (Hayes & Thompson, 2007). Perception of objects usually reveals consistent information about object structure that is relied on for feature similarity in making conceptual judgments (Goswami & Bryant, 2007). Prior data modeling studies with young children have shown that children's reliance on resemblance has been an important part of model-based reasoning (Lehrer & Schauble, 2007a).

Real world knowledge children have, such as causal and thematic knowledge, can however affect the way children generalise properties when categorising or classifying objects, and result in generalisations that are not bound by perceptual or feature similarities (Hayes & Thompson, 2007; Hayes & Rehder, 2012). Categorising using an unseen attribute has been described as "a paramount example of inference" (Kruschke, 2005, p. 184). This study's findings are consistent with research that children are open to and can reason about concepts that are not obvious, without depending on perceptually discernible attributes (Gelman, 2006). Perceptual resemblance in data modeling has been regarded as a bridge between form and function that helps move children "from literal similarity to analogical mapping of

systems of relationships" (Lehrer & Schauble, 2007b, p. 155). This study has found that children can move beyond perceptual resemblance and consistently create and apply attributes based on unseen properties. The complex and abstract attributes that the children generated contrast with the view that perceptual features of objects are a significant draw for young children when they need to arbitrate between these and relational properties such as function (Namy & Clepper, 2010). Children's demonstrated capacity and ability in exploring the categories meaningfully, and by inducing category properties based on known properties from prior experiences they considered to be relevant to the task at hand. The findings reveal that young children's capacity to draw from and meaningfully apply real world knowledge gained from experiences to more novel and complex situations of categorisation and classification is underestimated.

6.3.5 Using Data Context Knowledge to Generate, Select and Measure Attributes

Knowledge of the data context was specifically used to classify an object when a connection was made between the picture story book and an object for classification. In Baxter Brown Task 2, the needs of the main character in the picture story book, the dog Baxter Brown, appear to have been considered. The attributes of returnability and preserving the original form and function of the object was used as classification measures indicating regard for, and a logical connection between the story and the data. Finding a specific link to knowledge drawn from picture story book and the children's reasoning about attributes was found in the modeling activity Baxter Brown, but not in Michael Recycle. This may be explained by the findings discussed in Chapter 5, where the children were found to be interested in the unresolved problem during the reading of the picture story book *Baxter Brown's Messy Room* (English, 2009a) and the picture story book was meaningful and relevant for the children (Fox, 2006). Significantly, *Baxter Brown's Messy Room* was the only picture story book that drew the children into spontaneous responses to, and predicted solutions about, the dog character's problem presented in the story. The provision of an interesting and engaging picture story book in Baxter Brown fore-fronted the data context for the problem, drawing attention to it and supporting the children's interaction with the data (Paparistodemou & Meletiou-Mavrotheris, 2008).

Conversely, the children showed limited interest in the reading of the picture story book *Michael Recycle* (Bethel, 2008) and did not respond to the main character's efficient resolution of the problem in the plot. From a Models and Modeling perspective, the significance of the picture story book lies in its ability to stimulate the development and representation of a model to describe, explain or solve a contextualised problem (Lesh & Harel, 2003). Finding knowledge of the picture story book used in the Baxter Brown modeling activity and not in the Michael Recycle modeling activity may be due to the differences found in each story's capacity to stimulate interest, engage attention and provide information that was personally meaningful (Renninger & Hidi, 2011) such that children would connect the story to the problem to be solved. Finding specific references to the picture story book indicates that for some children, the modeling activity was contextualised by the story and they were mindful of it as they classified an object. Although an emergent finding, it is significant if beginning statistical learning aims to draw children into keeping the data context of the statistical problem in mind at all points in the investigation, including the design processes. The findings also provide insight into the characteristics of picture story books that contextualise reasoning when generating, selecting and measuring attributes. Explicitly linking the data modeling problem to the needs of the main character in the picture story book may stimulate an active engagement with the data context in statistical problem solving.

A speculative argument from the findings can be mounted about the role of the picture story book in providing the data context for the modeling activities. In Baxter Brown, the modeling tasks employed real objects and pictures of objects that represented objects explicitly referred to in the picture story book. Consequently, each classification of an object or pictorial representation could be considered, prima facie, an engagement with the story as the children worked to resolve Baxter Brown's sorting dilemma, which presented as an unresolved problem in the story that became the data modeling problem. In contrast, in the Michael Recycle modeling tasks the plot from the picture story book was extended to create the data modeling problem, and so the objects used in the task did not explicitly feature in the story narrative or illustrations in the book. As a result, a direct connection between the content of the picture story book and the data modeling problem in Michael Recycle

was not present in the same way as it was for Baxter Brown. If an authentic connection to the modeling activity from the picture story book was not established, it may have impacted stimulating model development using attributes to solve the modeling problem, which is suggested by the limited discussion found about attribute decisions. Given the importance placed on personal interest and connection to the context of a problem for children's active interest in the task (Clarke & Roche, 2009; Paparistodemou & Meletiou-Mavrotheris, 2008), further research that explores the strength of the connection between the engaging characteristics of the picture story book and the data modeling problem will benefit the design of future task contexts.

6.3.6 Contrasting the Task Contexts

Distinctions were found between modeling tasks in the types of knowledge children brought to the modeling processes. The first distinction was between tasks where real objects were used to apply selected attributes to classification and those where pictures or no objects were used. In tasks where pictures of objects were provided for classification or where category attributes were selected but not applied to objects, (when whole class discussion explored the meaning of categories), the children used knowledge from varied sources that did not rely on perceptual features of objects. Conversely, in tasks where real objects were used for classification, including tasks where the children drew pictures from real objects, the children relied exclusively on knowledge drawn from direct observation of how family members dealt with the objects at home. These findings may be explained by the abstract and generalised nature of open discussion in the absence of a requirement for the children to apply their ideas, and the use of pictures as a more abstract, symbolic representation of objects. The level of abstraction may have supported a shift in the children's perceptions of the attribute phenomena under investigation. It raises questions for further research. Do children rely on different knowledge that generates more abstract attributes when they are *not* required to use the attributes as a measure of classification? What value might this have in developing statistical thinking? Are there differences between the types of attributes generated and used as a measure when children use real objects as opposed to pictures of objects that are provided?

The second distinction found between modeling activities can be explained by the task design. There are stated design distinctions between the modeling focus for each activity that is reflected in the balance of findings between the two activities. A primary goal for the Models and Modeling perspective is to design modeling activities that engage children in situations that elicit the development of models and conceptual tools for making sense of the complex system under investigation (Lesh & Doerr, 2003; English & Doerr, 2004). The findings demonstrate that the primary role of the modeling tasks to stimulate children's engagement with specific statistical processes was fulfilled. Baxter Brown focused on the generation and selection of attributes (section 4.2, p. 107). Michael Recycle, focused on the identification and displaying of data (section 4.3, p. 113). The task emphasis is reflected in substantial findings from Baxter Brown on generating, selecting and measuring attributes that contrast with the limited findings from Michael Recycle with respect to this process. During Michael Recycle, determining attributes for categorising and classifying objects appeared to be integrated into the children's decisions about how to display the data, indicating a relationship between attribute reasoning and data representation. The role of statistical reasoning in organising and displaying data for both Baxter Brown and Michael Recycle are discussed in the next section.

6.3.7 Section Summary

The children's inductive and deductive reasoning skills were used statistically, to generate and apply attributes and make sense of the data. In the process of developing their attribute models to solve the modeling problems, the children drew from prior real-world knowledge. The children engaged with variation as they classified objects, including unseen features. The specific use of data context, as knowledge drawn from the picture story books used in each activity, was found when a meaningful connection was made between the picture story book and an object for classification. The complex, abstract attributes the children generated, such as returnability and change of form, may be the result of the differences in task contexts. The task contexts in both modeling activities engaged event or action categories that were not physically perceivable. There was a contrast between modeling activities that required classification of objects and those that did not.

Further, there was a deliberate distinction in the design focus for each modeling activity.

6.4 Findings: Organising, Displaying and Representing Data

The children's attention to organising and displaying data differed between the two modeling activities. In Baxter Brown, the children's attention was focused on how to organise the data requiring classification of the picture data into categories, and there was little discussion or interaction about how to display and represent the categories once the organisation decisions were made. In contrast, in Michael Recycle, the children's attention was focused on how to display and represent the data, with little discussion or interaction about how to organise the data.

6.4.1 Representational Awareness When Beginning Representation

Evidence of representational awareness emerged as the children developed their models and began to sort the object pictures and position them on paper. There were several examples of the children's attention to the spatial positioning of the paper and pictures on the paper in Baxter Brown. An initial data organisation and display decision made by each group was how to position the paper they had been given. The A3 paper the children had been provided was placed by the researcher in landscape position in relation to where two of the three children sat at the table, and the children did not reposition the paper during the course of the activity. The landscape A3 position was maintained consistently by all the groups in the class, but it is unknown whether this was a conscious decision or an unquestioning acceptance of the initial presentation of the paper. The landscape positioning however, made maximum use of the space available for the organisation, display and representation of the data selected by the children.

6.4.2 Variation in Representation

There was some variation in the data representation found in the models produced by the groups across both modeling activities. However, visual consistency was found in the pictograph models developed by all groups in Baxter Brown (Figure 4.5 (p. 111), 4.6 (p. 112), Figure 4.7 (p. 112) & Figure 4.8 (p. 112)) and the pictograph models produced by two groups in Michael Recycle (Figure 4.11 (p. 116) and Figure 4.13 (p. 117). All of the pictograph models show three category headings

displayed horizontally across the top of the paper with classified picture data represented in columns under the category headings. In contrast, Group 2's model in Michael Recycle represented two categories as a Venn diagram with classified picture data represented in each circle and the intersection between the circles. The development of these different models is presented in the next two sections.

6.4.2.1 Venn diagram representation.

The Venn diagram reduced the data using dual categories that allowed two sets of data, recycle and throw away to be represented, with an opportunity for classification into both sets using the diagram overlap. The circular display and representation for Group 2 was developed by two group members, Eliot and Jade. Eliot and Jade discussed the use and size of circles to organise and display the data as the task began. Jade's suggestion, "let's make it into a circle" was immediately agreed to by Eliot who affirmed, "yeah, into a circle". Jade responded by taking a pencil and drawing on the A3 paper in landscape position as she said, "we need to make, I'm just going to make, I'm just going to make a big circle". This exchange suggests that the idea of a circular display for the data was acceptable to both children.

The size and appearance of the circles was important for the children. A small initial circle was drawn by Jade, and as Sam and Eliot watched Jade draw the first of two overlapping circles, Eliot commented, "that's a *little* circle". There was progressive interaction between Jade and Eliot about the size of the circles, as Eliot, stated, "look out Jade", and began to draw a series of circles larger than Jade's on the same paper which resulted in an a Venn diagram (Figure 6.2, p. 180). Although not known, it may be that Eliot was not satisfied with the size of the circles and this was important to him. There is some support for this inference from the final model (Figure 4.12, p. 116) that shows that the circles Eliot drew encompassed sufficient space to physically accommodate the picture data represented in the two categories displayed in each of the two circles.

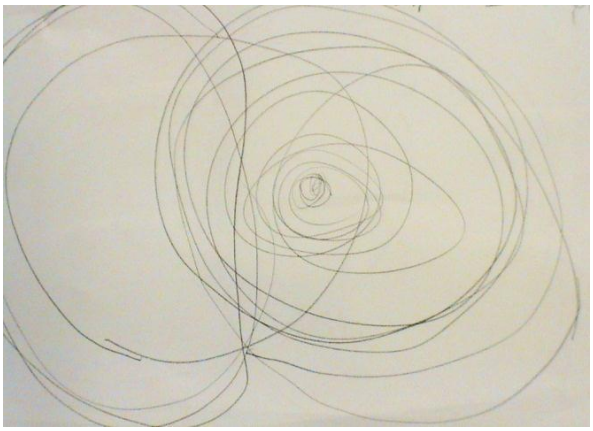


Figure 6.2 Initial circle attempts for data organisation and display.

In the following examples, Eliot's explanations during the task suggested that he considered the circles themselves as representative of the categories. Eliot's redrawing of the circles led Jade to complain: "now you make scribble!" to which Eliot responded, "I'm doing this so we know". When asked by the researcher how Michael Recycle would know from looking at the paper how the pictures had been sorted, Eliot replied, making circling motions over the paper with his hands, "well, um, there's, there's something!" Eliot initiated accessing another piece of clean A3 paper, saying "well we could get some more clean paper and then make two circles". He then drew two large circles as for a Venn diagram on the clean paper, as illustrated in the final data model (Figure 4.12, p. 116). These examples illustrate that Eliot had determined that two overlapping circles, consistent with a two circle Venn diagram representation, was an appropriate way to display the categories. Eliot's comments indicate that he understood the circles to be tools which would allow the data to be displayed and represented. The representation enabled classified picture data to be displayed for each category and one picture datum to be represented at the intersection of both categories.

There is a suggestion that Sam was aware of the function of the overlapping section of the two circles in their role as a Venn diagram. Sam placed his drawing of a bottle in the overlapping section of the diagram (as illustrated in Figure 4.12, p. 116). First, Sam placed the drawing and tried to give his reasons for doing so, as he said, "and I think this one goes in the middle because…" However, he was interrupted by Eliot talking before he could complete his explanation. Later, as the teacher asked about the objects and categories, the following exchange took place:

Teacher:	So the box is in recycle?
Jade:	Yes
Teacher:	And the can?
Eliot:	Yep
Sam:	And the bottle, this one goes in both (peels drawing from the overlapped section and replaces it, smoothing it down)
Teacher:	So the bottle goes in both, so it could be recycled or thrown away?
Sam:	Yep, it goes in both.

Sam attempted to draw attention to the bottle drawing's placement and to state and restate that it could be placed in both categories, which suggests that he is conscious of the purpose the intersecting section of a Venn diagram as a place where something can be classified into two sets. This example indicates that Sam saw the bottle picture as able to be classified as either recyclable or throw away and was aware that he could represent that decision by where he chose to place his picture.

6.4.2.2 Pictograph representations: Baxter Brown.

There were differences between the Baxter Brown and Michael Recycle modeling activities in the way the display of the categories was developed. In Baxter Brown, the categories were positioned linearly on the paper which was the result of an uncontested decision made by one member of the group. After the pictures were shared at the commencement of the task, all three children in Group 1 organised these on the table in front of them from left to right. In contrast, Group 2 members left their pictures randomly positioned on the table. However, as they commenced discussion about the task, in Groups 1 and 2, the three category pictures of recycle, reuse and throw away were arranged horizontally in a row on the paper being used to record their models. As presented in the following examples, these actions illustrated that as the children in both groups began the modeling problem, they were attentive to how the data for display would be structured.

In Group 1 (Carl, Isabel and Toby), Carl picked up the three category pictures and positioned them evenly across the top of the paper. Toby and Isabel did not contest Carl's actions in any way, which suggested that they approved of or were

untroubled by his decision. Later, Toby noticed that the category label pictures had been positioned but not glued to the paper, and commented, “we’ve got to stick these!” before gluing them onto the positions Carl had placed them. Toby’s comment and actions suggested that he was satisfied with or accepting of the position the category pictures were in, and chose to affirm this by fixing them.

The uncontested linear positioning of the category pictures was seen again in Group 2 (Sam, Jade and Sam). Jade picked up the category pictures and put them in a row across the top of the paper, saying, “we have to keep them here” but she did not glue them down. Later, Sam was sticking his first picture of a bone onto the paper under the recycle category heading and he was interrupted by Eliot who began to peel Sam’s picture off. Eliot justified this by explaining to Sam: “oh, you’ve got to put it at the bottom, there like that”. Eliot continued to lift the three category pictures off the paper one by one, and reposition them in a row in the lower right hand quadrant of the paper, gluing each one down in the process, without protest from Sam. Sam then placed his picture under the newly positioned recycling category heading. Although his reasoning is not known, Eliot’s actions suggest that he wanted to reposition the category label pictures and he maintained the horizontal, linear placement. As with Group 1, there was no discussion between the children about Eliot’s unilateral decision made about where the category pictures were to be placed. Neither Sam nor Jade challenged Eliot’s decision and Sam’s decision to reposition his classified picture suggests acceptance. The examples from Group 1 and Group 2 illustrated a consistent, unchallenged arrangement of the category pictures by one group member without discussion or intervention by other group members.

The horizontal linear placement of the category pictures resulted in visually consistent models developed by Groups 1 and 2 for the Baxter Brown data modeling problem that also was seen in the models produced by Groups 3 and 4. Audio and visual data were not collected for Groups 3 and 4 (section 3.5.5, p. 91) and it is not known how the group members managed their representation decisions. The data model representations seen in Figure 4.5 (p. 111), Figure 4.6 (p. 112), *Figure 4.6* Baxter Brown data model for Group 2.Figure 4.7 (p. 112) and Figure 4.8 (p. 112) illustrate the regularity in the use of columns to display the data, although the column positions vary in spread and placement on the paper. Group 1 (Figure 4.5, p. 111)

and Group 3 (Figure 4.7, p. 112) positioned the object pictures singularly under each other. Group 4, (Figure 4.8, p. 112) drew vertical lines between the columns and glued the object pictures irregularly within the columns. Finally, Group 2 (Figure 4.6, p. 112) clustered the columns in the bottom left hand quadrant of the paper and grouped the objects underneath them.

6.4.2.3 Pictograph representations: Michael Recycle.

In contrast to the findings in Baxter Brown, in Michael Recycle, there was discussion between, and actions by the children to work out how to display and represent the data. The primary focus for the children as they developed their models, was determining the position to display the categories on the paper. Categories were initially assigned verbally and through the actions of individual group members. The categories were later recorded by writing words or letters to label the representations.

Group 1's representation of the categories was impacted by challenges to the consistency of category display due to the initial verbal assignment of the position of the category on the paper. Unlike Baxter Brown, in the Michael Recycle modeling activity the children were not given category pictures to use and were tasked to determine their own categories. Accordingly, categories were determined and recorded by the children. Group 1 began with Isabel and Toby placing their sticky note drawings and naming the relevant category for classification for each. At the commencement of the activity, the following exchange took place:

Isabel:	I think jars are …recycle (places sticky note in the centre of the paper)
Toby:	(points to the paper) that's the mid one
Isabel:	Middle (smooths her sticky note down)
Carl:	It has to be higher up than that
Toby:	I think the box…I mean I think the paper goes in recycle (places the sticky note drawing above Isabel's)
Carl:	It's my turn (places his sticky note drawing to the right of Isabel and Toby's)
Toby:	That's, that's reuse
Carl:	No it isn't! (glares at Toby)

Toby:	Yeah
Carl:	Na
Toby:	Yeah
Carl:	No it isn't
Toby:	Is it throw away?
Carl:	Yes, it is *throw away*. I know, I know, I know (picking up a pencil) lets…I'm writing it, I'm writing it up the top! (gestures his hand horizontally across the top of the paper).

This example illustrates how category display was determined by a group member verbally assigning a category positioned on the paper. The establishment and maintenance of that position depended on agreement by the other group members. Isabel had verbally initiated the recycling category and positioned it in the centre of the paper when she placed her picture. Isabel's decision was accepted and confirmed by Toby when he placed his picture in the same category. The verbal assignment however was problematic, and differences about the positioning arose between Toby and Carl. Although he had not verbalised it, Toby had determined that the 'reuse' category would be in the position to the right of the established recycle category. Carl however, designated this position for the 'throw away' category as he placed his picture on the paper. When challenged, Carl sought to resolve the confusion by writing the category names across the top of the paper. When the labelling was completed, the categories read in horizontal sequence from left to right; 'recycle', 'reuse' and 'throw away', which altered the position of the recycling category and picture classification determined by Toby and Isabel. These examples illustrate that for Group 1, the verbal assignment of the position of categories for data display was problematic, but representing the categories by writing labels was considered a viable means of visually recording them.

The consequence of the changed category positions was evident when Isabel reported the group's model in Task 4. Isabel hesitated as she named the picture data and the categories they were organised in, saying "I thought my jar goes in…(looks at paper, looks up) mmm….". Isabel's response indicates that she was aware that there was an inconsistency between her original classification of the jar into recycle, and the category reuse that was represented in the model. Isabel then altered her

explanation to accommodate the changed category and confirmed that the jars were reusable because "I see my mum reuse jars". It is possible that Isabel was willing to change her explanation because she was satisfied that jars could be both recycled and reused. In contrast, when Toby was asked by the teacher about the classification of his paper drawing in the reuse category it was represented in, he did not accept the altered category, having initially classified the paper into recycle. Toby stated that he thought paper could be melted down, and "I thought that, that's because I thought that was recycling". Unlike Isabel, who adjusted her explanation to fit the altered category, Toby maintained his reasons for his original classification, while acknowledging that a change of category had occurred.

The development of the display of categories was similar in Group 2. Individual group members initially verbally assigned category positions, accompanied by the act of placing classified picture data in the category display position on the paper. Later, the categories were recorded by writing letters. Similar to Group 1, as a group member classified picture data into a category and placed it on the paper, a verbal statement was made. Jade stated, "I think this one goes in recycling" and she placed her drawing in the right hand circle while Sam, placing his jar drawing on the left hand circle, said, "I think this one goes in the throw away". Jade reaffirmed the category for the right hand circle when she placed her box drawing in it, saying, "I think this one goes in there because um…it is, that one (points to right hand side of the paper) is recycle". Eliot had placed his two drawings in the left hand side of the circle and had begun to write on the sticky notes. The letters "Thr" are visible on the top left hand corner of the peel drawing in the throw away left hand circle, and the letters "Re" are visible on the top left hand side of the can drawing in the recycling right hand circle (Figure 4.12, p. 116). Other indecipherable letters that could complete the word recycle are on the box drawing. It appears from these examples that the two representative categories, recycle and throw away had been implicitly accepted by all the group members without challenge or explanation. The categories had been verbally assigned to the right and left hand circles respectively, however Eliot had moved to record these representations by beginning to write the category names.

6.4.3 Section Summary

The findings from Baxter Brown and Michael Recycle revealed the children's competence in representing data, evidenced in the choices they made about data organisation, display and representation. The children's decision about categories for the data, and how data were classified into categories influenced how the data were organised. Decisions about the display of data were initiated by one group member with tacit group approval. The dominant form of representation was pictographs that were visually consistent across groups and modeling activities, with one group using a Venn diagram. Categories represented in the model were recorded as labels.

6.5 Discussion: Organising, Displaying and Representing Data

6.5.1 Introduction

In this section, the findings presented in 6.4 are discussed. The children's models reveal the "repertoires of representations "(Lehrer & Schauble, 2007a, p. 32) they drew from to represent data as pictograms and a Venn diagram. The models recorded the organisation structure and display decisions imposed by the children on the data. The reasoning and knowledge used by the children as they organised, displayed and represented data across the two modeling activities, and the role of the task context in data representation decisions, are now discussed. Implications for future research and practice are signposted through the discussion.

6.5.2 Data Representation And Category And Classification Decisions

The study findings show that data representation was the product of categorisation and classification processes engaged by the children, and process decisions made as models were developed, supporting Lehrer and Schauble's (2007a) view that in data modeling, "structuring and displaying data are intimately related" (p. 157). The children's development of attributes for categories and classification decisions about category membership organised the data, which in turn impacted data representation. Decisions made about generating, selecting and measuring attributes were ultimately decisions about data representation. Classification decisions made by the children created grouped data (category and category members) that needed to be physically organised and displayed. This finding supports other data handling studies with young children, where mental

actions of grouping and ordering data are visually represented, for example, using bar graphs (Nisbet et al., 2003). Data were organised and then displayed, that is, it was represented as models by the children, consistent with the notion that in modeling, the structure of data is constructed and imposed for a purpose (Lehrer & Kim, 2009).

6.5.3 Data Representation and Engaging Variation

The representational structure in the models the children developed, represented variation found in the data. The structure the children imposed on the data was bound by attribute variation between the categories they determined which in turn impacted on classifying objects when those attributes were used as a measure. This finding support Lehrer et al.'s (2007) research with fifth and sixth graders, which examined students' invented representations using a data modeling activity designed to focus their attention on the role of variation on the spread and shape of data. Although the age of the students and the design aim of Lehrer et al.'s study differed from this study, their findings highlight the importance of the modeling of statistical measure and the role of visual representation as a tool to facilitate data display. The models developed by the children in both Baxter Brown and Michael Recycle in this study reflect variation resulting from measure. Logically, classification was impacted by the existing variability between objects as well as variation that arose from measuring them. Once the objects were grouped and ordered, the categories and classified object pictures determined the structure to be displayed.

6.5.4 Transforming Data Through Representation

In this study, children made decisions about measurement that clearly showed categories and members of those categories in the way the data was represented. The children used the knowledge they had to make decisions and act to make sense of the data. This suggests that although data representation can be difficult for students, the children have done 'something' to the data to produce a representation (Chick, 2003). Chick (2004) notes that all representations that are produced "are intended to present data in such a way that the reader is convinced about the message within" (p. 1). Transforming data in this way suggests a type of thinking described as

"transnumeration" by Wild and Pfannkuch (1999). Transnumeration underpins Chick's (2003) proposed framework of techniques that can be applied to data to "find and display the message within" (p. 168), techniques that include grouping and sorting. The findings suggest the children transformed the raw data using grouping and sorting and the models they developed captured the representation. The finding also supports research that ordering data is a necessary requirement to being able to display it (Jones et al., 2000; Jones et al., 2001; Nisbet et al., 2003).

6.5.5 Representing Abstract Conceptions Of Data

This study found that the children's models did not represent perceptual attributes. This finding contrasts with research that young children tend to realism in representational displays and bend representational rules to accommodate realistic attributes (diSessa, 2004) and do so based on their understanding of the objects they are representing (Danish & Enyedy, 2006). As a result, young children's initial representational models that use objects, frequently show realism or focus on particular attributes to the exclusion of others (Lehrer & Schauble, 2000a). Lehrer and Schauble's study found that Grade 1 and Grade 2 children used idiosyncratic perceptions rather than attributes to categorise and differentiate objects to develop and justify their models. diSessa and Sherrin (2000) however, found that children who do *not* use realism, produced conceptual representations. What distinguishes this study from Lehrer and Schauble's work is that the categories the children worked with in the data modeling activities in this study (reuse, recycle and throw away) referred to events or actions. Potential category attributes were not visible or perceivable from the object stimuli provided, prompting the children to look beyond the perceptual features of the objects in order to generate and select attributes for specific categories, as discussed in section 6.3 (p. 167).

The categories the children determined were represented symbolically in both modeling activities, as category pictures with symbols and words in Baxter Brown, and by words recorded by the children in Michael Recycle. Symbolising objects by recording words is an abstract conceptualisation of the objects and removes any attention to realistic attributes the object may have. This was also evident when the children drew pictures of objects for sorting in Michael Recycle, where there was minimal reliance on drawing recognisable objects and the focus was on labelling the

data pictures. The children's drawn data may also indicate that they were moving towards a more abstract view of the data, by eliminating features they considered unnecessary and focus on "systematic representational rules" (diSessa, 2004, p. 322) such as the attributes they had determined for the categories. This finding also suggests that the children were beginning the process of objectifying the data, by basing their representations on the properties they found worth noticing, altering the data to facilitate its handling (Lehrer & Schauble, 2002). This abstract development is supported by the model development, as the children organised the picture data based on potential for physical change or return, or on prior observed behaviour with the objects, not on obvious physical properties. The findings reveal that task contexts that engage categories where the category attributes that are not perceptually obvious may support more conceptual representations of data.

6.5.6 Data Representation and Representational Competence

All models created for the Baxter Brown and Michael Recycle data modeling problems are found in Chapter 4 and reveal sophisticated representations, revealing the children's meta-representational competency. The models share representational features such as vertical picture graphing with models produced for similar data modeling tasks by 6 year old children with prior experiences in working with data at school (English, 2011). The findings of sophistication in the children's representations mirror diSessa and Sherin's (2000) comments on their own study findings, in that they "dramatically underestimated how much students know about representations and how much of this appears to exist before and independent of instruction" (p. 387). Watson and Neal (2012) note that some graph types suggested in the *Australian Curriculum: Mathematics* (ACARA, 2013) "appear to underestimate the ability of students to handle the task" (p. 92). The findings from this study indicate that children are capable of more advanced representations than the simple displays suggested in the Statistics and Probability strand content description for Foundation Year students in the curriculum.

The models constructed by the children reveal a native capacity or meta-representational competence (diSessa et al., 1991). Seven of the eight models developed (all four groups in Baxter Brown, and three of the four groups in Michael Recycle) constructed a pictograph. Only one model employed a two circle Venn

diagram. This finding suggests that the children's classroom work with Venn diagrams in a sorting lesson prior to the commencement of the study was not as compelling in guiding their representations as the knowledge they had gleaned from out-of-school experiences. What is surprising is that without formal instruction in the classroom, the children uniformly produced standard forms of graphical representation. Rather than creating non-standard displays, the models the children produced independently and after only five weeks of formal schooling, can be considered to be "reinvented" representations, (Friel, Curcio, & Bright, 2001). The children's representations support diSessa's (2004) findings that "students who have not been specifically instructed in representations such as graphs, can come remarkably close to inventing them, given time and support" (p. 299). The children in this study had no prior modeling experience or formal data handling learning experiences, and worked without adult support during their model development. Accordingly, the findings suggest that the children brought intuitive or meta-representational knowledge to the data display and representation in response to the data handling problem.

The specific origin of the children's knowledge of graphical displays is unknown. diSessa and Sherin's (2000) work has led them to believe that meta-representational competence develops from experiences such as drawing, where representations are produced and used. Intuitive or meta-representational competence is also thought to develop from out-of-school practices (diSessa, 2004) or everyday experiences prior to specific formal instruction (Leinhardt, Zaslavsky, & Stein, 1990). Children currently have access to a wide range of print and electronic media, including home based education and game software, where information may be organised in varying displays. Friel et al. (2001) noted that graphs are widespread in the media, and so it is not unreasonable to assume that the children would have had exposure to graphs through a range of media sources. If this is so, the children in this study have taken this visual information and used it as a means of communicating their sense making in the context of the modeling tasks.

Successful representation depends on both knowing what representational forms are available and useful, and transforming data using these (Chick, 2003) although children may not necessarily engage their intuitive ideas with a given task

or situation (diSessa and Sherin, 2000). Two aspects arise from Chick and diSessa's findings with respect to the findings in this study. The first is that intuitive ideas existed, were available to the children, and the ideas were engaged with as models were developed. The second is that the children were able to use prior knowledge to transform the data and communicate the category and classification structure that was imposed. What is remarkable is the whole class consistency in the children's knowledge and its application to the task. It is difficult to speculate how intuitive ideas about graphical display have developed for the children in this study. It is clear however, that because these children were in their sixth week of school, the knowledge has come from their out-of school experiences which would include their prior attendance at pre-school and that the experiences are persuasive.

There is remarkable visual consistency in the data representation found in the models that were developed in the Baxter Brown and Michael Recycle modeling activities. Young children have a variety of symbolic capacities from their prior to school experiences that can be used to communicate information, including drawings, graphs and diagrams as inscriptions (Lehrer & Schauble, 2006, 2007a). It was anticipated in this study that the children's age and limited formal school experience would result in the use of a range of drawings and diagrams for representation. The models however, show clearly identifiable data classification representations (Venn diagram) or graphical representations (pictographs). These representations developed by the children are effective representations of qualitative, categorical data and represent "what we see" (Lehrer & Schauble, 2002, p. 14). The children's focus on categorical representations is consistent with the conceptual emphasis built into the design of the task context for each modeling activity. There is a uniform finding however, that in handling data categorically, the children did not focus on quantitative treatment of the data to develop their models.

The majority of models the children developed used pictographs. There are limited studies of children's data representations in the absence of formal instruction, however the findings of this study contrast with the representations of kindergarten children described by Friel et al. (2001). The children in that study invented visual displays for survey data they collected. Their representations were characterised by the use of repeated written responses, numerals to quantify data items or data item

totals and tally marks. The findings in Friel et al. (2001) contrast with the models developed by the children in this study. Although the *variety* of representational strategies or approaches used by the children in this study were limited, the data were systematically organised to show all the relevant information in a way that enabled it to be accurately read with an overall good use of space, characteristics usually found in representations from older children (diSessa, 2004; Watson & Moritz, 2001). This latter characteristic in particular was important to the children in Group 2 in Michael Recycle Task 3. Considerable efforts were made to provide circles that would accommodate the data pictures, indicating that the children had judged the suitability of the display for the task (diSessa, 2004).

6.5.7 Data Representation and Task Context

The opportunity for collaboration between group members may have supported the construction of the representations due to the need to solve the problem and develop the model as a group (Terwel, et al., 2009). Interaction and negotiation with peers is a resource available to young children as they develop representations (Danish & Enyedy, 2006). Limited discussion between the children as the model was being developed was found in Baxter Brown Task 3, however, data representation was accompanied by hand gestures to position the category pictures or assign category places. The use of gesture during the development of the model was prominent during the development of the Venn diagram In Michael Recycle Task 3. Gesture created reference points and constructed shared meaning between the children (Danish & Enyedy, 2006). Hand movements can depict spatial ideas with recording them, and so may have focused attention how spatial information was transformed for representation (Ehrlich, Levine, & Goldin-Meadow, 2006). The relationship between the processes children employ to negotiate representational tasks and the use of gesture in children's representations is an area for further research. Additional discussion on the role of gesture in reasoning is found in section 7.7.2 (p. 220).

This study found that the children were readily able to both sort, order and represent categorical data. This contrasts with the findings from Jones et al., (2000), Jones et al., (2001) and Nisbet et al., (2003) that Grade 1 students had difficulties finding relevant order in the data, particularly categorical data, constructed

idiosyncratic or invalid data displays and had limited access to sorting and organising schema for representation. The contrast between the findings of these studies and the present study may be attributable to the task demands. Categorical data is generally established as less difficult for primary age children to organise than numerical data (Nisbet et al., 2003; Nisbet, 2008). Unlike Nisbet et al.'s 2003 study, the modeling tasks in this study did not ask the children to deal with numerical data, or to reduce data. Further, the modeling tasks were contextualised using picture story books that were relevant and used a familiar genre (Choi & Hannafin, 1997). The children had a familiar context as they worked in stable groups across the modeling activities to develop their model. In addition, the iteration of two modeling activities (Baxter Brown and Michael Recycle) developed the children's modeling with categorisation and classification, a finding that is consistent with progressive refinement of children's conceptions of data that characterises repeated exposure to data modeling (Lehrer & Romberg, 1996). The combination of these factors may have reduced the task complexity and cognitive load for the children and facilitated model development. The progression of modeling experiences with modeling activities that were expressly designed to focus on data handling using attributes and representation, may account for the relative ease the children demonstrated in sorting and constructing data representation, evidenced by the children's robust data sorting and representation.

The findings indicate that physically manipulating picture data supported constructing representations. This is consistent with Jones et al. (2001), who found that children were supported in their ability to develop representations by using technology which had flexible features. The modeling tasks provided opportunities for the children to manipulate picture data, establish and if necessary re-establish, display positions for the category columns for the pictographs. The establishment and reestablishment of category display for the Venn diagram in Michael Recycle was not as easily accomplished as the representative circles were drawn, but was achieved nonetheless with a flexible approach in the classroom to the children's access to resources. Although there were task differences between the modeling activities as to how much discussion accompanied constructing the category representations, uncertainty about the category position between group members was

resolved by writing the category names. This finding supports diSessa's (2004) view that young children use written language as part of their representations.

6.5.8 Section Summary

The children's development of attributes for categories and classifying data organised the data in both modeling activities transformed the data and impacted how the data were represented, the structure that was imposed on it and what was represented, including variation found in in the data. The children's models represented clearly identifiable data classifications in the form of pictographs and a Venn diagram that revealed meta-representational competence. The findings are that prior intuitive ideas about graphical display existed and were used to develop models. The representations were sophisticated, consistent across the groups and shared representational features that communicated the structure imposed on the data.

Task provision of categories that were events or actions supported the children to look beyond perceptual features. The children constructed attributes that were not perceivable from the objects that were provided for classification, and this may have supported moving the children towards a more abstract view of the data. The opportunity for group collaboration, use of gesture in instruction and data that could be physically manipulated are task characteristics that supported the development of representational models.

6.6 Chapter Summary

The findings in this chapter are from the children's model development and task solutions in the two modeling activities, *Baxter Brown* and *Michael Recycle*. Each modeling activity engaged the design system of data modeling where the nature of variables and their measurement are identified, however each had differing foci. Baxter Brown focused on generating, selecting and measuring attributes and Michael Recycle organising, displaying and representing data. The children's use of knowledge and reasoning revealed their engagement with the *data context*, and the influence of the *task context* as they found solutions to the modeling tasks and data modeling problems.

The findings underscore the integrated and underplayed relationship between knowledge and reasoning in statistical learning for young children, and how knowledge contributes to reasoning. The research questions addressed by the findings are Question 1: What knowledge and reasoning skills do young children bring to statistical problem solving as data modeling activities? and Question 2: What characterises task contexts in data modeling activities that engage young children in statistical reasoning?

The study found that children used both inductive and deductive reasoning to reason about attributes for categories. Inductive reasoning was found as the children generated and selected attributes, relying on induction to use specific knowledge they held from past experiences to reason to generalisations. Deductive reasoning was found as the children used attributes to classify objects into categories. The use of inductive reasoning is a core characteristic of statistics defined in this study, and the study revealed the children's engagement with this discipline specific reasoning. The finding confirms research that inductive reasoning is available from a young age and adds to the literature by considering the role of inductive reasoning in young children working with attributes in creating data in statistical problems.

The role of inductive reasoning in statistical problem solving is further highlighted with findings that suggest the children were aware of, and reasoned with variation when making decisions about attributes for categories, and classifying objects using those attributes as a measure. Inductive reasoning is employed in statistics to reason with uncertainty that results from variation in data. Variation is one of the "big ideas" in statistics as it is inherent in data, including the perceptual characteristics of the data, as objects and pictures of objects, which the children handled. The study findings support suggestions in research that an intuitive appreciation for variation develops early, a view that was further supported by findings on the reasoning used to impose structure on data, visible in the way the data was represented in the models. Attributes for the categories determined by the children were bound by variation between them, which in turn impacted on classifying objects into the categories.

The study found that children used a range of knowledge to generate, select and measure attributes for categories. Real world included actions by family

members to recycle particular objects, knowledge of recycling processes, such as melting something to change its form, and the consequences of recycling, such as objects being returned in some way but not in the objects original form. The findings support research that children learn from evidence of direct experiences and indirectly through information provided by other people. Knowledge of the picture story book, as data context was used when a connection was made between the data context and an object for classification, indicating the problem was contextualised by the story and children were mindful of it as they generated, selected and measured attributes. Use of data context knowledge occurred only with a picture story book the children were found to have interest in and where predicted solutions to the problem in the story had been made.

It was found that in the absence of perceptual stimuli from objects to support generating attributes for categories, the children did not rely on perceptual features to generate and select attributes but used more abstract features such as knowing or believing that particular processes could apply to some objects and not to others. The finding contrast with research in modeling that children's reliance on resemblance has been an important part of model-based reasoning and supports research that categories without perceptual stimuli can generate attributes that use unobservable facts. Further, in contrast with research that young children tend to realism in representational displays to accommodate realistic attributes, the children's models did not represent perceptual attributes and categories were represented symbolically with worded labels.

A range of intuitive knowledge was revealed as the children reasoned to make sense of the data, suggesting that intuitive statistically based procedures were used to engage inferential processes and draw on existing knowledge. The children's intuitive or meta-representational competency as prior knowledge was communicated in their models. Without prior formal instruction or modeling experience, the children developed systematic, categorical representations using standard graphical forms, as pictographs and a Venn diagram. The representations were consistent across all groups in both modeling activities. The finding adds to research by demonstrating that children's representational competency is significantly underestimated in research and curriculum expectations. The data

representation visible in the children's models further suggests that children's reasoning about grouping and sorting as a process of ordering the data was transformative. Data was readily represented in a way that conveyed the categorical data structure to others. The findings contrast with research that children have difficulty finding order in categorical data and produce idiosyncratic displays.

The study findings suggest that task context influenced children's reasoning. Participating in modeling activities required the children to decide what attributes were relevant and how best to measure them. The findings reveal that task contexts that engage categories where the category attributes that are not perceptually obvious, may support generating attributes that go beyond perceptual features. Further, the type of objects used in the task context and the task demands can impact on how children reason with attributes. In tasks where pictures of objects were provided for classification, or where category attributes were selected but not applied to objects, the children did not rely on perceptual knowledge of the objects. Conversely, in tasks where real objects were used for classification, including tasks where the children drew pictures from real objects, the children relied exclusively on knowledge drawn from direct observation of how family members dealt with the objects at home. In addition, findings indicate that explicitly linking the modeling problem to the needs of the main character in the picture story book may stimulate an active engagement with the data context in statistical problem solving. Connections between children's reasoning and the data context may be supported further by engaging aspects of the story directly in the modeling tasks, such as using real objects.

Finally, the task design for the modeling tasks in this study did not ask the children to deal with numerical data, or to reduce data, provided data that could be physically manipulated and provided a familiar context by employing picture story books to contextualise the problem and repeated modeling opportunities in stable small groups. These combined factors may have reduced the task complexity and cognitive load for the children and facilitated model development and therefore statistical reasoning.

In summary, the findings from this chapter were that young children have existing capacity and potential to reason inductively when engaged with statistical

problem solving. The children engaged a wide range of real-world, data context and intuitive knowledge to interpret experiences and extend known information, such as category concepts, to unknown situations using inductive reasoning and to develop representational models. Some task context characteristics supported the way the knowledge and reasoning was facilitated.

Chapter 7 DISCUSSION AND FINDINGS: Children's Reasoning about Prediction and Inference

7.1 Introduction

In this chapter, the findings that emerged from the theoretical and thematic analysis of two modeling activities, *Litterbug Doug* and *Charlie and Lola*, are presented and then discussed. Both activities required the children to read, interpret and extend data found in tables in order to make predictions in Litterbug Doug, and form inferences to find a solution to a problem posed as a question in Charlie and Lola.

The principal theoretical and methodological vehicle examining statistical reasoning in this study was the Models and Modeling framework (Lesh & Doerr, 2003), specifically data modeling. Data modeling comprises two related systems of activity, design and analysis. The second, *analysis,* is where inference interacts and co-ordinates with data representations to find a logical solution to the problem (Lehrer & Schauble, 2007a). The two modeling activities addressed in this chapter focused on the components of the analysis system of activity found in data modeling. Findings from themes that arose from analysis are therefore situated under headings of components found in the analysis system of data modeling (Lehrer & Schauble, 2003; Lehrer et al., 2007).

The chapter is in two parts. First, findings for the children's interactions with data representations are presented. Second, the findings as data analysis by the children during modeling tasks are discussed.

7.2 Findings: Interactions with Data Representations

Two modeling activities, Litterbug Doug and Charlie and Lola, were implemented consecutively in week 8 of data collection. Brief descriptions of the component activities that comprised Litterbug Doug and Charlie and Lola, and the data analysed for this chapter are found in Figure 7.1.

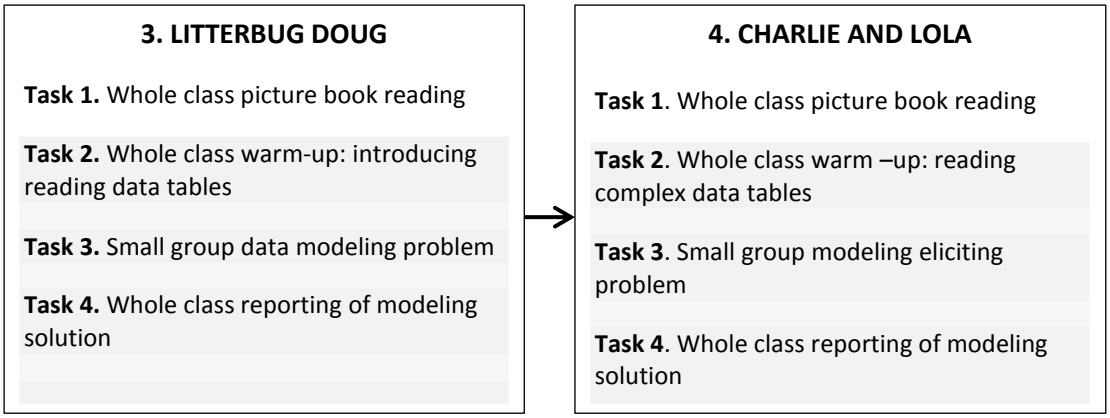


Figure 7.1 Highlighted description of tasks drawn on for analysis in Chapter 7.

7.3 Responding to Data of Interest

In this section, the children's responses when introducing the data table used in the Litterbug Doug modeling activity are described. The children responded spontaneously and to questions from the teacher during the task.

7.3.1 Zero as a Data Value

During Litterbug Doug Task 2, several children spontaneously observed and explained the presence of a zero value in the data table (Figure 4.15, p. 118). The children connected knowledge gleaned from the picture story book *Litterbug Doug* (Bethel, 2009) to their observations. Carl noted that the zero in the cheese row of the data table, and commented, "he maybe didn't like mouldy old cheese". Next, Gina paused after reading the values across the cheese row and said quizzically, "um I don't know why um Litterbug Doug didn't collect any cheese". The teacher indicated the zero value in the Wednesday column of the cheese row with his hand and asked, "on this day?", and Gina nodded and agreed. Carl and Gina's comments indicate that both children had read the zero in the data table and speculated about a connection between it and the actions of the picture story book character Litterbug Doug.

7.3.2 The Absence of Data Values

The blank Thursday column in the data table stimulated spontaneous speculation by some children to explain the absent values in Litterbug Doug Task 2. The explanations connected the empty column to the picture story book. Four examples illustrate the children's reasoning about the absence of values. Toby was

the first to query why the Thursday column might be blank and he stepped up to the electronic white board where the data table was displayed and ran his hand up and down the Thursday column, stating, "this has nothing on it". Toby then touched the zero in the cheese row and explained further:

Toby:	That one probably is from all of them because he doesn't like anything on this day (runs his finger up and down the Thursday column), maybe it goes with the zero (touches the zero in the cheese column)
Teacher:	So you think that day's blank because he didn't collect anything and you think it goes with the zero?
Toby:	(Nods) Maybe he could probably goes with the zero

Toby's gestured explanation connected the Thursday column to the zero in the Wednesday column of the cheese row. His reasoning suggests that as a consequence of Litterbug Doug not liking, and therefore not collecting any cheese on Wednesday, nothing was collected on Thursday. Toby's reasoning indicates that he had drawn on the story character's personal preferences to explain the data in the table, reasoning that Litterbug Doug collects rubbish based on whether he likes something or not. Toby's explanation was similar to Gina and Carl's in that it illustrated that he had read the data table and worked to connect what he had observed to his knowledge of the picture story book.

Second, Isabel's explanation of the blank column was directly connected to the picture story book. She moved to the board and gestured along each row, and up and down the Thursday column, as she carefully explained what she saw:

> Um, I noticed that um, he probably, I um, think he didn't collect any mouldy cheese that day, actually, I think he didn't collect any apple cores this day, or tin cans this day, or any newspapers this day or banana skins this day or smelly old old mouldy cheese this day um, that's because um this is the day when Michael Recycle showed, um, um Litterbug Doug help.

The teacher queried Isabel, asking, "So you think this is the day that Michael Recycle helped him?" to which Isabel responded, "Yes, to throw away all his garbage". Isabel systematically acknowledged that the blank Thursday column applied to all of the objects in the data table through gesture, by moving her hand along the row for each object, naming them and moving her hand up the blank Thursday column at the end of each row. Her explanation drew directly from the plot

in the picture story book when Michael Recycle arrived and taught Litterbug Doug to recycle and clean up.

Third, Jade's explanation for the blank column explicitly linked the data table to the picture story book. Jade stood up, and moving to the board, ran her hand along each row of the table as she read each value for Monday, Tuesday and Wednesday's column along each row. She then touched each blank cell in the Thursday column with her hand and said:

> And there's nothing there, nothing there, nothing there, and nothing there because he didn't really collect anything on Thursday because he didn't wanna do that because he had his mound um of rubbish (crouches down) go bigger, bigger bigger, bigger, bigger, bigger, bigger, bigger, bigger, *bigger* (slowly rises and uses her hand to show the increased size) and that's why he didn't collect anything on this day, 'cause there wasn't any more things that, there wasn't any more apple cores, and tin cans and newspapers and banana skins and cheese (touches each picture on the data table) and the um, and because on that day, the old, this was all gone and this was all gone, this was gone, this was all gone and this was all gone (touches each empty cell in the Thursday column) and that's why there was none on Thursday.

Jade explained that Litterbug Doug had collected all the rubbish that was available to collect and had used it all to make his enormous rubbish pile. As a result, there was nothing left to collect on Thursday. Jade's detailed verbal and gestured depiction of the mound of rubbish can be linked to the rubbish mound that was described and illustrated in the story.

Finally, Carl explained the changes he observed in the data values, and why he thought Thursday's column was blank. Gesturing with his hand across the rows in the data table, he said:

> Ah, Monday he could only find 2 apple cores, on Tuesday he could only find 5 apple cores and on Wednesday he could only find 4 apple cores, on Monday he could only find 4 cans and on Tuesday he could find 3 and only 2 here mm and on this day (indicates Thursday column) Thursday, Michael Recycle come on that Thursday then, then every person helped to get rid of all the rubbish and recycle it.

Carl provided two different explanations for two different observations he made about the data table. The first was that the changes in data values in the table were the result of the number of objects available for collection on any given day by "he", that is, by Litterbug Doug. The second explanation reasoned that the blank Thursday

was the direct result of events in the picture story book plot. Similar to Isabel's explanation, Carl reasoned that Thursday was the day when other characters in the picture story book helped Litterbug Doug to clean up. Both of Carl's explanations drew on his knowledge of the picture story book to explain what he had observed in the data table.

7.3.3 Section Summary

Observations that the children made about the data table that they considered anomalies were articulated, such as the blank Thursday column and the presence of zero. The children's explanations for the observed anomalies directly connected to knowledge from the picture story book.

7.4 Children's Reasoning with Data Context

In this section, findings of the children's use of picture story book knowledge when reasoning to develop their models are presented. The picture story book in each modeling activity, Litterbug Doug (Bethel, 2009) and Charlie and Lola (Child, 2009), provided the data context for the modeling problems. In Litterbug Doug, the children developed models for a prediction data modeling problem. In Charlie and Lola, the children used data to find a solution to a problem posed as a question in a model eliciting problem.

7.4.1 Picture Story Book Knowledge Explanations When Predicting

Some children explained the predicted values in their models using knowledge drawn from the picture story book, when an explanation was requested by the teacher or researcher as to how they reached their conclusions. During Litterbug Doug Task 3, as the children developed their models, there were instances where the teacher or researcher asked children to explain the predicted values they had recorded. Some explanations were based on the children's knowledge or perceptions of main character's preferences or actions. When asked to explain predicted values in the Thursday column for their models, Bryce in Group 4 explained, "because, because they ate apple cores". There were several examples from Group 2 (Jade, Sam and Eliot). Sam explained "because, um, because um, he um, he like-ed the tin cans so he collected from that day", and Eliot stated, "Er because he um likes to know what to do, so he just collects them". When asked about why he might have

collected five newspapers, Jade explained, "Yep because um because he because I think he needed five of those". The picture story book *Litterbug Doug* (Bethel, 2009) illustrated apple cores, cans and newspapers in the piles of rubbish Litterbug Doug collected, and the character Litterbug Doug wore an apple core around his neck. These examples highlight that information the children gleaned from the picture story book influenced the knowledge the children drew from to explain their predictions, and the characters *likes* and *needs* justified those predicted values.

Other explanations for predicted value offered by the children centred on the availability of items for the character to collect. Gina (Group 3) said, "because um, um, Litterbug Doug just found them", Isabel (Group 1) stated, "that's because I'm thinking he collected them all in the dump", and Sam suggested that Litterbug Doug only collected two cheeses, "because um he couldn't find any more". Eliot suggested that Litterbug Doug only collected four apple cores because:

> 'cause um, he he because, 'cause he didn't have, 'cause he didn't have that many in the ah thing, 'cause he um like there might be more at his dump, 'cause um, 'cause um er, er its popoolar and he likes, he might like four.

Sam and Eliot's explanations suggested that access to an object explains predicting its availability. However Eliot's more detailed description appeared to link Litterbug Doug's collection on Thursday to the character's rubbish pile that featured in the picture story book. Eliot's explanation implies that he considered Litterbug Doug as he was described in the picture story book *before* he became the Litter Police and helped clean up the town. However, the data modeling problem the children were working to solve was contextualised with Litterbug Doug in his role at the end of the story, as the Litter Police. Eliot's response indicates that he did not distinguish between Litterbug Doug's two contrasting roles in the story and was not mindful of the extension of the plot in the picture story book presented for the data modeling problem scenario when explaining his prediction.

7.4.2 Picture Story Book Knowledge Explanations When Analysing

Two children made recognisable references to the picture story book when asked by the teacher to explain their answers to the task question "Who the best recycler was and why?" in Charlie and Lola Task 3. Eliot said "I think er, Lola's um Charlie's sister was the best recycler 'cause um she was helping Charlie and I think

that um er er Lotta, Lotta and Charlie were the best recycler, because they were good". Eliot's comments refer to the picture story book plot where the characters help each other to reach the target number of recyclable items needed to win a tree for the school. Eliot's response focused on the goodness of the character as the determining attribute of "best" to answer the question. The personal quality of one of the characters was also considered by Sam, who said:

> I think um I think Marty is the best recycler, Marty is the best recycler because um, because um, he um he didn't wanted to give up, and, and um he helps everyone in the class to collect the leaves, collect the leaves all up to the top.

Sam's account clearly connects to the plot in the picture story book where the class collected enough recyclable objects to fill a poster with paper leaves and win a tree. Sam refers to actions undertaken by the character Moreton in the picture story book and he may have confused the names as there were three characters whose names begin with 'M'. Alternatively, Sam may have interpreted the use of the objects from the character Marty's room to help win the recycling competition as honourable, as Marty did not want to relinquish anything from his room. On either interpretation, Sam has considered the helpfulness of the character as the determining attribute for the best recycler in order to answer the question.

7.4.3 Real World Knowledge Explanations When Analysing

The children drew on real world knowledge from out-of-school experiences when they answered the first task question in Charlie and Lola Task 3; "Do you agree all the objects can be recycled?" The children were asked to consider the different objects presented in the data table (plastic bottles, glass jars, broken plates, food scraps, old books) and determine if each object shared attributes for the category recycle. Time constraints limited this activity to five minutes, and therefore reduced the opportunity for the children to interact in their groups. Despite this, the children canvassed all five objects categorised in the data table and were able to articulate an answer.

The first task question posed to the children in Charlie and Lola Activity 3 did not ask *why* the children might agree that the objects were recyclable. It asked for agreement or not, inviting a yes/no response. There was consistency agreement across the four groups of children that the food scraps were not recyclable. Many of

the responses in Group 2 and Group 3 reflected the form of the question and explanations were not provided. For example, in Group 2 (Jade, Eliot and Sam), Jade pointed to the picture of the food scraps and said, “no we can’t do that recycled”. Sam responded “maybe throw away” and Jade and Eliot immediately agreed, each saying, “yeah throw away!” In Group 3 (Blake, Gina and Lee), Blake pointed to the broken plate picture and stated, “old plates” to which Gina responded, “throw away” and Lee agreed, saying “yeah”. These examples demonstrate that the children reached a consensus without proposed decisions being justified by group members.

Explanations that accompanied the answers provided by the children to the first task question relied on real world knowledge. Carl (Group 1) explained:

> And I think the glass things get recycled because its glass, and the books don’t go in recycle …and also I think those three (places a finger on each of the food scraps, broken plates and book pictures in the data table) don’t go in recycle, those two and the books? I don’t think so! They have staples in them (mimes stapling action with his hands).

Carl did not justify why glass was an attribute for recycling or why broken plates and food scraps would be excluded, however he explained that staples in books would preclude recycling them, suggesting knowledge of the paper recycling process. Isabel stated that plastic bottles were recyclable, because, “these plastic bottles, I thought they could be melted with the melting gun”. Isabel’s statement draws on her out-of-school knowledge and that she believes an object is recyclable if its form can be changed. Blake (Group 3) challenged Gina’s suggestion that food scraps would not be recyclable and stated “I don’t agree, I think, I think that that (points to the picture of the food scraps) would be recycled because um, worms like to eat um. That’s how it’s recycled”. Blake’s response relied on his knowledge and belief that food scraps eaten by worms is a form of recycling.

7.4.4 No Explanation for Prediction

Some children did not provide an explanation for a predicted value when asked by the teacher or researcher to explain why a predicted value had been selected. During Litterbug Doug Task 3, Group 3 (Ted, Gina and Blake) were asked by the teacher why there would have been five newspapers to collect. Ted stated, “because he did” and Gina said, “I know, I know, I know! (pause) I don’t know”. These two responses illustrate that articulating a reason for a predicted value in the

Thursday column did not come readily. Members of Group 1 (Toby, Carl and Isabel) were unable to provide explanations when asked by the researcher why a certain number of objects might have been collected on the Thursday. Isabel was asked why Litterbug Doug might collect eight cheeses, and she suggested, "because, um, because he might have found it in the dump in the city". Isabel was the only group member who offered an explanation, and her explanation appeared to draw on knowledge from the picture story book. In comparison, Toby and Carl deflected the question in a number of ways, writing their names and numerals on the bottom of the data table and whistling. Toby responded with a puzzled expression and said, "I don't know, I think, I thought the zero there as well". The interaction with the researcher ended as the children were unwilling to engage any further or offer reasons why objects might have been collected on Thursday. This was apparent when simultaneously, all three children disengaged. Isabel gazed across the room, Carl sat back in his chair with his arms behind his head and Toby looked closely at the table with his head down. Later, in Litterbug Doug Task 4, Carl articulated that the prediction task was difficult, and stated "ah it was hard to choose, so I just put four there". These non-verbal responses by the children indicate that they were unwilling to provide an explanation, with Carl's comment further indicating that the task may have been perceived as one for choosing values that did not involve or require an explanation for the choices made.

7.4.5 Interest in Picture Story Book Knowledge and the Modeling Problem

This study found that some children did not accept the data modeling problem context when it did not align with the picture story book, and this may have impacted the knowledge they drew from as they developed their prediction models. This was apparent from the children's widespread disregard for Litterbug Doug's altered role as the Litter Police found in the whole class discussion in Litterbug Doug Task 4. During the discussion, it emerged that many of the children did not accept Litterbug Doug's character as the clean Litterbug Doug who became the Litter Police on the last page of the book. The children were asked by the teacher whether the townspeople would have been happy with the rubbish that Litterbug Doug collected on Monday, Tuesday and Wednesday. The values in the data table for these days represented rubbish collected by Litterbug Doug in his role as the Litter Police as he

cleaned up the town. The majority of children put their hands up to indicate that the townspeople would *not* be happy and they offered varied reasons as to why. Carl said, “everyone didn’t like his rubbish and also because he didn’t pick up his rubbish and they didn’t like rubbish”. Sam suggested that, “because it was too much rubbish and it was stinky”, an idea supported by Isabel, who said “I agree”. Ted suggested that, “he thinks rubbish smells good but all the other people doesn’t”. Eliot stated, “he er, he likes um rubbish”. Eliot elaborated on his explanation, differentiating it from Sam’s response, and said:

> Um, well I agree with Sam but different. I think they didn’t like it but um, um they but he cleaned up the town after he um like messed it up ‘cause M, Michael Recycle helped him and learned him to help and um he and he just er and that’s why um people would be his friend.

The teacher restated Eliot’s idea, and said, “so you think they were not happy to begin with but were a bit happy because he was starting to clean up with Michael Recycle”, to which Eliot responded “yep”. Eliot’s statement indicated that he was able to recognise that his idea had common elements to Sam’s and that the townspeople were unhappy with Litterbug Doug. Isabel stated that she agreed with Sam, and qualified her understanding, saying, “I agree with Sam that they didn’t like it because it was stinky”. Mia also stated that she agreed with Sam, that the townspeople would not be happy, as did Gina, who said, “I agree with Sam, Isabel, and Mia!” When asked by the teacher that she agreed to the idea that they would not be happy, Gina nodded. These collective statements and explanations strongly suggest that in solving the data modeling problem in Litterbug Doug Task 3, the children may not have considered Litterbug Doug in his transformed role as the Litter Police and there would have been a disconnection between the information provided in the picture story book and the context of the data modeling problem.

7.4.6 Section Summary

Some children drew on knowledge from the picture story book when requested by the teacher or researcher to provide explanations for decisions when analysing data tables and developing prediction models. Explanations were drawn from the perceived needs, actions or personal attributes of the main character in the picture story book which contextualised the modeling activities. Explanations were not always provided by children for their prediction models, even when specifically

requested by the teacher or researcher. When working independently, some children drew from real world knowledge to answer questions for data table analysis that did not ask for or require an explanation. Finally, the children drew from their knowledge of the picture story books when developing their prediction models and answering data based questions. The children drew from knowledge of the books, even when the scenarios contextualising the data modeling problems had been extended beyond the information found in the books.

7.5 Children's Reasoning with Data

In this section, findings of the children's use of knowledge from data tables when reasoning to develop their models are presented. The task context for each modeling activity provided the children with data tables to develop their models (Litterbug Doug: Figure 4.15, p. 118; Charlie and Lola, Figure 4.28, p. 128). The children developed models for a prediction data modeling problem in Litterbug Doug. In Charlie and Lola, the children used data to find a solution to a problem posed as a question in a model eliciting problem.

7.5.1 Observing Range and Frequency

The children observed the range and frequency of data values provided in the data table (Figure 4.15, p. 118) in Litterbug Doug Task 2. The teacher asked the class what they noticed about the data table and a number of children noticed the range of values. Blake commented that, "the numbers only go up to six", demonstrating that he had found the maximum value in the table. Gina stated that, "Umm, the newspaper has 6 newspaper and and 3 newspapers and 2 newspapers". She traced a row in the air, moving from left to right and said, "also the zero and the three and the two on the mouldy cheese". These comments reveal that she had observed changes in the values across the newspaper row and cheese row, reading the latter from right to left. She followed up her observations of the data values, saying; "and the cheese and the banana peel, it's 1, 2 and then it goes up to 3 and then 4, and then it goes up to 5 and then up to 6 and there's no 7". Gina pointed her finger and moved her hand as she spoke each number, tracking the number sequence 1, 2, 3, 4, 5 and 6 and noting that six was the maximum value, as "there's no 7". Her description indicated that she

had also observed changes across different rows and had selected consecutive numbers. In addition, Gina's gestures supported her observations.

7.5.2 Considering Range and Frequency When Predicting

The children were conscious of the range of data values provided in the table, found in their actions and discussion as they developed their models in Litterbug Doug Task 3. Most children in the class were observed to touch existing numbers with their fingers or pencils and to visually scan along rows at various times as they considered what numeral to write in the blank Thursday column. For example, in Group 1 (Toby, Isabel and Carl), Isabel carefully scanned across the "tin can" row as she said, "I think Litterbug Doug, um, I think tin cans, I think Litterbug Doug collected um, (scans back and forth along the row of numbers 4, 3, and 2) 5 tin cans". In Group 2 (Eliot, Sam and Jade), Eliot predicted how many apple cores were collected on Thursday, explaining as reasoned:

> Um, I think that, um, Litterdut Bug [sic] (scans the data table up and down)…Litterbug Doug collected zero apple cores on…no, um, um er, (scans along the apple core row) I think Litterbug Doug, ah, collects that many (points to the number 4 in the apple core row). Guys, what do you think? That Litterbug Doug collected 4 on that day?

These examples illustrate the children scanning and touching the values in the data table as a precursor to selecting a prediction value. Scanning and touching numbers in the data table indicated that the children were considering the range and frequency of the numbers already in the data table before making a predicted value decision. The children's final models (Figure 4.23, p. 124; Figure 4.24, p. 125; Figure 4.25, p. 125; Figure 4.26, p. 126) support this conclusion. With the exception of Group 2, who had two numeral 3s, none of the values predicted by the children in the Thursday *column* were repeated in the predicted value column.

There was some replication of predicted values found in a relevant *row*, suggesting that existing values were salient for prediction for that object. Group 1 (Figure 4.23, p. 124) repeated values in the apple core row and cheese rows, Group 2 (Figure 4.24, p. 125) showed recurring values in the apple core, tin can and cheese rows, Group 3 (Figure 4.25, p. 125) used recurrent values in the banana skin row and Group 4 (Figure 4.26, p. 126) restated values in the newspaper and banana skin row. However, the replicated numbers the children placed in the Thursday column were

not always a repeat of the last number in the object row they were considering and were taken from various positions across the row. The predicted values determined by the children suggest that the range and frequency of values in the data table, particularly the row for a particular object, were considered when prediction decisions were made. In addition, the predicted values in all four groups' models fell within zero and ten, indicating that the children's sense of "reasonable" for a value fell in this range, given the existing data values (between zero and six) provided in the table.

Predicted values were calculated and explained based on existing values already provided in the data table. During Litterbug Doug Task 3, the following exchange took place between the group members in Group 1 (Isabel, Toby and Carl), as they determined a predicted value the number of tin cans:

Isabel:	I think Litterbug Doug collected um, (scans the data table) five tin cans
Carl:	I think two (pauses, scans the data table), no I think five as well
Toby:	(scans the rows) I think six
Isabel:	(scans the data table) Actually, I think seven, because there's no seven.

The scanning actions and explanations demonstrated that the range of predicted values suggested by all three children took the range of available values in the table into account. In addition, Isabel articulated that her predicted value was not represented in the data table and suggested seven tin cans. The other two group members proposed predicted values that fell within the existing range of values in the data table and the following exchange took place:

Isabel:	Who agrees with me?
Carl:	(puts his hand up) Me!
Isabel:	Seven?
Carl:	I agree with five.
Toby:	I agree with six.
Isabel:	I agree with seven

Toby: Then you can do whatever number you want.

Although there was no consensus about what value should be selected, Toby's suggestion that Isabel make a choice for herself was accepted. This implies that the range of values each child had proposed were acceptable to the others, including a value that fell outside the existing range.

Similar consideration of the range and frequency of existing table values was found in Group 2 (Jade, Sam and Eliot). Jade stated her choice of a predicted value of five for apple cores, stating:

> Um, I think this day he done um I think this day he done is this one (taps the apple core row) um, and I think um um there is the number (scans the table) um five. Who agrees with me?

Jade explained her prediction of four tin cans, saying, "ah, because um I think he collected um, 4 tin cans on *that* day" (taps pencil on the Monday column of the tin can row). Jade's explanation suggested that if four tin cans or five apple cores had been collected on one day in the week, it was not unreasonable to suggest that this quantity could be collected again. Further insight into Jade's thinking about frequency and range was evident during Litterbug Doug Task 4, when the model solutions were reported. Jade was asked by the teacher why five newspapers were predicted. Jade replied, "because um, they was, because there was too many of the 2s and 3s and oh, the 6s and the 2s and the 3s, so I did a number". Her response demonstrates that she had taken into account both the frequency and range of numbers. She selected a number that did not repeat those she considered to be frequent that also fell within the range already available in the data table. Jade's explanation was comparable to Blake's explanation in Group 3 (Gina, Ted and Blake), when he was asked the same question by the teacher. Blake responded and said, "because um there was five of *those*" (points to the five in the apple core row). Blake's explanation further illustrates that the children considered the range and frequency of the existing data table values when proposing a predictive inference for rubbish that Litterbug Doug collected on Thursday.

7.5.3 Considering Outliers When Predicting

Awareness of outliers by some children was found. Outliers are values that differ markedly from other values in the data table and were proposed by two

children as predicted values. The first example occurred in Litterbug Doug Task 3, when Eliot (Group 2), was working out a predicted value for banana skins. He scanned the data table, saying, "I think that um er, Litterbug Doug got…." He sat back, smiled widely, and looked at the other members of the group, (Sam and Jade), and said loudly "100 on this day!" Eliot's verbal and non-verbal communication indicated that he was aware that what he was proposing was amusing or improbable. There was an immediate response from Sam, who threw his body back into his chair and exclaimed "daaahh!" and from Jade, who stared at Sam with her mouth open. Sam and Jade's responses indicated that they considered the number Eliot proposed as implausible. The following exchange then took place:

Eliot:	I think he collected…(scans back and forth across the data table)
Jade:	One hundred (looks at Eliot)
Eliot:	No (looks at the data table) this many (taps the number 3 in the can row), this number, three (writes a number three, looks closely at it, then writes another).

This exchange illustrates that Jade may have accepted the proposed one hundred as a reasonable prediction. Eliot however rejected her suggestion and chose a prediction value within the range found in the table. The second number three that was written may be the result of Eliot being dissatisfied with the form of the first numeral three he wrote.

The second example occurred in Group 3 (Gina, Blake, Ted) during Litterbug Doug Task 3. Gina wrote numerals into the Thursday column as she and the other group members proposed predicted values, as illustrated in this exchange:

Gina:	Ten in this one? (indicates cheese row)
Blake:	Yes!
Ted:	(points to newspaper column) 5 in that one
Blake:	Yes, 5 in that one, and 1, 1 (taps finger on the tin can row)
Gina:	One in that one?
Ted:	(nods) Yep.

This example demonstrates that predicted values were quickly proposed and accepted without challenge from group members. The data table was completed, when Gina said, "I know, we can do a *big* number". She laughed and wrote, covering the Thursday column with her hand. She altered the original numeral seven in the apple core row to 701, changed the numeral one in the can row to 150, and transformed the numeral two in the banana skin row to 201041. Gina exclaimed "we've got a big number now, the biggest on this page, the biggest number in this (gestures to the data table)". Gina's verbal and non-verbal communication suggested that she was aware that altering the recorded predicted values to "big numbers" was extraordinary to the prediction task and that the quantities she had recorded were well outside the range of the values provided in the data table. Blake did not comment on Gina's actions, however Ted looked puzzled and asked "why was there all that?" Gina responded by laughing. Ted's response suggests that he found the altered numbers unusual and sought an explanation for them, which Gina did not provide. Gina's response suggested that the improbability of the numbers did not require an explanation.

7.5.4 Considering the Range of Column Totals When Analysing

Some children took the range of column totals in the data table to determine who the best recycler was in Charlie and Lola Task 3. Examples were seen across three groups. In Group 3, as Gina was asking who the best recycler was, Lee ran his finger down the character Marv's column that had the lowest total, and said, "this one's not". Lee's comment indicates that he had excluded Marv from consideration because his column had the minimum value in the range of total items collected. In Group 1, Carl identified two characters as potentially the best recyclers based on their total collected objects value in the table. He pointed to the Lotta and Moreton characters and said "I think it's out of that one or that one ah because you have (taps the total value at the bottom of the column for Lotta and Moreton) 20 and 20". Carl's actions and statement indicate that he had identified two potential "best recycler" candidates on the basis that both characters had equivalent, maximum total collected objects values.

Similarly, some children located and named the total collected objects value in the table when working to find who the best recycler was. Although the total

values were identified, how or if the knowledge was used in their reasoning to determine the best recycler was unclear. An example was seen with Jade in Group 2. Jade placed her finger on the pictures of the characters Marty and Moreton, with column totals of 19 and 20 respectively, and said:

> I think um Marty and Moreton, Marty was the best one and and Marty got (reads the values down Marty's column) 4, 5, 2, 1, 7 and what's a one and a nine?...nineteen. And and Moreton got (runs finger down Moreton's column) Moreton got 7, 7, 4, 0, 2, 22. And that's it, *so those two won!*

Jade's account and actions indicated that she was aware that the values in the column for each character related to each character. However, when she considered each character, she did not appear to distinguish between the *individual* values provided in the data table for each type of object the character collected and the *total* objects collected value at the bottom of the table. Further, Jade did not appear to distinguish between the two total values for each character although the values for each character differed. There is nothing to indicate why Jade was adamant that the two characters were jointly successful as best recyclers. During the group reporting in Charlie and Lola Task 4, however, Jade qualified her responses, and stated that she thought Marty was the best recycler "because um because um he got 4, 5, 2, 1, 7 and he didn't get any zeros!" Jade's qualification indicated that at that point, she had selected the absence of any zeros in a character's column as the defining attribute for best recycler, and had determined Marty as the only character that met the criteria.

Additional but inconclusive evidence of the role of a character's totals values in the children's reasoning occurred during Charlie and Lola Activity 4. Eliot reported that he had struggled to decide between Lotta and Charlie as the best recycler, and said:

> I though the um Lotta or um Charlie were the best, I didn't know which one was it, so I thought it was both, so I picked both, 'cause I thought both of um 'cause I dunno which, 'cause I didn't know which one so it might have been one or em both of em.

When asked by the teacher why he might have thought it was both characters, Eliot responded:

> Cos um they they um, cos er cos er maybe they collected the most stuff? I don't know how much they collected, they got up to this number (points to the totals row at the bottom of the data table), well I think.

Eliot's explanations suggest that he was conscious that the total objects collected values for each character were significant information that may influence his decision. However, Eliot's statements suggest that he was unable to take that information further because he could not read the numbers, further indicated by his hesitation and use of uncertain language such as "maybe" and "might". Eliot's explanations illustrated that although the task appeared to be challenging for him, Eliot was working to articulate a justification for his thinking and to explore the possibilities for a solution with the information that he had.

7.5.5 Considering the Range of Column Values When Analysing

There were findings that the range of individual values that were found in each characters column was persuasive information for analysis during Charlie and Lola Task 3. In Group 1, Toby determined who was the best recycler, and said, "I think Marty, because everyone, some, everyone else has a zero". Isabel agreed, and declared, "I agree with Toby about Marty being the best 'cause he doesn't have any zeros". Toby and Isabel's explanations indicated that the minimum range in the individual values was considered to be a worthwhile fact to determine who the best recycler was. This reasoning was repeated across two other groups. As presented in an earlier finding, during Charlie and Lola Task 4, Jade qualified her decision to choose Marty as the best recycler because he did not have a zero in his column. Group 4's reported decision in Task 4 also revealed that Ted had chosen Marty as the best recycler on the basis that he did not have any zeros in his column. These findings connected three of the four group decisions to choose Marty as the best recycler because he was the only character who did not have a zero in his column, although overall, Marty had collected fewer objects than other characters. It is possible that Isabel, Toby, Jade and Ted had considered the plot in the picture story book, and reasoned that a character that collected something of every type object for the recycling competition was a better recycler than a character who had failed to collect one type of object and had a zero in his or her column.

7.5.6 Considering the Column Total and Individual Values When Analysing

There is a suggestion that one child may have co-ordinated the information from the two categories presented in the data table in responding to the question

"Who is the best recycler and why?" in Charlie and Lola Task 3. The two categories in the data table were the objects collected, and the characters that collected the objects. Carl (Group 1) isolated the characters Lotta and Moreton as potentially the best recyclers on the basis that they both had the maximum value for the total objects collected. When Carl was asked by the teacher why he thought it might be either of the two characters, the following exchange took place:

Carl:	Ah, because you have 20 and 20 (taps each of the total numbers at the bottom of each characters column) and look at the different…7, (taps each number in Moreton's column as he speaks) 7, 4, 0, 2 (moves hand to Lotta's column and taps each number in Lotta's column as he speaks) 5, 0, 5, 9, 1.
Teacher:	What would help you decide between the two?
Carl:	That one (points to Moreton) 'cause 7, 7, 4, 0, 2, seven plastic bottles (moves pencil back from the numeral across the row to the pictures on the far left of the row), seven glass jars and four broken plates and zero food scraps and two books.

The teacher was called away at this point, and said as he left, "and what about Lotta?" Carl responded after the teacher moved away, "Moreton, Moreton's the best". Carl's actions and description suggest that he had observed differences in the individual values for each character's column and was examining each column to see if he could distinguish between them in some way. Carl gestured his hand across the rows to connect the values in Moreton's column to the objects that were collected. This indicates that he was associating the categories of objects to the quantities Moreton had collected and possibly considering the differences in values for the different objects that led him to decide on Moreton. It is speculative, but as food scraps had been excluded from being recycled by all groups in response to the first question in Charlie and Lola Task 3, the zero in Moreton's column for food scraps may have influenced Carl's thinking. The opportunity to hear the remainder of Carl's reasoning was lost. However, during reporting in Task 4, the teacher asked Carl why he had decided Moreton was the best recycler, and the following exchange took place:

Carl:	Because he has 7, 7, 4, 0, 2, because Morton has sevens, two of them, and do you know why I didn't choose Lotta? She has 5, 0, 5, 9, 1
Teacher:	What helped you make that decision?

Carl: Well, Lotta has a one at the end and Moreton has a 2 at the end (points to the old books value numerals at the bottom of each column for each character) so I chose Moreton because he has a two at the end.

Carl's explanation indicated that he had not co-ordinated the two categories of values information for the types of objects collected by each character to come to a decision. His explanation does indicate that the frequency of the values was considered, (Moreton's two sevens), as was the range (Lotta's one and Moreton's two), although the logic in applying the column values to arrive at the final decision is unclear.

7.5.7 Section Summary

The children observed and considered the range and frequency of values in data tables in developing their prediction models. The range of column values and column totals were used by some of the children and taken into account to identify and exclude categories when analysing data to answer a question. The minimum value in the range of individual quantities of objects collected by the characters influenced selected decisions. Some children demonstrated awareness of outlier values. The children did not co-ordinate two categories of information to answer a data based question. Finally, the children's gestures were an important source of information about their data knowledge.

7.6 Children's Reasoning with Data Context and Data

In this section, findings of children's use of data context knowledge and data to answer a question are presented. Some children referred to knowledge from the modeling activity picture story book when they analysed and interpreted data values. This was found in Charlie and Lola Task 3 when the children answered the question "Who do you think is the best recycler and why?" The question required analysis and interpretation of data values in a table for objects that were collected by the five characters from the picture story book *Charlie and Lola: Look After Your Planet* (Child, 2009).

In Group 1 (Carl, Isabel and Toby), Toby and Carl studied the data table and discussed excluding the character Marty from consideration. Charlie ran his pencil across the row of characters at the top of the data table as he said, "it's out of any of them". Toby immediately responded and the following exchange took place:

Toby:	Not Marty, because he wasn't actually cleaning up though
Carl:	Yes! He collect, he collect (taps each number down Marty's column as he reads) 4, 5, 2, 1, 7 twen…twenty one, so
Toby:	But we didn't see him did we
Carl:	No
Toby:	We didn't see him
Carl:	Yeah, we didn't know what he looked like, but that's what he looks like when he's good (taps the picture of Marty on the data table).

This exchange demonstrates that Toby and Carl were considering the picture story book as they read the data table. Marty was the character in the story who had a room "like a complete pigsty" (Child, 2009, p. 3), would not throw anything away and who did not participate in the recycling activities with the other characters. In addition, Marty was not shown in any illustrations in the picture story book. Toby raised this information when he stated that Marty had not cleaned up and had not been seen. Toby's responses and his repeat statement that Marty had not been seen, suggest that he was questioning whether Marty should be included in the data table for two reasons. First, Marty's characterisation in the data table as a recycler, did not fit with his characterisation in the picture story book as someone who never threw anything away. Second, Marty had not been pictured in the story. Toby appears to be uneasy with the inconsistency between the two characterisations and he may not have been convinced that the picture in the data table was Marty. In contrast, Carl's responses demonstrates that he was prepared to consider Marty's data values as evidence that he did collect objects, and he was willing to accept the picture as one of a reformed Marty who is now "good". Carl appears to have reconciled the differences he observed between information in the data table and knowledge he had from the picture story book. Toby and Carl's responses also indicate that "goodness" of the character is an attribute worth attending to. For Carl, a character that recycles might be good, and for Toby, a character who is messy and unhelpful may not be someone who could participate in a recycling competition.

Similarly, in Charlie and Lola Task 3, Sam, Eliot and Jade in Group 2 made explicit reference to the picture story book plot to explain information observed in the data table. Jade pointed to Marty's picture in the data table and said:

> Morton got all of those um bottles out of Marty's room, and and Moreton, Moreton put the um glass, the glass jars and he got all of the things from Marty's room and he got all the food scraps out of Marty's room and he, he put it, Moreton put it all of the books in so because he wanted to um because he wanted to figure out and then he wanted to fill the tree up. And then and then Marty said *who's been in my room* (said in a growly voice).

Jade's description re-enacted part of the plot in the picture story book when objects were taken from Marty's room to be recycled. Each object subsequently awarded a paper leaf that was used to fill a tree poster for the recycling competition. Jade described what occurred in the plot, integrating specific objects represented in the data table, objects that were not mentioned in the picture story book. Jade's account explicitly connected the picture story book to the data table however she did not connect the story to the values found in the table. This suggests that she had assimilated the information from each source as a means of making sense of the question. These examples illustrate that knowledge from the picture story book was drawn on to make inferences, to challenge and reconcile inconsistencies between the data table and the picture story book or to integrate and explain unexplained information observed in the data table.

7.7 Discussion: Data Analysis by Children During Modeling Activities

7.7.1 Introduction

In this section, the findings presented in sections 7.3 – 7.6 are discussed. First, findings connecting gesture with reasoning are discussed. In the subsequent sections, the children's observations of data of interest, their use of data to predict and answer a question and their explanations as they reasoned modeling problems to a solution in each modeling activity are discussed.

7.7.2 Gesture and Reasoning

Gesture was used by the children to assist explanations as they developed their models in both of the modeling activities. The children's use of gesture may have been supported by gesture used by the teacher during the implementation of the

modeling activities as he scaffolded reading data tables with the children (section 4.4.2, p. 115). Combining gesture with speech provided visuospatial information about the table reading task and focused attention on the essential information needed to read the table (Cook & Goldin-Meadows, 2006). This use of gesture during instruction may have facilitated the children's learning by providing gesture components (moving the hands across rows and up and down columns) that could be replicated by the children and encouraging them to use gesture as a resource, reducing the need for speech and therefore reducing cognitive load (Cook & Goldin-Meadows, 2006).

Learning a strategy for reading the data table that included gesture, may have supported transfer of the technique to the subsequent data tasks (Alibali, Spencer, Knox, & Kita, 2011) where the data tables were used in developing models. In turn, the children used spontaneous gesture as they developed their models, using it to indicate the row and column structure, and when demonstrating an awareness and consideration of individual values in the data tables. Gesture, when accompanying speech, is an external communication of information and ideas the gesturer holds about the task (Goldin-Meadow & Wagner, 2005). Gesture is therefore one of the symbolic capacities and representational formats children use to represent their world (Lehrer & Schauble, 2006). A child's use of gesture reflects his or her knowledge of a task, and may also play a role in creating knowledge by assisting children to connect their understanding of a problem with their existing knowledge and mental representations (Cook & Goldin-Meadows, 2006; Goldin-Meadow & Beilock, 2010). The findings indicate that gesture is a symbolic representation that is integral to young children's model development.

7.7.3 Children Analysing When Modeling: Responding to Data of Interest

In this section, the children's responses to, and reasoning about statistical characteristics during modeling tasks are discussed. The discussion addresses the children's use of outliers and zero, range and frequency of data values in solving data modeling problems and their spontaneous explanations for data of interest in the data tables.

7.7.3.1 Outliers and zero.

The study found that some children demonstrated interest in, and awareness of, extreme values in the given data. Two examples in Litterbug Doug Task 3 revealed an awareness of outlier values, when a predicted value that went well outside the range of 0-6 found in the data table was proposed by a group member (Eliot). The proposed value of 100 was accompanied by gesture and comments that suggested that the proposition was extraordinary, and was met with questioning or incredulity by other group members. Eliot's gesture and speech when he proposed the outlier value and the reactions of the other group members, suggests that all children were aware that the proposed value was improbable. The children's responses indicate an awareness of distribution and probability and that the range of values was meaningful for them and taken into account. This would explain why the proposed outlier value was considered unexpected, given the distribution of the range of values provided and may reflect an intuitive understanding or beliefs about chance (Watson, 2006), an aspect of children's prediction that is discussed further in section 7.7.3.2 (p. 224). The finding supports English's (2012) data modeling study of this prediction task with first grade children where proposed outliers by group members during model development were dismissed as unlikely. Makar and McPhee's (2009) study with 8 year old children explored concepts of average and found that children were capable of considering informal concepts of range, including outliers, if they had a meaningful sense of the range in the context. What is interesting in this study is that the children did not respond to an outlier, but rather created their own outlier value that was atypical in the context of the existing values. This finding provides insight into unexpected starting points for developing distribution and chance concepts with young children.

The children's awareness of, and interest in, extremes values was also observed when particular attention was paid to the representation of a zero value in a row, and to the absence of values in a column by some children in Litterbug Doug, Task 2. Two children observed and spontaneously explained the presence of zero, and four children generated spontaneous explanations as they speculated about the absence of values in the blank Thursday column. There are strong indicators that the absence of values in the column was considered by the children to represent zero.

The explanations provided for both the zero numeral found in a row and the empty column, suggested a perceived relationship between the representation of no collection on one day, and the lack of representation for the same object the following day, when the column was blank.

The children's interest in the presence of zero was also found in Charlie and Lola Activities 3 and 4. The zero values in the data table provided for the modeling activity was powerful enough to sway some children to their conclusion about who was best recycler, by choosing the only character in the data table whose column did *not* have a zero value represented. It is speculative as to whether reading zero in the character's column values was viewed as representing "no collection" of objects, however the absence of zero clearly influenced their final decision to answer the question. The children considered the context of the problem question and may have determined that someone who managed to collect some of *every* object to be a better recycler than someone who collected more objects overall, but failed to collect anything in one of the categories. Further discussion of the context knowledge found in the children's explanation is found in section 7.7.6 (p. 233).

The findings in relation to zero indicate that a number of children had an understanding of zero as representing no value, affirming research that many children in their first year of school understand the concept of zero (Clarke et al., 2006). The children's acceptance that a category value in the data table was represented by the numeral zero, contrasts with the limited research on children's graph reading and how children interpret missing data or zero value data. Asp et al.'s (1994) study with 4th grade children's interpretation of bar graphs found that when a scaled graph indicated a category with a zero value, children read a quantity into the category. Their study used bar graphs and collected data through interviews, so the task and data collection method differed from this study, where data were presented as numerical values. A table of information can have advantages by providing an intermediate step in organising data before graphs are made, a suggestion that may further explain the finding (Friel, et al., 1997). Presenting data numerically in this study may have provided information that, given children's number sense and experiences in prior-to-school years (Perry & Dockett, 2008,) was more readily

identified and assimilated by the children than graphical representations such as bar graphs.

This study found that particular values in a task that are very small or large, act to sign post variability (Shaughnessy, 2007) and can be a point of interest for children. Evidence of children's interest in the extremes of a distribution can inform designing task contexts. Incorporating task features of extreme values may help develop an understanding of distribution, which is required to be able to describe and predict data sets (Bakker & Gravemeijer, 2004).

7.7.3.2 Range and frequency.

Some children were found to spontaneously observe the range and frequency of the data values within a category. This was evidenced when differences between column totals were observed during the Charlie and Lola modeling activity. Further evidence was found in Litterbug Doug Task 2 when the data table was introduced, and children spontaneously noticed the maximum values and changes in values across a row in the table. One child (Gina) tracked a growing number sequence across various rows and noted the maximum value. These findings indicate that some children were observing variability as similarity and difference between the values (Masnick & Morris, 2008). The findings also support suppositions made by Mulligan and Mitchelmore, (2009) that children search for mathematical structure and pattern as predicted regularity. The children's responses during the two modeling activities may indicate early mathematics curriculum influences on detecting patterns (Watson, 2006), and may reflect prior-to-school experiences from the children's attendance at pre-school. The children's consideration of range and frequency as they developed their models in Litterbug Doug and Charlie and Lola are discussed further in section 7.7.4.2, p. 226.

7.7.3.3 Spontaneous explanations for data of interest.

The children's spontaneous explanations of zero drew on direct knowledge from the picture story book. Gil and Ben-Zvi (2011) identify that explanations are a reasoning tool that can serve to help students consider context when making sense of data representations. The minimum value of zero in the data table and particularly the absence of values, seemed to be surprising or significant to the children, and they

sought to create connections with what they knew from the picture story book to explain the anomalies. The knowledge used by the children to explain what they observed in the data supports research that children use reasoning to resolve doubt or uncertainty by using prior knowledge (Cunningham et al., 2005). In this instance, the children's prior knowledge has come from the picture story book. The children's use of knowledge of the picture book in problem solving with data supports research that children use context knowledge to draw conclusions about data. It further supports research that this occurs when children are familiar with the data context (Mooney, Langrall, & Nisbet, 2006), and where there is a fit between the data provided and children's prior knowledge (Masnick et al., 2007).

7.7.4 Children Analysing When Modeling: Using Data to Predict

This section discusses the models the children developed in Litterbug Doug Task 3 to find a solution to a data modeling problem engaging prediction. The development of the children's models provided evidence of probabilistic reasoning, indicating that the task activated intuitions about chance. The words "chance" and "probability" are found interchangeably in the literature, including the *Australian Curriculum: Mathematics* (ACARA, 2013). Watson (2006) however, describes the word *chance* as "precursor to probability" (p. 127) having more intuitive connotations and less formal connotations than probability, which quantifies chance, a distinction supported in the findings. The discussion in this section will address intuition and prediction, engagement with prediction, the children's reading of the data and finally the influence of the task context on the children's models.

7.7.4.1 Intuitions and prediction.

The study found the children used existing data, knowledge of the data context and probabilistic reasoning to make predictions. In developing their models, the children determined that given the data provided for three days rubbish collection, it is possible that more, less or equivalent amounts could be collected on fourth day. This is supported by research that states that probabilistic reasoning "consists of drawing conclusions about the likelihood of events based on available information or personal knowledge or beliefs" (Morsanyi, Primi, Chiesis, & Handley, 2009, p. 210). As the children did not have any previous formal instruction

in chance or probability, this finding brings to light the role of children's emerging probabilistic intuitions to make their predictions. The children's predictions suggest that finding a solution to the problem used knowledge and reasoning capacities and competencies drawn from individual experiences outside formal instruction (Fischbein, 1975). Research varies in its agreement about the ages and the ways in which children understand uncertainty. A factor in determining when and how probabilistic intuition develops may be the task characteristics children are provided with (Langrall & Mooney, 2005). The following sections incorporate discussion of children's probabilistic intuitions as they engaged in a prediction task.

7.7.4.2 Engaging with prediction.

This study found that all children drew from the available data to develop their prediction models. The finding contrasts with the small number of studies that have examined young children's prediction from data where children found prediction tasks difficult. Pereira-Mendoza (1995) found that 7 year olds could interpret graphical information, but could not use the information to make realistic predictions. As previously discussed, Asp et al.'s (1994) study found that many 4th grade children who were asked questions that required them to predict using bar graph data could not give data based reasons, or simply guessed. Watson and Moritz's (2001) detailed study of children aged 6-16 years found that the majority of 6 year olds responses to the prediction task did not refer to the given data, with one child unwilling to predict on the basis that there was not enough information. Watson and Moritz concluded that few children "realized that existing data may assist making approximate estimates for missing data. This improved from Grade 6" (p. 73). In contrast, the findings from this study strongly suggest that the children were able to make use of the range and frequency of the available data values to predict a reasonable missing data value, if a suitable context is used. This finding is consistent with the view that data modeling supports separating data from the event that created it.

The children in this study made predictions based on the available data provided in the task, however, the children's verbalising during small group work as the models were developed did not make reference to information in the picture story book. The children drew exclusively from knowledge of the picture story book to

explain their predicted values if they were specifically asked to explain their decision by the researcher or teacher, and even then, explanations were not readily available for some children. This finding supports the view that making predictions is about seeing relationships in the data that are separated from the event that created it, and "using those relationships as a basis for making predictions about new cases" (Lehrer & Schauble, 2002, p. 23).

7.7.4.3 Reading the data.

The children read and considered the range and frequency of data values in the data tables as they developed their prediction models. As models were generated there were multiple examples of children touching data values along rows in the table with fingers or pencils and reading the values out aloud before writing a predicted value. Friel et al. (2001) note that the structure of tables share common features with the structure of graphs. The finding in this study is consistent with studies of children reading graphs, and suggests that the children were engaging in a literal reading of the data and so had developed knowledge of the form and structure of a data table that enabled them to do so. Some of this knowledge may have developed from scaffolding by the teacher for table reading, as knowledge of conventions for representing content supports comprehension and the ability to predict (Curcio, 1987).

Providing data in a table may have supported the children's access to the information needed to develop their prediction models. In contrast to previous studies of prediction tasks with young children that employed bar or pictographs, the task context in this study provided a table of data for the children to work with. Prior studies have found that children's attempts to explain when drawing inferences from data are often grounded in personal experiences and not the data or the data context. Periera-Mendoza and Mellor (1990) found that Grade 4 students would not make a prediction when information was not on the graph, and speculated that the students may have viewed the graph as a complete picture, and that they could not go beyond it. Watson and Moritz's (2001) study that included 6 year olds, used pictographs tasks that asked the students to use data "to estimate missing values beyond the data set" (p. 61). The 6 year olds were not able to provide responses that referred to the given data, or were unwilling to predict because of insufficient information, and

some engaged personal knowledge to explain their reasoning. Asp et al. (1994) found that Year 4 children could not give reasons, guessed or used their own experiences as prior knowledge to explain a prediction task using a bar graph. The finding for this study indicate that the task design supported the children to "read the data", "read between the data" and "read beyond the data", descriptions of levels for graph reading described by Curcio (1987). The children's models suggest that the children read the data table to locate information. The children's hand, finger and head movement gestures and their specific verbal references to values revealed they could locate information using the features of the table by tracking along rows and up and down columns and isolating individual values associated with particular objects. The structure of the table, with picture labels of categories heading lists of values in a row, was a format that made the information accessible and able to be comprehended (Friel et al., 2001).

The prediction models the children developed suggest that they had knowledge and reasoning skills that enabled them to "read between the data" (Curcio, 1987, p. 384), that is, to interpret, integrate and find relationships in the information available in the data table (Curcio, 1987). The ability to read between the data indicates that children were able to find an association between the data as it was represented, and integrate and interpret the information. What is notable is that the data values in the table of values provided to the children did not provide patterns that may have assisted seeing or forming such connections. That the children could predict in the absence of pattern in the data contrasts with Watson and Moritz (2001), who concluded from their research that observed patterns in data were used by children to inform predictions. Further, the children's models revealed some replication of values found in the row for each object, and that these predicted values are reasonable, given the sample range provided for each object. This finding indicates that the children had drawn associations from the data that revealed some understanding or intuitions of reasonable distributional variation, (Watson, 2006), even in the absence of pattern in the data.

The children's predictions required analysis and reasoning from the data, indicating that they could "read beyond the data" (Curio, 1987, p. 384). The children were able to make decisions about predicted values that were reasonable in the

context and took account of the existing data (Leavy, 2009). It is not suggested here that the children's data based explanations fulfill the requirements for informal inferential reasoning. The finding is that when predicting, the children were able to draw conclusions about the data and generalise beyond it using data to support the decision, decisions that include elements of statistical inference (Makar & Rubin, 2007; Reading, 2009). Although the children's explanations did not impliedly or implicitly acknowledge uncertainty (Makar & Rubin, 2007; Watson & Neal, 2012), their reasoning processing did include engagement with aspects of variation and distribution, which are building blocks for informal inferential reasoning (Reading, 2009).

7.7.4.4 Task design - contextualising the task.

The study found that the task context of the data modeling task supported eliciting children's intuitions about probability to form meaningful predictions from data. Prior studies on probabilistic thinking in young children have relied on artificial chance devices. Artificial chance devices have been used in researching probabilistic thinking even though it is suggested that intuitions in probability are based in human behaviour. People's behaviour can be explained in causal terms, whereas there is no causal explanation to understand artificial chance device outcomes (Schwartz & Goldman, 1996). In Jones et al. (1997) for example, children's understanding of the probability of an event was studied using interviews and problem contexts such as gumball machines, and spinners. The task context in this study however, used natural variation to contextualise the problem. Natural environments provide frequency information from past events that provide information as naturally sampled frequencies that it is suggested can be used to statistically predict outcomes and support statistical inference (Brase, Martinie, & Castillo-Garsow, 2013). The children were not asked to identify the probability of outcomes of the event (Jones, Langrall, & Mooney, 2007), but to make a prediction about a possible outcome, which they have chosen to express as a data value. The finding suggests that task design features that tapped into natural frequencies of an event supported children to use the data they were provided with to problem solve.

The human context of the task problem may have influenced the children's model development. The task asked the children to predict about an everyday

context, picking up rubbish. Children borrow from the experiences and concepts they have, including their messy everyday experiences with chance, (Greer, 2001) and their propensity for causal reasoning (Goswami, 2007; Lombrozo, 2006) to solve problems. Schwartz and Goldman (1996) argue that probabilistic intuitions about explaining behaviour to solve problems are complicated. This is because in statistical reasoning inference must be coordinated with understanding that the causal nature of an outcome, and chance (as the statistical measurement of that outcome) have to be considered at the same time. For these reasons instruction should be based on situations where everyday interpretations can be elicited so that these intuitions, as prior knowledge, can be advanced over time to a more organised, statistical system of problem solving (Schwartz & Goldman, 1996). The finding supports task design that engages everyday contexts to render intuitions visible to educators and enable pedagogical facilitation of ongoing learning.

The role of the question that stimulates the prediction task in eliciting prior knowledge is highlighted in this study. The question posed in the data modeling problem used everyday language and asked; "how many different things do you think Litterbug Doug might have collected on this day?" The language used in the question contrasts with Way's (2003) study where children (average age 5 years 8 months) were asked questions that included probability language, such as "most likely" and "better chance". The questions asked in Way's study required experience, understanding and appreciation of the statistical nature of how the language was defined and the study found that children had a "minimum understanding of randomness" (p. 3). The way the question was posed in the data modeling problem in this study may also have prompted the children to read beyond the data. The question was one that could "provoke student's understanding of the deep structure of the data presented" (Friel et al., 2001, p. 130), and required the children to engage with data for Monday to Wednesday and form inferences that moved beyond the available information in the data table to predict Thursday's data. Friel et al's suggestion is supported by Watson (2006), who states that "a first step towards inference is the interpretation of what has been created" (p. 190). The children's prediction models in this study contrast with the results in Way's study, where task based interviews with random generating devices that relied on visual impressions from the devices that

would not connect the likelihood of events to the sample. The models in this study reflect those found by English's (2012) data modeling research using this prediction task with first grade children. The children in her study recorded prediction values of zero to ten, indicating informal awareness of range, frequency and variation as trends in the data. The findings indicate that task context that combines embedding prediction tasks with questions that require engagement with the structure of data tables, can support young children's entry into data prediction.

7.7.4.5 Section conclusion.

The prediction models were explained by a combination of the children's ability to make connections between the data, the data context and the data problem (Friel et al., 1997) and an awareness of the variation in numerically represented data that supported inferences needed to make data based conclusions (Masnick et al., 2007). Watson (2006) states that beginning statistical instruction should engage children in discussing the influence of variation on drawing inferential decisions, and this study showed that this is possible from the time children begin school. The lack of studies on prediction in the last decade belies the importance of prediction in statistical reasoning.

7.7.5 Children Analysing When Modeling: Using Category Data to Answer a Question

This study found that when given two categories of data in a table, the children considered one category only to come to a data decision. The children did not take the category of objects into account when they determined who the best recycler was in Charlie and Lola Task 3. The children had previously made determinations about whether the objects were recyclable when they answered the first question in the task "Do you agree that all items can be recycled?" (section 4.5.3, p. 129). This question did not ask the children to consider the quantitative values of the objects, and the finding suggests that the children engaged the classification reasoning they had demonstrated in the Baxter Brown and Michael Recycling modeling activities discussed in Chapter 6. The children used qualitative attributes and relied on real world knowledge to answer the question. The children did not co-ordinate their decision about the recyclability of the objects with the quantitative information about the recyclers in the competition to answer the second

task question “Who do you think is the best recycler?” This second question asked the children to consider and compare categories and their distributions and make a decision about how the information in one informs or is associated with interpreting the other (Neill, 2012).

Reasoning about relationships or covariation between two variables is an important and complex statistical concept that involves coordinating multiple processes (Zieffler & Garfield, 2009). Not coordinating two variables is consistent with children’s propensity to focus first on a single variable before developing consideration of bivariate data (Moritz, 2005), which may be available at grade 5 level (Watson & Neal, 2012). The finding in this study supports Watson’s (2006) research that young children consider one variable at a time, that is, their responses show they can engage purposefully with the data, but without an integrated understanding of the data as a whole. The finding indicates that the children did not see the data as a whole or aggregate (Bakker, 2004; Konold et al., 2004). Konold et al. (2004) note that an aggregate perspective is “a statistical perspective” (p. 7), considered a necessary requirement for drawing inferences from data (Rubin, Hammerman, & Konold, 2006). The children’s responses cast light on how the children perceived the data as they worked to answer the model eliciting question in Charlie and Lola, which is discussed next.

The findings indicate that the children considered aggregate characteristics of the single category of recyclers, but did not consider the category in association with the recycled objects category. Some children read and considered the range of column totals and used the information to eliminate or narrow the choice of who could be considered the best recycler. Other children read and were aware of the individual values in columns for each character as they determined who the best recycler was, including the presence of zero as a persuasive value to come to a decision. This indicates that the children were considering frequencies and trends, consistent with the pre-aggregate lens suggested by English (2011) where column totals and values across rows were compared. This was evident in the children’s interest in and consideration of equivalent values (the two column values that were the same) and minimum values (zero and the lowest column values). The finding is interesting in that the children consistently attended to the category variable in the

data that connected to the model eliciting problem, "who is the best recycler?" and so they attended to the column data for the competition participants in the modeling problem. The children's attention to the column data that related to the modeling question revealed the children's attention to data characteristics, as 'signals' in the data that could support making a generalised, inferential claim to solve the problem (Ben-Zvi et al., 2012).

7.7.6 The Role of Explanations in Statistical Reasoning: Connecting to Inference

The children's explanations revealed important information about the contextual basis for the prediction decisions they made. This study considered the role of explanation as statistical reasoning. Gil and Ben-Zvi (2011) argued that statistical inference and explanations are linked when students engage in informal inferential reasoning. They describe explanations as verbalisations of inferences made from data that expose and clarify statistical reasoning. Explanations draw on prior knowledge and hunches and reveal the contextual basis for reasoning. Gil and Ben-Zvi examined explanations as a means of differentiating inferential statistical reasoning (as a generalisation from data about a population) from "mere interpretations of the sample at hand" (p. 91). Chiasson (2005) argues that resolving uncertainty occurs through making inferences. Picture story books that captivate interest, such as Litterbug Doug (Chapter 5), and data that provokes uncertainty, such as the inclusion of unexpected data values or novel data table characteristics, may stimulate inductive reasoning that draws from, and significantly connects to, the data context of the statistical problem. As the findings from this study reveal, young children's explanations of their interpretations of the data, revealed the contextual basis and inductive reasoning used to make data decisions. Just as importantly, their explanations revealed the use of inductive reasoning in making those decisions, which are discussed next.

7.7.6.1 Providing explanations for prediction.

The limited studies of prediction tasks involving bar or pictographs, found that children had difficulty in making predictions, but instead made guesses based on previous experiences but not on the data (discussed in section 7.7.4.1, p. 225). In this study, there was a difference between the explanations for predicted values the

children provided as they worked independently, and the explanations the children provided when asked by the teacher or researcher. In the former, the children's explanations for their prediction decisions were based on the existing data in the table, and in the latter, the explanations were based on the picture story book that contextualised the data modeling problem. The children's explanations for *selecting* predicted values consistently used the existing data in the table. This suggests that the range and frequency of the data provided was strong evidence for the children's predictions (Reading, 2009). There were no findings of data context based, causal explanations for the predicted values made by the children as they developed their models. In contrast, when asked by the teacher or researcher about why there might have been that many items collected on the Thursday, the children drew from the picture story book to provide causal based explanations; for example, the character in the book might have wanted more of an item. The importance of the distinction between these findings is discussed next.

This study's findings indicated that children's primary intuitions for chance were engaged to use existing data to explain prediction decisions as they developed their models. Intuition in chance can be suppressed by an emphasis in school instruction on deductive reasoning that can lead children to look only to causal factors to interpret phenomena (Meletiou-Mavrotheris, 2007). In this study, as the children developed their models they focused on the existing data, and the explanations they provided to each other were data based. The children's focus on data based reasoning indicates that although children have a propensity to attribute causal effects or deterministic modes of reasoning to chance (Langrall & Mooney, 2005), this was not the children's immediate explanatory response to solving the prediction problem. Non-data based explanations for the predicted values only surfaced when the children were specifically asked for an explanation by an adult. Some children were unwilling or unable to offer an explanation, suggesting that data context based beliefs for the predicted values were not quickly accessible. Those explanations that were provided drew from knowledge of the picture story book and considered the availability of objects, (the character couldn't find any more, he had collected them all, or he had more at his dump).

Explanations that refer to availability may be attributable to a link between intuition about frequency and the children's interpretation of the data, the problem and other causal or affective knowledge they hold (Greer, 2001), which would include knowledge of the picture story book. Gelman (2006) noted that from a constructivist perspective, children work to use and connect causal or other explanatory knowledge they do have in order to build and organise domain specific concepts through inference. Differences between child initiated responses during model development and adult requested responses raise questions about the task context; adult directed questions may lead children to think that a causal explanation is required for probabilistic determinations. Cultural biases towards deterministic thinking in school that emphasise causal explanations can challenge the rational description of probability (Langrall & Mooney, 2005). Ultimately, probability is a complex combination of understanding that known and unknown generators can lead to chance, correlated or causally attributed variation (Metz, 1998), but essentially, probability describes events that cannot be explained causally (Langrall & Mooney, 2005). The children's data based model development for the prediction problem stimulates thinking about the role of the task design. The question it raises is whether an explanation should be expected or encouraged, or whether young children should rely on their intuitions to begin exploring and working with probability concepts.

7.7.6.2 Picture story book explanations about prediction.

This study found that when children did provide explanations for data based reasoning about prediction, they drew from knowledge of the picture story book associated with the modeling activity. The argument in this study is that the picture story books initiating the modeling activities provided the context of the data problem. The context of data for a data problem is defined by Mooney et al. (2006) as "the real-world phenomena, settings or conditions from which data are drawn or about which data pertain" (p. 1), and it provides the knowledge base to answer the question that students are engaged with. The picture story book *Litterbug Doug* (Bethel, 2009) was a source of knowledge the children drew on to account for what they observed in the data. This finding is consistent with research that finds that analysis and interpretation of data are dependent on interaction with contextual knowledge (Langrall, et al., 2011).

Children's beliefs about the data context, drawn from the picture story book, played a role in their reasoning with data, a finding that is consistent with research that students are inclined to rationalise data and generate reasons why data are there (Langrall et al., 2011) and that discovering meaning in data requires conjecturing about the context of the problem based on the data (Pfannkuch, 2011). Previous studies have shown that real world knowledge and beliefs that children hold about the data context can disrupt the use of data-based evidence (delMas, 2004; Garfield & Ben-Zvi, 2007). In this study, the children's principal knowledge base visible through their explanations when developing models and in modeling tasks was anchored to the data context provided by the picture story book. In this respect, the picture story book served to provide a data context that was drawn on by children to explain or read data, without evidence of other real-world knowledge the children held being used to do so. The significance of the children's use of the data context is that it suggests that children have the capacity and ability to draw meaningfully from data context knowledge to explain data observations, if the connection to the data context source is meaningful. However, as discussed next, children's knowledge of the picture story book can act as real-world knowledge and beliefs, influencing statistical reasoning as any real-world data context knowledge would.

Some children relied on knowledge from the picture story book that interested them when asked for an explanation for predicted values. Langrall et al. (2011) note that students' understanding of the data context is knowledge that can act as filters when reasoning a data based solution, particularly when the knowledge and data contravene each other. This suggests that interest in, and knowledge of Litterbug Doug's "messy" characteristics was preconceived knowledge that the children used in preference to the modeling problem information about his reformed role as the Litter Police (Wild & Pfannkuch 1999). The practical result of the children's preference for the messy Litterbug Doug is not obvious from the children's models. The predicted values the children decided on were compatible with either view of the main character; they determined what rubbish he collected, irrespective of his motive for collecting. The children's use of knowledge from characteristics that interested them however may have influenced their reasoning about the predicted values. For example, messy Litterbug Doug may have been someone who was considered to

collect more items than litter police Litterbug Doug. Explanations the children offered provided examples of how predicted values were made having considered that Litterbug Doug was adding to his rubbish collection. This is an emergent finding, as prior research that used picture story books to initiate statistical problem solving with young children (English, 2010, 2011) did not investigate children's interest in the story. These findings, while preliminary, suggest that the characteristics of a picture story book that interest children can influence their reasoning in statistical problems solving. Task context design should consider how the modeling problem connects to the picture story book and the influence this can have on young children's statistical reasoning.

7.7.6.3 Picture story book explanations to answer a question.

The study found that some children relied on knowledge of the picture story book that interested them to answer a modeling question when there was misalignment between the data provided for the question and the story. In Charlie and Lola Task 3,the data table provided for the children to use to answer the model eliciting question included the character Marty. The modeling eliciting problem had Marty as a character competing in the recycling competition. In the book used in the modeling activity, *Charlie and Lola; Look After Your Planet* (Child, 2009) however, Marty was an unseen, messy, character who resisted recycling. Marty's presence in the data table stimulated discussion between two children, Toby, who questioned the inclusion of the character, as "he wasn't actually cleaning up" and not represented in the illustrations in the book and Carl, who suggested that the picture of the character was what he looked like "when he's good". Differences between the information in the picture story book and the modeling task altered the children's perceptions of the validity of the data. Toby appears to have determined that the data does not relate to the problem however Carl used Toby's expressed doubt to search for an explanation for the anomaly. The finding supports the view that evidence which contradicts personal belief or knowledge may be ignored in favour of evidence that supports it (Ben-Zvi et al., 2012; Mooney et al., 2006). The finding also suggests that illustrations are story-related components that have the potential to cognitively engage and interest children (Elia, et al., 2010).

There were children who were influenced by characteristics of the picture story book that were of interest to them. Qualities that the children had shown interest in during the initiating picture story book reading (Chapter 5) were revealed when children explained their decisions as to who was the best recycler. For example, the story character who showed the most "goodness of character", by being good, persistent and helpful was judged to be the best recycler, to the exclusion of any data based support for the decision. The children's explanations illustrate that they drew from their knowledge of the picture story book, and particularly, knowledge of interest to them, and that the moral dimension of the characterisation in the stories was of interest to the children (Nucci, 2001). The finding is that for these children, the characters' qualities of interest were more persuasive than the data, and the picture story book had a powerful influence on their decision making.

7.7.6.4 Statistical reasoning with context in mind.

The children did not simply observe the data but used their intuitions and knowledge from the data context to make decisions. These findings reflect research on students' informal inferential reasoning where hypothetical, contextualised reasons or generated hunches are used by children to explain the data (Gil & Ben-Zvi, 2011; Makar & Rubin, 2009). Although general agreement is not found amongst researchers about what components are necessary for informal inferential reasoning, the children in this study used their observations about data with context in mind, to make decisions, engaging fundamental aspects (Makar & Rubin, 2007; Reading, 2009). Prior research suggests that the children did engage abductive reasoning as a form of inductive reasoning by "providing a contextual or theoretical support for the data being as they are" (Gil & Ben-Zvi, 2011, p. 92). Abductive reasoning was observed when the children drew from the data context to explain the data, for example, when knowledge from the picture story book was used by Jade to explain zero in the table used in Litterbug Doug, or when Jade explained the object categories in the data table by linking them to the plot in the story. If a view of inference in statistical problem solving is taken broadly (Bakker, Derry, & Konold, 2006), then the informal ways the children in this study engaged inductive reasoning and their knowledge of the data context to come to decisions about or explain data is a valuable starting point on the pathway to informal inferential reasoning.

The children's reading of the data to find solutions to the data modeling problem in Litterbug Doug and Charlie and Lola raises two critical aspects for knowledge use in statistical reasoning. First, it suggests that the children were conscious of the distribution of the data. Konald and Pollatsek (2002) state that in looking for patterns in distribution that children must search for the "signal" amongst the "noise" of the variation in the data. The children paid attention to features in the data and recognised that these features had meaning when working to predict a data value. This suggests that data characteristics were used to draw conclusions about the problem the children had been given, and they had ideas about variability characteristics that were represented as decisions based on informal notions of statistics (Masnick, et al., 2007). The act of predicting a data value, or of reaching a decision about who was the best recycler, engaged inferential reasoning based on children's informal knowledge of the variation found in the data values, an important aspect of reasoning about data (Reading & Reid, 2010). The findings may therefore be explained by the children's use of knowledge about reasonable value alternatives they gleaned from the data table rows and used to infer a probability judgment (Hayes, Heit, & Swendsen, 2010; Watson, 2007). On this line of reasoning, the predictions and decisions the children used would then be based on the strength of the available evidence, a desirable statistical practice (Ben-Zvi et al., 2012).

7.8 Chapter Summary

The findings in this chapter are from the children's model development and task solutions in the two modeling activities, *Litterbug Doug* and *Charlie and Lola*. Each modeling activity engaged the analysis system of data modeling where inference interacts and co-ordinates with data representations, however each had differing foci. Litterbug Doug was a data modeling activity that focused on reading, interpreting and extending data in an abstract format to make predictions. Charlie and Lola was designed to engage the children in reading and considering given data in a table in order to discuss and find a solution to a problem posed as a question. The children's use of knowledge and reasoning revealed their engagement with the *data context*, and the influence of the *task context* as they found solutions to the modeling tasks and data modeling problems.

The findings underscore the integrated and underplayed relationship between knowledge and reasoning in statistical learning for young children, and how knowledge contributes to reasoning. The research questions addressed by the findings are Question 1: What knowledge and reasoning skills do young children bring to statistical problem solving as data modeling activities? and Question 2: What characterises task contexts in data modeling activities that engage young children in statistical reasoning?

The role of gesture in statistical problem solving was highlighted by the children's spontaneous use of gesture to indicate rows, columns and individual values as they developed their models. The children's use of gesture indicated their ability to read the data table and use the information to make statistical sense of the data.

The study found that some children demonstrated interest in, and awareness of, extreme or minimum values in the given data as outliers or zero values, indicating that the values may have highlighted variability in the data values and drawn attention to distribution. Some children understood the value zero as 'nothing', affirming research that many children in their first year of school understand the concept of zero. Spontaneous explanations for the presence of zero drew on picture story book knowledge, suggesting that the children considered the data context to make sense of perceived anomalies in the data representations.

The development of the children's models provided evidence of probabilistic reasoning as they used the range and frequency of existing data to make predictions. This finding supports research that probabilistic reasoning is used to make judgments about the likelihood of events using available data, if a suitable context is used. The finding contrasts with research that young children find prediction tasks difficult, however children did not readily explain their predictions to adults when requested. In contrast, the children's explanations for selecting prediction values as they developed their models drew from the existing data values. This finding supports the view that making predictions is about seeing relationships in the data that are separated from the event that created it, and indicates that the children's primary probabilistic intuitions for chance were engaged.

The study found that the children engaged with reading data tables at a number of levels. The findings indicate that the children had developed knowledge of the form and structure of a data table that enabled them to literally read the table. The children were able to find and interpret relationships between existing data that supported predicting values that were reasonable in the context, even in the absence of patterns in the data. The children did not simply observe the data but used their intuitions and knowledge of the data context to make decisions. These findings reflect research on students' informal inferential reasoning where hypothetical, contextualised reasons or generated hunches are used by children to explain the data. Abductive reasoning was observed when the children drew from the data context to explain some data. When given two categories of data in a table, the children only considered one category to come to a data decision, supporting research that young children can consider aggregate characteristics of data, but without an integrated understanding of the data as a whole. These findings indicate that the children had drawn associations from the data that revealed some understanding or intuitive knowledge of reasonable distributional variation and the ability to draw inferences about it.

The children's explanations revealed the use of data context knowledge for making prediction decisions and reasoning with data to answer questions. This study found that when children did provide explanations for data based reasoning about prediction, they drew from knowledge of the picture story book as data context knowledge. This finding is consistent with research that analysis and interpretation of data are dependent on interaction with contextual knowledge and inclinations to rationalise and explain data. The children's principal knowledge base visible through their explanations was the data context provided by the picture story book, with little evidence of other real world knowledge. This finding suggests that children have the capacity and ability to draw meaningfully from data context knowledge to explain data observations, if the connection to the data context source is meaningful. Meaningful characteristics that interested the children found in the picture story books became knowledge that influenced their statistical reasoning and this knowledge was preferential and persuasive in the reasoning process.

The study findings suggest that task context that used natural variation of an event to contextualise the problem and a question using everyday language, supported eliciting children's intuitions about probability and make meaningful predictions expressed as data values. The task design contrasts with prior research where task context has relied on artificial chance devices and children were asked to identify the probability of outcomes of the event.

The presentation of numerical data in a table may have provided information that, given children's number sense and experiences in prior-to-school years was more readily accessible, comprehended, identified and assimilated than graphical representations such as bar graphs. The findings suggest that numerical data in a table may have supported successful reading and interpretation of the data, including missing data and zero values, and triggered the use of probabilistic intuitions. The use of gesture by the teacher to scaffold reading the data table may have further facilitated the children's access to information in the data table, by providing a replicable strategy for the children.

In summary, findings from this chapter were that young children have existing capacity and potential to reason inductively when engaged in statistical problem solving. The children engaged a range of intuitive, data context and real world knowledge to interpret experiences and extend known information to make predictions and form inferences about data to answer questions. Some task contexts supported accessibility to intuitive knowledge and reasoning.

Chapter 8 FINAL DISCUSSION AND CONCLUSION

This chapter presents a summary of the key arguments, findings and implications of the study by returning to the research questions. In addition, the limitations of the study, suggestions for future research, and concluding remarks are presented.

8.1 Summary of Study Purpose, Aim and Design.

The purpose of this study was to gain a greater understanding of young children's statistical reasoning by exploring the knowledge and reasoning skills young children commencing formal schooling bring to statistical problem solving and the task context that supports this.

This study was guided by the following research questions:

1. What knowledge and reasoning skills do young children bring to statistical problem solving as data modeling activities?
2. What characterises task contexts in data modeling activities that engage young children in statistical reasoning?
3. How does young children's use of context knowledge and reasoning skills develop as they undertake and solve data modeling activities?

The research questions were answered by identifying key statistical concepts and processes in order to (1) extend understanding of statistical characteristics that influence young children's statistical learning, (2) explore connections between knowledge, reasoning and data engaged during statistical problem solving, (3) identify characteristics of task contexts that engage and influence statistical reasoning, and (4) facilitate identification of theory and pedagogy that accommodate young children's access to statistical reasoning.

The study assumed a qualitative, interpretative methodological orientation to address the research questions. Using an educational design research approach, informed by the Models and Modeling perspective (Lesh & Doerr, 2003), young

children's data based statistical reasoning was explored in the classroom environment. The child participants in the study were viewed as active and informed in the research process, who possessed diverse and powerful mathematical competencies and provided reliable, genuine and valid data. The study's methodology and methods enabled access to young children's competencies by using stimulating, meaningful problem solving contexts. Task design for the activities in which the children engaged was underpinned by the Models and Modeling perspective (Lesh & Doerr, 2003). The primary means for collecting data was by video and audiotaping the modeling activities. This method of data collection enabled a focus to be placed on the children's data reasoning processes. Additional data collected were the children's representational models, meetings, conversations with the teacher, and researcher journal notes. In conjunction with data from the modeling activities, data were theoretically and thematically analysed to describe and explain young children's data based statistical reasoning and the characteristics of task influences on the reasoning processes.

8.2 Answering the Research Questions.

Findings presented in Chapters 5, 6, and 7 are drawn on to address the research questions. These three chapters presented findings of varied elements of young children's statistical reasoning that were addressed in the study design. Chapter 5 found children's interest in the characteristics of picture story books that played a dual role in contextualising the data modeling activities. The picture story books provided the statistical *data context* for the modeling problems and were integral to the *task context* by initiating and framing the modeling tasks and problems. Chapters 6 and 7 presented findings from the four modeling activities that identified the role of the data context and the task context in young children's statistical reasoning. Specifically, Chapter 6 focused on the *design system* of data modeling, comprising the generation, selection and measuring of attributes and the organisation, display and representation of data. Chapter 7 focused on the *analysis system* of data modeling, comprising the interpretation, analysis and inferences drawn from data representations. The findings from these three chapters provide a broad, exploratory snap shot of young children's statistical reasoning in data based problem solving across key processes in a data investigation. The findings

underscore the integrated and interrelated relationship between knowledge and reasoning in statistical problem solving for young children, including how knowledge contributes to reasoning. The research questions in relation to the findings are addressed next.

8.2.1 Research question 1.

What knowledge and reasoning skills do young children bring to statistical problem solving as data modeling activities?

The core findings of this study revealed young children's use of knowledge and reasoning, including their engagement with the *data context* and the influence of the *task context*, when solving data modeling problems. Young children brought inductive reasoning skills to solving data modeling and model eliciting problems, and this reasoning was employed across both the design and analysis systems of statistical problem solving. The children used inductive reasoning to determine attributes for categories and to transform raw data into data representations when working in the design system. The study found that when working in the analysis system, children used inductive reasoning to answer a data-based question, to predict or explain uncertainty about the data.

The use of inductive reasoning is a core characteristic of statistics defined in this study. Inductive reasoning is a disciplinary specific reasoning process needed to form and support statistical arguments about statistical uncertainty, and to draw inferences from data. Inference is considered "a foundational area in statistics" (Pratt & Ainley, 2008). The children engaged inductive reasoning as they encountered statistics concepts that triggered a need to manage uncertainty, such as encountering variation in the data. The children's explanations revealed the use of data context knowledge for making prediction decisions and reasoning with data to answer questions. The explanations indicated that analysis and interpretation of data are dependent on interaction with contextual knowledge. This finding reveals that the children were inclined to rationalise and explain data by drawing meaningfully from data context knowledge to explain data observations, if the connection to the data context source was meaningful. When engaging in data based statistical reasoning, this study found that young children bring their inductive reasoning skills to a range

of statistical processes, including categorisation and classification when determining attributes. The study findings serve to highlight the importance of children's reasoning competence and their capacity to apply inductive reasoning processes to make sense of data.

Statistical research has focused on the role of inductive reasoning as a skill that underpins informal and formal statistical inference (Gil & Ben-Zvi, 2011). Statistical inference is required for interpreting data to draw evidenced conclusions that extend beyond the immediate, available data (Makar & Rubin, 2009) and is seen as the final step in statistical problem solving (Watson, 2007). Early development of informal inferential reasoning in statistics is advocated and encouraged (Makar, Bakker & Ben-Zvi, 2011; Watson & Moritz, 2001), however inductive reasoning is employed more broadly than this in statistical problem solving. Inductive reasoning is used to make decisions based on existing knowledge that is engaged in novel situations that apply to a range of statistically relevant processes (Hayes, Heir, & Swendesen, 2010), such as categorising and decision making, as found in this study. The findings suggest that when considering how to begin young children in statistical learning at school, given the central role of uncertainty and induction in statistics, it would be valuable to expand the current view of what defines inferential reasoning. A broader statistical definition would acknowledge that inductive reasoning occurs across all aspects of statistical problem solving. As a result, there would be recognition that young children do engage in inductive reasoning when they make sense of data. For young children, inductive reasoning is used to come to conclusions when there is uncertainty, such as during categorisation, prediction and data analysis. When children use inductive reasoning in this way, they are reasoning statistically.

One core finding of this study was that the children brought and engaged intuitive knowledge to reason solutions to data modeling activities. The findings are notable for the consistency and sophistication of thinking that they revealed. The use of intuitive knowledge was evident in the design and analysis systems in data modeling. In the design system, the children's models of data representation revealed meta-representational competence that was used to transform the data into conventional, representational forms to communicate the structure they imposed on the data. The findings suggest that the children had intuitive knowledge of

representation conventions for data tables and intuitive appreciation for variation and probabilistic intuitions. This knowledge was used to reveal their interest in, and use of data range and frequency to reason to make data based decisions and to develop prediction models for a future event. In the analysis system, the children's models provided evidence of probabilistic reasoning as they used the range and frequency of existing data to make predictions. This finding indicates that probabilistic reasoning is used to make judgments about the likelihood of events using available data, if a suitable context is used. The children's use of data based explanations when predicting, suggests that predictions were based on perceived relationships in the data. Prediction occurred in the absence of patterns in the data, suggesting that the children separated the data from the event that created it. The finding further suggests that the children's primary probabilistic intuitions for chance were engaged. Together, these findings demonstrate that children's representational and intuitive competency are significantly underestimated in research and curriculum expectations.

Other core findings expanded understanding of the range of knowledge children brought to making sense of data. Perceptual features of objects were not used to generate and select attributes for categories, or to represent data. Children can therefore create and apply attributes based on unseen properties and perceptual features of objects are not a significant draw for young children. Children demonstrated their capacity to read data values, to observe and understand extreme values, such as zero and outliers, range and frequency and aggregate characteristics of single category data. Further, the children interpreted data to predict contextualised values. Abductive reasoning was observed when the children drew from the data context to explain data and generate hypotheses. These findings highlight the powerful mathematical ideas young children possess and bring to school that have developed from their prior-to-school experiences (Perry & Dockett, 2008), and children's capacity to use such knowledge to make sense of the data in the context of solving modeling problems. The intuitive, informal competence children bring to beginning school statistical experiences can be supported and developed in learning contexts that are meaningful for young children.

The use of data context knowledge was marked by the distinct differences found between the types of knowledge the children drew from in finding solutions to problems in the design and the analysis system in data modeling. The study found that the children actively made connections to a range of existing knowledge to develop their models across all modeling activities. The use of the picture story books to contextualise problems however, enabled the children's use of data context knowledge drawn from the stories, to be visible as they reasoned solutions to the modeling problems and associated tasks. The modeling activities that focused on the design system revealed that the children drew predominantly from their real-world knowledge of family experiences and how objects are used and processed. This knowledge was used to generate and select attributes, and to apply those attributes to classify objects. The data context was drawn on only when an active connection was made between the picture story book and an object for classification. In contrast, in the modeling activities that focused on the analysis system, the children drew extensively from their knowledge of the data context for the modeling problem. Picture story book knowledge was used to solve the modeling problems, particularly if there was uncertainty expressed about the data. In addition, the children used characteristics of the story that this study found they were interested in. This finding indicates that knowledge the children gleaned from the picture story book as data context knowledge, was strong and persuasive when searching for solutions to statistical problems, particularly when reasoning was required for data analysis.

The study found that data context knowledge was visible and dominant in the modeling activities focused on the analysis system. This finding is in keeping the critical interaction between knowledge of the data context, and data analysis and interpretation in statistical problem solving (Moore, 1990; Wild & Pfannkuch, 1999). Context knowledge however, is critical in all aspects of data analysis, and data analysis is involved in all aspects of the statistical process. This includes both the system that designs data and the system that analyses and interprets the results (Scheaffer, 2006). The study's findings highlight that the design system involves undervalued analytical statistical reasoning. This reasoning also draws from data context knowledge of the statistical problem. If the context of the statistical problem is interesting to children, then they may draw on that knowledge when analysing in

the design system. The study found that analysis using data context knowledge can be achieved in the design system, if the connection to the data context knowledge is meaningful to young children.

The study found that children bring predominantly inductive reasoning skills and a range of real world, intuitive and data context knowledge to the solution of data modeling activities. The children's knowledge and reasoning skills are used to make judgements and take actions to make sense of data and therefore, reason statistically.

8.2.2 Research question 2.

What characterises task contexts in data modeling activities that engage young children in statistical reasoning?

A core finding from the study is that the picture story books, that integrated the data context and the task context, provided characteristics which interested the children. These characteristics were used as knowledge and were brought to the statistical problem solving process. One finding identified that children's spontaneous comments and questions indicated their interest in characteristics of the picture story books that were used to initiate modeling problems. The children were interested in a range of characteristics, including familiar story genres, recognisable characters and amusing or ambiguous illustrations. A key finding was that children responded to the uncertainty created by an unresolved problem in the story, and an unresolved problem stimulated predictions by the children about how to resolve the problem. Another key finding was that problems resolved in a story did not generate spontaneous prediction responses, and could limit interest. Interest in a resolved problem can be stimulated however, if children have concerns about the character and/or and how the problem was resolved. In stories where the story was resolved, interest was generated when the children identified with the character's "goodness" and how this had created, and led to, the resolution of the problem in the story. The children's responses highlight important differences in interest responses based on how problems are presented in a story. Either a picture story book that arouses spontaneous interest in an unresolved problem, or where the problem is resolved but

the character and the resolution of the problem is of concern to the children, may be best placed to stimulate model development.

Core findings indicated that explicitly linking the modeling problem with characteristics of interest in the picture story book, such as the needs of the character or items described in the plot, may stimulate directing the children's attention to the data context when developing models in statistical problem solving. When young children drew from data context knowledge to reason in a modeling task, particularly in tasks in the analysis system, they grounded their knowledge firmly in the story content. Knowledge that drew directly from the story was used in preference to knowledge provided by the modeling problem as an extension of the story plot. The children's use of the data context highlights the impact of data context knowledge on young children's model development and to the explanations of data they observed. The findings indicate that explicitly linking the modeling problem directly to the picture story book stimulates an active engagement with the data context in statistical problem solving.

Another core finding was that task characteristics supported children to look beyond perceptual features of objects when generating attributes. When the task context provided categories that did not have perceivable qualities (e.g., recycle), the children were able to construct attributes. Further, where the task that did not require objects to be classified, or where pictures of objects were used, attributes were generated that did not rely on perceptual features of the object. These task characteristics may have supported moving the children towards a more abstract view of the data.

The structure and numerical representations of data in tables provided information that supported the children's identification and location of data. Task contexts where data draws on natural variation and frequencies, uses everyday human contexts and asks questions in everyday language may elicit and support children's emerging use of probabilistic intuitions. The teacher's use of gesture to scaffold reading the data table may have further facilitated the children's access to information in the data table, by providing a replicable strategy for the children. The role of gesture in statistical reasoning was highlighted by the children's spontaneous use of gesture to indicate rows, columns and individual values as they developed

their models. This indicates that the ability to read the data table and use the information to make statistical sense of the data was supported by a task context where gesture is modelled as a strategy to find information and read tables.

The task context findings provide considerations for the design of meaningful modeling activities. Task contexts should be relevant to children's prior knowledge and provide situations that elicit the development and extension, exploration and refinement of significant mathematical constructs (Lesh & Doerr, 2003). The task design of modeling activities should forge a connection between a child's real world knowledge and experiences and possible solutions to problems by embedding core mathematical constructs that are mathematically generative and elicited as children work the problem and develop their models (English, 2003). In addition to revealing task design characteristics for modeling activities, the findings demonstrate that data modeling activities provided young children with conceptual access to statistical ideas (English & Watters, 2005; Perry & Dockett, 2008) and stimulated statistical processes as young children reasoned about, and imposed structure on, data to construct their models (Lehrer & Schauble, 2000, 2005).

Task contexts in data modeling activities that engage young children in statistical reasoning are characterised by initiating picture story books that interest children. Interesting stories draw young children into developing models to solve statistical problems, and support use of the picture story book knowledge as data context knowledge to reason statistically. Task context that presents data in accessible forms facilitates children's use of data when engaging in statistical reasoning.

8.2.3 Research question 3.

How does young children's use of context knowledge and reasoning skills develop as they undertake data modeling activities and solve data modeling activities?

The findings from young children's models demonstrate development and understanding of statistical ideas and reveal a competency and capacity to participate in statistical practices. These findings are explained by the design conditions in which they occurred and the design characteristics that instigated, mediated and supported their reasoning (Lehrer & Schauble, 2007). The children used models as

tools and symbols to engage in statistical practices, including reasoning and explanation, to articulate their cognitive models of development (delMas, 1999). Statistical practices were visible as the children applied reasoning and knowledge to data to make sense of it. This was achieved by categorising and classifying to generate, select and measure attributes, displaying and representing data, and analysing, predicting and inferring from data. The children's statistical reasoning revealed their statistical ideas and knowledge, including intuitions and meta-representational competence. They also demonstrated that they could make decisions about variation as they considered range, frequency, and aggregate characteristics of categorical data. The children transformed data by developing pictograph and Venn diagram models of data structure, and interpreted statistical and contextual features of the modeling task problem by evaluating data and using picture story book knowledge to predict and answer data based questions.

Young children's use of context knowledge and reasoning skills develop as they repeatedly engage with modeling activities that engage them to take the knowledge and reasoning skills they have, and apply them to find a solution to data modeling problems.

8.3 Further Research.

This exploratory study has deepened understanding of young children's statistical reasoning in naturalistic classroom settings as they begin formal schooling. The use of educational design research as a "genre of inquiry "(McKenney & Reeves, 2012, p. 7) takes account of defining statistical concepts and processes, current theoretical understanding of young children's learning, and pedagogical design that supports young children's access to relevant and meaningful problem solving activities. Educational design research aims to increase the relevancy between learning research and learning practice, to advance learning theory and develop applied design knowledge that is sharable and impacts on pedagogical practice (Design-Based Research Collective, 2003).

The study has contributed to existing literature on the learning and pedagogical content knowledge needed to support young children's statistical learning, and specifically, to the literature on data modeling activities. The study

adds to understanding how core statistical concepts and reasoning processes develop within the data modeling context. This understanding further supports the development of theory to inform pedagogical practices for young children's early statistical experiences at school. The study further contributes to understanding the problem-solving task context that supports young children's development and use of statistical reasoning.

The study findings offer alternative perspectives on the skills, knowledge, statistical processes and task design that can support young children's statistical reasoning. Young children have competency and capacity and have existing knowledge and reasoning skills that can be used to reason statistically, that is, to draw from and meaningfully apply their knowledge and ideas to make judgements or take actions to make sense of data. With young children's competency and capacity in mind, several aspects have emerged from this study that invite further investigation. These are presented without any particular order.

Further research is needed to examine how young children's meta-representational competence and intuitive knowledge can be supported and developed through appropriately designed and meaningful activities. Young children's intuitions are powerful resources that connect children's understanding of the problems with existing knowledge and mental representations, and form part of the symbolic and representational formats children have at their disposal (Lehrer & Schauble, 2006). Specific areas that have emerged from the findings in this study include young children's use of gesture to read complex data tables and competency in standard graphical representations (pictographs and Venn diagrams). Research is needed in children's use of probabilistic intuitions to make contextually valid predictions, and their use of preliminary intuitions about variation. Variation was used by young children to consider range and frequency as distribution, particularly where very small or large data values may offer entry points of interest. The findings offer insights into starting points for further theoretical and pedagogical investigation.

The informal ways young children in this study engaged inductive reasoning and used their knowledge (data context, data knowledge and real-world knowledge) to come to decisions about or explain data, are valuable starting points on the

pathway to informal inferential reasoning. Inductive reasoning was present across both data modeling systems, design and analysis, where variation was encountered. Given the critical importance of variation in statistical reasoning and thinking (Moore, 1990; Shaughnessy, 2007; Watson, 2006), the role of variability and variation in young children's reasoning, particularly with attributes, needs more attention. Therefore, research is needed that supports and extends young children's inductive capacity to consider variation as variability when they reason about attributes as they classify and categorise.

Further research is needed on the characteristics of picture story books that initiate and contextualise statistical problem solving activities and how these can be best utilised to benefit the design of data modeling activities. Personal interest and connection to the context of a problem is important for young children's active interest in a task (Clarke & Roche, 2009; Paparistodemou & Meletiou-Mavrotheris, 2008). Given the influence the picture story books had on the knowledge young children drew from when reasoning, research could explore how connecting characteristics of interest in a story based data context and a modeling problem can support young children taking the data context into consideration as they problem solve. In addition, the capacity of an unresolved problem in a picture story book to stimulate model development in the analysis system of data modeling remains untested.

Research in the role of task context in stimulating children's use of intuitive knowledge is needed, particularly for tasks that trigger children's prediction. Task characteristics that can be considered include the use of everyday language to pose prediction questions, the use of natural variation in everyday contexts and presenting data numerically in tables. These aspects of task design may strengthen and facilitate engagement with the structure of data tables and therefore support young children's entry into data prediction.

An aspect of task design that merits further attention is the use of pictures and open discussion. Task context characteristics that require the use of categories without perceptual properties may stimulate more abstract reasoning when dealing with attributes. The findings in this study provide a further provocation in exploring the development of statistical reasoning, as children may rely on different knowledge

that generates more abstract attributes when they are *not* required to use the attributes as a measure of classification.

8.4 Limitations.

The knowledge produced from educational design research about how and why an intervention works is contextualised to the conditions and characteristics in which it operated. This study aimed to contribute theoretical building blocks (Cobb, Confrey, diSessa, Lehrer & Schauble, 2003) and make a practical contribution to educational products and processes that support statistical learning (McKenney & Reeves, 2012). As for case studies, findings cannot be generalised. Rather, the findings can assist in developing principles that can be applied and tested with ongoing replications, in order to add to broader theoretical understanding of the problem that brought the intervention into being (Plomp, 2007).

Design principles result in "heuristic principles" that give guidance and direction about theory practicality and effectiveness (Reeves, 2006). Accordingly, the study's practical contributions are limited by the conditions that characterised and contextualised the study, including the setting, the participants, the data modeling activities and the implementation of those activities. Chapters 2 and 3 describe the aspect of statistical phenomena under investigation, and the learning theory that informed its study. Chapter 3 details the contextual variables for the setting and participants and Chapter 4 presents a description of the full implementation of the modeling activities. The theoretical principles that emerge are limited by the particular aspects of the phenomena being investigated within the specific ecological context, producing "humble" or local theory (McKenney & Reeves, 2012). Design based methodology stipulates its limitations as the description of the ecological and theoretical context in which the study occurred.

8.5 Concluding Remarks.

The two visible tales of young children's statistical reasoning during statistical problem solving are *data context* and *task context*. The integrated relationship between the two contexts allowed young children's use of specific knowledge found in picture story books, as data context, to be tracked as the children developed their models to solve statistical problems. The task context focus, as

modeling activities, enabled the task designs to expose their impact on reasoning processes during the modeling processes.

The study revealed that the informal and real world knowledge and reasoning skills that young children bring to beginning school learning is extensive. Young children have the ability to integrate contextual information and their existing knowledge to make sense of data across the design and analysis systems in data modeling, that is, they can reason statistically. Children's informal knowledge and intuitions are already in place as they enter school. Their competency and capacity needs to be acknowledged and built on in classroom learning that engages statistical problem solving. The findings of this study are a reminder that modeling enables young children access to statistics as a discipline and provides meaningful, contextualised statistical problems that can be used to begin conceptual engagement with statistical reasoning.

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Appendix A Baxter Brown data modeling activity

Baxter Brown's Messy Room - Teacher Instructions

Core Learnings

Posing questions

Generating and selecting attributes

Measuring attributes

Organising data

Displaying and representing data

Developing an understanding of caring for the environment

Developing an understanding of reducing, reusing, and recycling rubbish

Applying learning to other contexts

Resources needed

The story, *Baxter Brown's Messy Room*.

For each group of 3-4 children, a photo of Baxter Brown, a photo of his messy room, and cut-outs of the following:

- 8 bones
- 7 apple cores
- 5 plastic bags
- 6 old toys
- 9 empty drink cans
- 7 cereal packets
- 8 biscuits
- 4 old shoes
- 5 newspapers
- 6 milk cartons

For each group, two sheets of chart paper.

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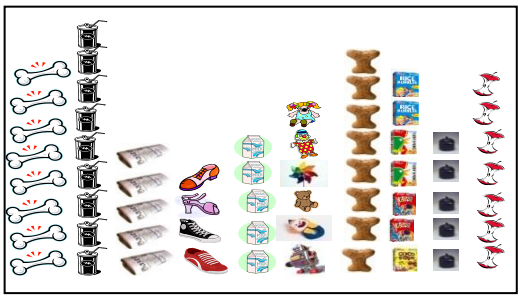

© Lyn English 2009

Instructions

Can *you* help Baxter Brown clean up his room? He really needs your help to solve his rubbish problem. Here is how you can help him:

1. Explore some of the different things Baxter Brown has collected in his room. (*cut-outs provided*)
2. Tell your group members what these things are and how many of each there are.
3. Talk with your group members about how you might sort these so that you can decide:
    - Which things Baxter Brown *must throw away* in the garbage bin.
    - Which things Baxter Brown need not throw away and that could be *reused* in his home or elsewhere.
    - Which things Baxter Brown could put in the *recycling* bin.
4. Tell *why* you sorted Baxter Brown's rubbish in this way.
5. Could you have sorted his rubbish in *another way*? Try this. Tell about how you sorted his rubbish in a *different way*.
6. Now take a piece of chart paper and show one of the ways in which you have sorted Baxter Brown's rubbish.
7. Can you show this in *another way*? You can use the other piece of chart paper to do so.
8. Now tell your class about the ways in which you sorted Baxter Brown's rubbish and tell about what you have shown on the pieces of chart paper.

Appendix B Michael Recycle data modeling activity

Activity 2: Michael Recycle and Litterbug Doug

Core Learnings

Identifying and measuring attributes

Organising and analysing data

Displaying and representing data in different ways

Interpreting tables of data and working with the data

Posing questions

Drawing inferences

Making predictions

Resources needed

A cut-out figure of *Michael Recycle* for each group of children; the books, *Michael Recycle* and *Litterbug Doug* for the class teacher; post-it notes and sheets of A3 paper for each group; the data chart for teacher, data chart for the groups; spare A3 sheets – QUT to provide all items

Focus of the Activity (two components, A – Michael Recycle and B – Litterbug Doug)

Now that the children have displayed a range of creative and innovative ways of sorting and resorting the items in the first activity, the primary aims of **part A** of this second activity are for children to:

(a) Identify and display data, initially using drawings/labels on posit-notes, followed by
(b) Representing the concrete/pictorial data in a more sophisticated/abstract form on A3 paper.

The transition from concrete/pictorial display to more formal representation is a large step for young children. We are keen to see the different approaches and reasoning processes

they use here and do not wish to stipulate one specific approach for them to follow. They might do simple vertical or horizontal picture graphs, or more abstract bar graphs, or they might make use of word lists, or simple Venn diagrams etc. We were very impressed with the range of representations they used in the revised first activity. Their reporting back gives us further insights into their creative and innovative approaches and reasoning processes as well as their developments in dealing with data.

In **part B** of this second activity, we are introducing the children to reading, interpreting, and extending data represented in an abstract format. We are interested in the different ways the children might interpret and deal with the data, and the inferences they might draw regarding *Litterbug Doug's* collection of items (and his "performance") across the three days.

PRE-LESSON

1. Teachers will read both *Michael Recycle* and *Litterbug Doug* before the lesson.
2. Teachers will have set up the classroom displaying reusable/recyclable and waste items in various areas of the classroom: one set of items per group. The items will comprise 2 waste items and 6 reusable/recyclable junk items per area, 7 separate areas in total
3. Teachers will have discussed reading data from a simple table of data but will not refer to the tables to be used in this and the next activity.

PART A – Michael Recycle

1. Remind children of the *Michael Recycle* story and discuss with the children the concepts of junk and waste, ensuring children understand that junk can be recycled/reused and waste is to be thrown away.
2. Explain to the children that in today's first activity they will be finding recyclable/reusable items as well as waste items in the classroom area in which their group is situated.
3. Please give a *Michael Recycle* hand-out to each group, explaining: "*Michael Recycle would like to join you in finding some recyclable/reusable and waste items in your area. Here is what he would like you to do: Each person in your group is to*

take 2 post-it notes and draw one of the items you find on each post-it note. You can also write the name of the item on the post-it note."

4. "*Michael Recycle would then like you to sort these items and display them however you like on the chart paper in your area*."
5. **Once the children have done this, each group can report back to the class on what their items are, how they have sorted them, and how they have displayed them, remembering the emphasis here is on displaying the data not sorting.**
6. Next, explain to the children: "*Michael Recycle really likes the different ways you have represented your recyclable/reusable and waste items on your chart but now he would like you to represent what you have collected in a* ***different*** *way on your chart*." Children to return to groups to do so using a new piece of paper but no post-its; *the focus here is on different representation not different sorting*.
7. **Have each group report back in turn to the class, explaining how they have changed their representation from the previous one.**

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Appendix C Litterbug Doug data modeling activity

Activity 2: PART B - Litterbug Doug

1. Remind the children of the *Litterbug Doug* story. Explain: "*Now that Litterbug Doug has become the Litter Police, the townsfolk are interested to see what he collects in Central park during his first three days. They also want to know if Litterbug Doug is doing a good job of collecting litter in Central Park.*
2. Show children the A3 Chart showing "What Doug collected" and the Monday column **only**. Explain: *As a start, the town's mayor asked Litterbug Doug to show him what he collected on his first day, Monday. Litterbug Doug showed the mayor what he saw and what he collected in the park*."

What Litterbug Doug collected	**Monday**
	2
	4
	2
	1
	2

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3. **Ask the children the following questions (whole class):**
   (a) What things did *Litterbug Doug* collect on his first day, Monday? (Children to identify each item listed in "What Doug collected")
   (b) What kinds of things did he collect? (Here children might say waste and recyclable, or food and non-food etc.)

(c) How many newspapers did he collect on his first day?

(d) How many pieces of cheese did he collect on his first day?

(e) Which thing/item did *Litterbug Doug* collect the most of on his first day? The least of?

(f) Is there anything else you notice about the numbers of things/items *Litterbug Doug* collected on his first day? (It is hoped the children will notice that he collected the same number of apple cores as newspapers as pieces of cheese; perhaps a child might tally how many items Litterbug Doug has collected on the first day).

(g) Litterbug Doug does not think he has done a good job collecting litter on his first day. What do YOU think? Why/why not?

4. Explain: *Litterbug Doug has now collected litter in Central Park for three days and the townsfolk are keen to see how much he has collected*. Show children the complete A3 Chart showing "What Doug collected on all three days."

What Litterbug Doug collected	Monday	Tuesday	Wednesday	Thursday
	2	5	4	
	4	3	2	
	2	6	3	
	1	4	2	
	2	3	0	

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Explain: *We call this a table of data. Do you know why we call this a table of data?* (You might need to explain that it is a special, organised way of showing how many of each thing Litterbug Doug has collected on each of his first three days. Please refer to each *column* and *row* to familiarise the children with these terms, rows and columns.)

5. Explain to the children that they are going to explore the table of data and talk about the numbers of items Litterbug Doug has collected across the three days. Have children move to their groups and hand out copy of complete chart to each group. Please give the following sets of instructions and have children report back as indicated:

(a) In your groups, first talk about what you notice about the numbers of things *Litterbug Doug* collected on his second day, *Tuesday*, and also on his

third day, *Wednesday*. If you would like to write anything down, you can do so underneath the data table on the paper given to you.

(b) Now in your groups, talk about how the numbers of things *Litterbug Doug* collected have changed over the three days. Have a think about why this might be the case.

(c) Now look at the Thursday column. It is blank. How many different things do you think *Litterbug Doug* might have collected on Thursday, his fourth day?

Now have each of the groups report back.

6. Next, ask the class: *Do you think the mayor and the townsfolk would be happy with Litterbug Doug's collection of litter during his first three days? Why/why not?*
7. Finally, please ask children: *Do you have any questions that **you'd** like to ask Litterbug Doug about his litter collection?*

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Appendix D Charlie and Lola model eliciting activity

ACTIVITY 3: HELPING LOLA

Focus of activity

This activity introduces the children to an elementary model-eliciting activity where children create their own model or system for solving a novel problem comprising sets of data. The activity encourages children to generate their own mathematical ideas as they solve the problem. Specifically, the activity engages children in:

- Interpreting tables of data
- Analysing and working with data
- Ranking data
- Posing questions
- Making decisions
- Justifying their decisions
- Classifying recyclable and non-recyclable items

Resources needed

Blank A3 sheets for each group; the A3 table of data for each group; set of questions and instructions in large type for each group; pencils. All items to be supplied by QUT except for pencils; children to use own.

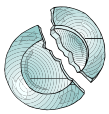
Pre-Lesson

Teachers to read *Look after your Planet* before the lesson. Teachers to discuss the characters within the book but to go no further into questioning children about items in procedure 1 overleaf.

Procedure

1. Remind children about the book, *Look after your Planet*, then please ask the class these questions:
   (a) Who are Lola's friends in the book?
   (b) Why is recycling a good thing?
   (c) What did Lola and her friends have to do to win a tree all of their own?
   (d) What are some things that Lola and her friends could *not* recycle?
   (e) What is a good recycler? Do you think Lola is a good recycler? Why/why not?
2. Explain to the children: *Lola's teacher was so impressed with Lola's recycling that she asked her to judge their school recycling competition. The competition asked children to keep a list of the items they recycled for one week. Lola has to judge five of the children: Charlie, Marv, Moreton, Marty, and Lotta. She has to decide who the* ***best recycler*** *is for that week. But she cannot do this on her own! She needs YOUR help. Here are the items that they recycled.*

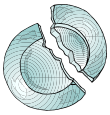
Items recycled

	Plastic Bottles	Glass Jars	Broken Plates 	Food Scraps	Used Books
Charlie	6	7	4	5	4
Marv	5	4	0	2	9
Moreton	4	5	2	1	7
Marty	9	6	3	4	3
Lotta	7	4	3	0	0

Note 1: Table above to be enlarged to A3 to show students

3. Allow students time to answer the questions overleaf in their groups and then report back to the class.

In your groups:

1. Tell what items Lola and her friends recycled.
2. Are all the items recyclable? Which ones do you think are not recyclable?
3. How many glass jars did Charlie recycle?
4. How many food scraps did Marty recycle?
5. Who recycled 9 books?
6. Who recycled 3 broken plates? 
7. Remember what your task is. What do you think best recycler could mean? It can mean different things.
8. Look at all the data and work out a way of deciding who the best recycler is for that week. Explain how you worked this out for Lola. Write it down if you can.
9. Now think about all the recyclers. See if you can list them in order from the best recycler to the worst recycler.

Best recycler	1
	2
	3
	4
Worst recycler	5

10. Explain to Lola how you decided on this list and write it down.

Appendix E Children's brochure

Can you help me find the answers to my big questions?

This brochure is to tell you a bit more about why I would like to spend some time in your classroom while you have some lessons with your teacher.

I have some **big questions** about how you **think** and **learn**. If I spend some time in your classroom, I can listen to what you say, and see what you draw and write when you are doing some special lessons. This will help me to answer my big questions.

In the **special lessons**, the teacher will have a story book to read. There is a problem in the story that needs to be solved. You will work out how to solve the problem in little groups with 2 or 3 other children. Sometimes I will talk to you while you are doing this. There will be lots of things for you to think about and **talk** about and do. You might need to **draw** some pictures and do some **writing** to help you work things out. Sometimes the whole class will talk together about how to solve the problem.

When you are working out how to solve the problem in little groups, I will **record** what you and the other children are saying and doing. Then I won't miss any of the **interesting** and **important** things you and the other children say and do. When I can look and listen to the recordings, I can see if you have helped answer my big questions. I would use a microphone and two video cameras.

I will only record **if it's OK with you**. If you decide any time that you don't want me to record you and talk to you, that's OK. No-one will be upset with you. Not me, or your teacher or anyone.

I will talk about what you have said and done with some other people who are on my 'big questions team'. Then I have to write a little book about whether I have found an answer to my big questions. I will also write some other things for people to read. People are interested in what you have said and done, because it helps them to work out what sorts of lessons help you learn and think the best. But no-one else **ever** gets to find out who you are or what your name is. This is **confidential**, which means 'private 'and 'top secret'.

I hope you will be happy to help me answer my big questions!

Appendix F Consent form (child/student)

CONSENT FORM for QUT RESEARCH PROJECT
Child/Student

Research Team Contacts	
Ms. Virginia Tragoras, PhD candidate 0407 782 950 virginia.tragoras@students.qut.edu.au	Professor Lyn English, Chief Investigator (07) 3138 3329 l.english@qut.edu.au

Young children's statistical reasoning
(linked to: ARC Project DP 0984178 - Restructuring statistical reasoning in the early school years: A longitudinal study of data modeling)

Statement of Child/Student Consent

Your parent or guardian has given their permission for you to be involved in this research project about how you think and learn when you are solving problems.

This form is for you to let me know whether you are happy to be involved.

By marking one of the faces and signing below, you are showing that your parent or guardian has talked to you about the project and that you are happy or not happy to be in the project.

YES

NO

You name:.....

Date: 2010

Please give this to an adult in your family and they can return it to us using the envelope we gave them.

Appendix G Introductory letter to parents

Dear parents,

This letter is to introduce myself to you. My name is Virginia Tregenza, I am a qualified early childhood teacher who is now doing further study at University and I will be spending a few days each week this term in your child's classroom as a helper.

Why am I here?

I am doing a study on children's thinking and learning about mathematics, and I am especially interested in how children who are just starting school learn. As parents, you know that your child has lots of knowledge and ideas about the world from all their experiences before they start school. My remember my son at 5 years old, as seeming to have both questions about and answers to just about everything! I want to know more about the sorts of 'before school' ideas and knowledge children have about mathematics and what they do with this information when they begin school. When we find out more about how children learn from studies like this, it helps teachers to plan lessons that best meet young children's learning needs.

To do my study, I need to be able to work with a group of curious and energetic children who are just beginning school with a caring and enthusiastic teacher, and your child's class is perfect! I will also need to video and audio tape eight of the children's mathematics lessons, and I will need your permission to do this. Information about the study and consent forms will be sent home to you in week 2, and I will be available to answer any question you may have. I hope you will be happy to

My study has been approved by the Department of Education and Children's Services and the Queensland University of Technology where I am studying, and the Principal has given permission for me to work in your child's.

Appendix H Letter to parents explaining research procedure

Information for children and parents

Research project- 'young children's statistical reasoning'

Researcher: Virginia Tregenza (PhD candidate Queensland University of Technology)

Dear parents and/or caregivers,

My name is Virginia Tregenza and I am studying at University to find out more about how children learn and use mathematical ideas. I am especially interested in the ideas and thinking that children have about the world they live in and how they use these ideas and thinking to solve problems where they have to sort out information. I think that sorting out information to solve a problem is how children begin to 'think statistically'.

How young children 'think statistically' is something that we don't know very much about, but we know that it is something that is becoming very important for the complex world we live in and the types of thinking we have to do to live well in it. This research project, which aims to increase our understanding of young children's statistical reasoning, has been approved by the Queensland University of Technology's Ethics Committee and the Department of Education and Children's

I hope that your child will help me to learn more about this by taking part in this project. Your child's participation in the project would involve them attending school and lessons as normal, however, 8 of the science lessons in the term would use curriculum activities that have been specially prepared for the project. These involve using children's story books to provide a problem for the children to solve that requires them to work with data, including working out what information they need, how to find it, how to sort it out, and to see if it helps solve their problem. In doing this, they will use mathematical and scientific ideas.

It is important to me that your child is comfortable and happy to have me in his or her classroom and also that he or she has an understanding of why I am there. To help with this, I have put together a brochure about what I am doing and why. It would be very helpful if you could take a few minutes to read this with your child.

You will have received a Queensland University of Technology (QUT) Participant Information and Consent Form with this letter, which provides additional information, including details with respect to confidentiality and use of any images of your child. Your written consent is needed for your child to participate in the research project. If you are happy to do this, please complete the consent form and return it to your child's teacher.

If you have any questions, please do not hesitate to contact me. My phone number is 0407 782 950, and my email address is virginia.tregenza@unisa.edu.au.

Thank you for considering this request.

Virginia Tregenza

Appendix I Participant information form (parent/caregivers)

CONSENT FORM for QUT RESEARCH PROJECT
Parent/Caregiver

Research Team Contacts	
Ms. Virginia Tregenza, PhD candidate 0407 782 950 virginia.tregenza@unisa.edu.au	Professor Lyn English, Chief Investigator (07) 3138 3529 l.english@qut.edu.au

Young children's statistical reasoning
(linked to: ARC Project DP 0984178 - Restructuring statistical reasoning in the early school years: A longitudinal study of data modeling)

Statement of consent

By signing below, you are indicating that:

- you have read and understood the information document regarding this project
- you have had any questions answered to your satisfaction
- you understand that if you have any additional questions you can contact the research team
- you understand that you can contact the Research Ethics Officer on +61 7 3138 5123 or ethicscontact@qut.edu.au if you have concerns about the ethical conduct of the project
- you have read the information brochure to your child and discussed the project with him or her
- your child has an understanding of their participation requirements
- you understand that you are free to withdraw your child's participation at any time without comment or penalty
- your child understands that he or she may withdraw from participation at anytime without comment or penalty
- you agree to allow your child to participate in the project
- you understand that the project will include digital audio and video recording and photography
- you give permission for these digital recordings, images and photographs to be used in publications, reports and teaching materials arising from both the PhD and ARC project
- you understand that while information gained in the study may be published, your child will not be identified and all information will remain confidential
- you understand that there will be no payment for your child taking part in this study

Name .....

Signature .....

Date ..... / ..... / .....

Statement of Child consent

Your parent or caregiver has given their permission for you to be involved in this research project. This form is to seek your agreement to be involved. By signing below, you are indicating that the project has been discussed with you and you agree to participate in the project.

Name .....

Signature .....

Date ..... / ..... / .....

Appendix J Consent form (parent/caregiver)

CONSENT FORM for QUT RESEARCH PROJECT
Parent/Caregiver

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- you understand that you can contact the Research Ethics Officer on +61 7 3138 5123 or ethicscontact@qut.edu.au if you have concerns about the ethical conduct of the project
- you have read the information brochure to your child and discussed the project with him or her
- your child has an understanding of their participation requirements
- you understand that you are free to withdraw your child's participation at any time without comment or penalty
- your child understands that he or she may withdraw from participation at any time without comment or penalty
- you agree to allow your child to participate in the project
- you understand that the project will include digital audio and video recording and photography
- you give permission for these digital recordings, images and photographs to be used in publications, reports and teaching materials arising from both the PhD and ARC project
- you understand that while information gained in the study may be published, your child will not be identified and all information will remain confidential
- you understand that there will be no payment for your child taking part in this study

Name .....

Signature .....

Date ..... / ..... / .....

Statement of Child consent

Your parent or caregiver has given their permission for you to be involved in this research project. This form is to seek your agreement to be involved. By signing below, you are indicating that the project has been discussed with you and you agree to participate in the project.

Name .....

Signature .....

Date ..... / ..... / .....

Appendix K Participant information form (teacher)

PARTICIPANT INFORMATION for QUT RESEARCH PROJECT: Teacher

Young children's statistical reasoning
(linked to: ARC Project DP 0984178 - Restructuring statistical reasoning in the early school years: A longitudinal study of data modeling)

Research Team Contacts	
Ms. Virginia Tregenza, PhD candidate 0407 782 950 virginia.tregenza@unisa.edu.au	Professor Lyn English, Chief Investigator (07) 3138 3329 l.english@qut.edu.au

Description

This project is being undertaken as part of a PhD project for Virginia Tregenza. The project is linked to and funded by the Australian Research Council (ARC) Project DP 0984178 – *Restructuring statistical reasoning in the early school years: A longitudinal study of data modelling*. The funding body will have access to the data obtained during the project. The PhD Candidate is a student of the Queensland University of Technology (Brisbane, Qld) who resides in South Australia and is supported as an external student by the University of South Australia.

The purpose of this project is to:

1. Trace and document young children's use and development of core statistical ideas, knowledge and reasoning skills that they bring to finding solutions to real world data modeling problems that involve mathematical and scientific data;
2. Increase our theoretical and empirical knowledge base of the context and conditions created by real world data modeling problems that support young children's engagement in statistical reasoning and learning.

The PhD candidate requests your assistance to gather data by implementing real world data modeling problems in a real world classroom.

Participation

Your participation will involve the implementation of several instructional activities (data modeling problems) in the third term of the 2010 school year. This will involve 4 activities involving two 45 minute sessions in a week (8 sessions in total), with intervening periods of 2 weeks across a 10 week period (a school term) and 2-3 liaison sessions of 20 minutes with the PhD researcher. Data collection for the research project will require audio and digital recording of classroom activities and discussion and the collection of children's artifacts generated during the activity sessions.

Your participation will involve teaching as part of your normal school classes within existing curricula and will not compromise student's learning. Rather, it is anticipated that the experiences will have benefits that will enhance learning.

Your participation in this project is voluntary. If you do agree to participate, you can withdraw from participation at any time during the project without comment or penalty. Your decision to participate will not impact in any way upon your current or future relationship with QUT (for example your grades), the University of South Australia or with the Australian Research Council.

Expected benefits

It is expected that this project will benefit you and the students. It is expected that this research project will engage young children in data modeling and statistical reasoning and thinking. The foundational statistical ideas and processes, core mathematical and science learning developed will lay the groundwork for children's subsequent study of key learning ideas in mathematics, science and society and environment. In addition, data-modeling is a fundamental tool for many future-oriented disciplines needed for productive participation in an increasingly complex society.

Risks

There are no risks beyond normal school attendance associated with your participation in this project. However, as part of my responsibility as a researcher, please note that in the unlikely event that this research causes adverse effects, QUT provides for limited free counselling for research participants who may experience distress as a result of their research participation. Should you wish to access this service, please contact the Clinic Receptionist of the QUT Psychology Clinic on (07) 3138 4578. Please indicate that you are a research participant.

Appendix L Consent form (teacher)

CONSENT FORM for QUT RESEARCH PROJECT: Teacher

Research Team Contacts	
Ms. Virginia Tregenza, PhD candidate 0407 782 950 virginia.tregenza@unisa.edu.au	Professor Lyn English, Chief Investigator (07) 3138 3329 l.english@qut.edu.au

Young children's statistical reasoning
(linked to: ARC Project DP 0984178 - Restructuring statistical reasoning in the early school years: A longitudinal study of data modeling)

Statement of consent

By signing below, you are indicating that you:

- have read and understood the information document regarding this project
- have had any questions answered to your satisfaction
- understand that if you have any additional questions you can contact the research team
- understand that you are free to withdraw at any time, without comment or penalty
- understand that the project will include digital, audio and video recording and photography
- give permission for digital recordings and images of yourself to be used in publications, reports, teaching and instructional materials arising from both the PhD project and the ARC Project.
- understand that you can contact the Research Ethics Officer on +61 7 3138 5123 or ethicscontact@qut.edu.au if you have concerns about the ethical conduct of the project
- agree to participate in the project

Name .....

Signature .....

Date ..... / ..... / .....

Appendix M Baxter Brown – book cover and story text

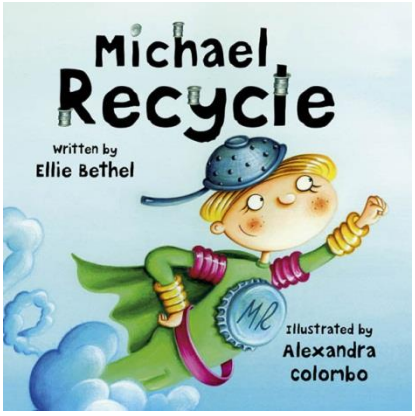
© Lyn English 2009

Baxter Brown is a very special dog. He is a white Westipoo. Do you know what a Westipoo is? It is a cross between a West Highlander Terrier and a Poodle. Baxter brown is so lucky he has his very own bedroom in Mr and Mrs Brown's home. But Baxter Brown's bedroom is always very messy because he loves to collect things. Here are some of the things he collects: bones, apple cores, newspapers, cereal packets, old toys, empty drink cans, plastic bags, biscuits, old shoes and milk cartons. Baxter brown has collected so many different things that he can hardly move in his bedroom. He has empty packets, biscuits, cans, apple cores everywhere - on his floor, in his bed, on his chair, on his book shelves, and in his cupboards. One morning, Mr and Mrs Brown noticed that Baxter Brown was missing. Where could he be? Is he sleeping in his washing machine, one of his favourite places? Mt and Mrs Brown looked everywhere. They looked in the laundry, they looked in the lounge room, they looked in their bedroom, they looked outside, and they looked in Baxter Brown's bedroom. He was nowhere to be seen. "Where on earth has Baxter brown gone?" wondered Mr and Mrs Brown. We need to search the house and the yard one more time. Baxter was not inside the washing machine. He was not behind the couch. He was not outside in the yard and he was not in his bedroom. "Wait a minute," thought Mr and Mrs Brown. "How do we know Baxter Brown is not inside his bedroom? He has gathered so much junk that it is difficult to find anything in his

bedroom. Let's check one more time!" What do you think Mr and Mrs Brown noticed? …Pages 7 and 8

Finally, Mr and Mrs Brown reached the long, thick white tail that was waving above the rubbish. "Is that you Baxter Brown?" The tail kept swaying. "We have to remove some of his rubbish to see if it is him." Mr and Mrs brown removed: 3 bones, 5 empty drink cans, 4 cereal packets, 3 biscuits, 2 old toys, 2 plastic bags. "Is it Baxter Brown?" Yes, it is him. What are you doing under all that rubbish, Baxter Brown?" "I got lost in my room. I didn't know how to get through all the rubbish. What should I do?" What do you think Baxter Brown should do? "Yes, I think I need to clean up my room!" replied Baxter brown. "Well, we certainly think so" replied Mr and Mrs Brown.

Appendix N Michael Recycle – book cover and story text

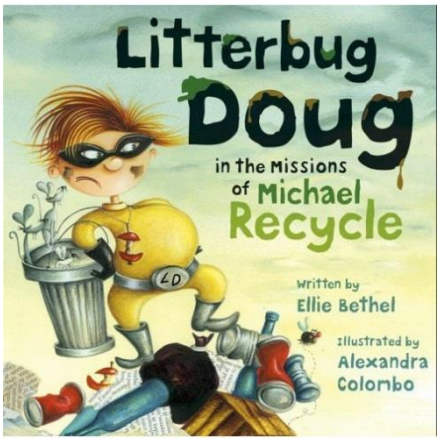


Michael Recycle (2008**)** Ellie Bethel. Illustrated by Alexandra Colombo. Koala Books: Mascot Australia.

There once was a town that was really quite grimy, where rubbish was left to go rotten and slimy. It never smelt fresh and the air was all hazy; and the people were wasteful and useless and lazy! But then something happened that none could explain. It wasn't a bird and it wasn't a plane. A green-caped crusader stupendously swooped, descending to earth with a great loop-the-loop! He bounced off the earth with a thump and a bump, and came to a stop on a big rubbish dump. "I'm Michael Recycle for all that I'm worth! I'm green and I'm keen to save planet earth! "You must stop this now! You've got to act soon. There are towers of trash that reach up to the moon! Now pass on this message, get yourself heard: wasting is rubbish. Recycling's the word! Then crushing a can, he gave them a wink, and vanished from sight before they could blink! With whispers of wonder they turned to each other, and sister told brother, while dad said to mother, "A clean and green town would be so nice to see! The boy's got a point, just how hard can it be?" They recycled their paper, their cans and their plastic, transforming old junk into something fantastic! They even began a "be greener campaign" where they grew their own food and collected the rain. So proud was the town of their green transformation they threw a big party, a grand celebration! They covered the town using green toilet paper (but carefully rolled it back up to use later!) When Michael flew back in to visit town, he

didn’t get angry or dejected or down. The people did everything they had been told, the streets were a wonderful sight to behold! “Look at our town!” “It gleans and it glitters! And nothing is wasted and nobody litters!” “To Michael Recycle! The green-caped crusader our super-green hero, our planet’s new saviour!” But Michael recycle was nowhere around, he’d already gone on to save the next town. So if you should see a dark silhouette, that streaks through the skies like a super-fast jet, Just give him a wave as you shout out his name, it’s Michael Recycle, recycling again!

Appendix O Litterbug Doug – book cover and story text

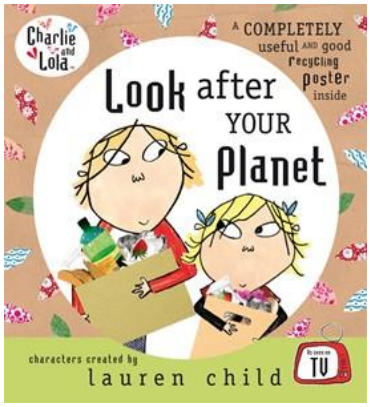


Litterbug Doug. Ellie Bethel. Illustrated by Alexandra Colombo. Koala Books: Mascot Australia.

In a beautiful valley, in the shade of a hill, was a clean little town that was full of goodwill. But the quaint little town had a problem to face for on top of a hill stood a mountain of waste! And who was the culprit? Who was the thug? It was lonely and lazy-boned Litterbug Doug! His house was a rubbish dump, full of old stuff, that was rotting and mouldy and smelly enough to make your eyes water (the pong was so strong) but Doug didn't think he's done anything wrong. And his only real friends were a hundred odd rats (except for two lazy and fat tabby cats). From alone on his throne Doug thoughtlessly threw all manner of litter and so the pile grew. A rotting banana, some mouldy old cheese, faulty fridge freezers, and smashed up TV's. A table, a tandem, an old three piece suite, all kinds of old rubbish was hurled on the heap. And then to the joy of the hundred odd rates, Doug even got rid of his two tabby cats! The cats were so fat that they made the dump fall, and down came the rubbish heap, rats, cats and all! But then something happened that none could explain. It wasn't a bird and it wasn't a plane. A green-caped crusader stupendously swooped, descending to earth with a great loop-the-loop! "Litterbug Doug," said our green-hero Michael, "littering's rubbish, you've got to recycle!" But Doug just

retorted, “I won’t make amends. I don’t need these people, the rats are my friends! “But Doug don’t you care that the litter you’ve hurled is rotting and reeking, polluting our world? “it’s hard to believe but I guess it depends, do you really want rats and not people as friends?” Then thinking aloud Doug said “I suppose, they do give me fleas and they nibble my toes! They make quite a racket, their hygiene’s not great, I’d love some real friends but is it too late? “Of course not!” said Michael, “with all hands on deck, we can work hard together to save you just yet!” They formed a big chain from Doug’s rubbish to Michael, to sort out the rubbish and what to recycle, And soon all the town was so neat and pristine, the only thing left was to give Doug a clean! So now he was neater and no longer smelled, they gave him a job at which he excelled. So watch out! Don’t litter or drop one small piece, Doug’s there in a flash, he’s the Litter Police.

Appendix P Charlie and Lola – book cover and story text



Charlie and Lola. Lauren Child. Puffin Books: London.

I have this little sister Lola. She is small and very funny. Lola loves keeping things. All kinds of things. Boxes, old broken toys…just things. ”Not any more!” says Lola. I say, “has it got anything to do with when we went to Marv’s house?” And Lola says, Mmm, maybe…” Yesterday, Marv said, “I dare anyone to go into my big brother Marty’s room. He doesn’t let anyone touch any of his things and he won’t throw anything away. Mum says his room looks like a complete pigsty.” I say, “he can’t be that bad.” When we sneak into Marty’s bedroom, Lola says, “ooh, it’s pongy.” But then we hear, “get out of my room! …NOW!!” And Marv shouts, “Run!” “So you see, Charlie, I do not ever, never want my room to look like Marty’s. So I am throwing everything away. Because I do not need it. “ “Why don’t you reycle it?” And Lola says, “Bicycle it?” “No, re-cycle it.” “Recycle it? What is that?” says Lola. “Well, it’s a way that people can reuse old things in a different and NEW-ish way.” “Why?” says Lola. “Because if we throw everything away, then we will all be completely buried under a massive, huge pile of rubbish. “And if we don’t use things again, in the end we will just run out of everything. So recycling is a good thing. Did you know there are these places where they make new paper out of old paper. The old paper gets squidged up with water and things. And then they press it

all flat. “Then they make all sorts of NEW types of paper, like…writing paper, egg boxes, wrapping paper, and colouring in paper.” “That is clever,” says Lola. Later Lola says, “Look, Charlie! Mum bought me this special comic. It’s called Look After your planet and there’s lots about recycling in it. “ And I say, “Ooh! A competition. You can win a tree all of your own to plant.” “What do we have to do?” says Lola. “We have to collect a hundred of each thing. One hundred tin cans, one hundred plastic things, and one hundred things made out of paper.” “That’s a lot of things,” says Lola. “Look, Lola! Your very own tree counter.” “Every time you collect something to recycle you can stick a leaf on a branch. When your tree counter is completely full up you can get your very own real tree to plant.” Lola says, “I would love to plant a tree.” “Well, you’d better get recycling.” And Lola says, “OK, Charlie! This box is for all the plastic things and this one is for tin cans and this one is for paper. And I have already recycled two plastic things, a baked bean tin and some paper.” I say, “I’m not sure we will be able to collect a hundred of each thing in just two weeks, Lola, all on our own.” And Lola says, “Of course we can, Charlie. Have you finished? Good…” Later Lola says, “See, Charlie! I can recycle these toilet rolls.” And I say, “The idea is to use the paper really slowly and not waste it – so we don’t have to cut down lots of trees! The you recycle the rolls.” “Well, we need some more leaves on our tree counter. So maybe we need to ask even more people. “ Then next day at school, Lola says, “We have to save the trees and stop us being covered in a big large pile of rubbish. If we fill this tree with leaves, we will win our very own real tree for the school. Everyone is excited and says, “I want to do recycling…pass it on.” “I want to do recycling…pass it on.” “I want to do recycling…pass it on.” So everyone at school starts recycling. “Look how many I’ve got!” “I’ve got lots too!” “You are a very good recycler, Lotta!” “Oh, Morton, you’re not helping.” So Morton goes home…and he finds more things to recycle. When everything is recycled, Lola says, “Oh, no. We have NOT filled up the whole tree…so we will not be getting our own real tree.” But then Morton comes along. Lotta says, “Look at what he’s got!” And soon we have filled up the tree counter. “Thank you Morton!” says Lola. “You are a very good recycler.” Then Marv whispers to Morton, “Where did you get all that?” And Morton says, “Marty’s bedroom.” Marv says, “You are going to be in such big trouble.” The next day we all go outside to plant our real, actual school tree. “Look! Our very own real school

tree!" says Lola. "We are extremely very good recyclers, aren't we!" Later, when we are all around at Marv's, suddenly we hear, "Who's been in my ROOM?" "Let's get out of here!" says Marv. And Morton says, "Quick! Run for it!"