An Investigation of Young Children's Understanding of Graphs

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This paper contains no material which has been accepted for the award of any other degree or diploma in any tertiary institution and to the best of my knowledge, contains no material previously written by another person, except where due reference is made in the text of the paper.

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CONTENTS

Abstract

> Statistics, tables, charts and graphs abound in our daily world. We see them in advertisements, in newspapers, and on televised weather forecasts. However, many students are not exposed in school to experiences using statistics and graphing (Hitch & Armstrong, 1994, p. 242).

This paper highlights the need for the teaching of statistical ideas to begin in an explicit and intentional manner in early childhood settings. It proposes a rationale for the introduction of statistical ideas, based on the need for all people to have effective data handling skills in an information rich society and recommendations made in recent curriculum statements and policies. It is suggested that data handling processes provide a meaningful context for the introduction of a wide variety of mathematical ideas, enabling teachers to use classroom approaches which are acknowledged as effective for young children's learning.

Research into Tasmanian kindergarten children's understanding of simple graphs and various forms of data representation, is reported. Results of this investigation indicate that it is possible for the teaching of statistical ideas to begin in an intentional and meaningful manner in early childhood settings. Recommendations for future classroom practice and future research in this important area of mathematics are also made.

Chapter 1

A Rationale For Data Handling in Early Childhood Mathematics Curricula

Data Handling- An important mathematical concept for all children?

Few predictions for the future in recent decades have omitted reference to 'the information age' and suggestions that we increasingly need to know how to manage and make sense of the large amounts of data which confront us on a daily basis. The advent and ever-increasing power of computers enable us to access information from world-wide data bases and the media bombard us with graphs, charts, tables and other statistical information.

> Data handling refers to the collection and analysis of information and its presentation in forms which convey a message or which assist people to draw conclusions or distil concise, but meaningful summaries (Department of Education and the Arts [DEA], 1993a, p. 5).

More than a decade ago Jones in his forward-thinking publication *Sleepers Wake* (1982) alerted decision makers to statistics that indicated the extent to which we are reliant on data.

> Australia is an information society in which more people are employed in collecting, storing, retrieving, amending, and disseminating data than producing food, fibres and minerals and manufacturing products (p. 173).

He urged employers and governments to consider changes to policies, including educational curricula to prepare Australians for life in a post-industrial information-based society. It is only in recent years however, that recognition of the importance of data handling skills for all Australians has become evident.

It is not only in the workplace where we depend on access to data, as we base many of our daily decisions such as supermarket purchases on numerical information gleaned from a variety of sources. In fact it is suggested by many that:

> To be an informed citizen or productive worker today, a person must have some facility for dealing with data and for making intelligent decisions based on quantitative arguments (Burrill, Scheaffer & Rowe, 1991, p. 3).

In order that tomorrow's adults are able to make such interpretations and decisions, it is desirable that schools begin the teaching of statistical concepts as early as possible. Classroom experiences should build on what children have been exposed to even before school, as a result of interactions with the media or life experiences they may have had. This chapter proposes a rationale for the inclusion of planned and ongoing experiences in data handling for children in the early childhood years (kindergarten - Grade 3).

Three main reasons will be cited for the inclusion of data handling concepts:

- the importance of these ideas for later life,

- the potential for these experiences to help children understand what it means to behave as a mathematician does,

- the potential for classroom experiences in this area of mathematics to capitalise on what we know about the way young children learn best.

Each of these will be discussed in turn.

The importance of data handling to future mathematical literacy

The publication of curriculum documents such as *A National Statement on Mathematics for Australian Schools* (Australian Education Council [AEC], 1991a) has lead to increased discussion and professional learning about appropriate mathematics curricula for the 1990s and beyond. One area of mathematics learning which has been given new emphasis in response to our changing and increasingly technological world is data handling. The AEC (1991b) suggested this is an important area of study for all students when it stated that:

> Developments in communication technologies have meant a flood of information is now available to all of us. To be able to interpret and use this information requires us to have some understanding of such things as statistics, probability, estimation and orders of magnitude. It is important that these aspects of mathematics become part of school mathematics for all students (p. 17).

It has been suggested that mathematical literacy in the current context is dependent on skills in information processing and data interpretation. Recent curriculum documents have recommended changes to mathematics curricula based on the influence of statistical ideas in our lives at a personal and national level.

> Current issues - such as environmental protection, nuclear energy, defense spending, space exploration, and taxation - involve many interrelated questions. Their thoughtful resolution requires technological knowledge and understanding. In particular citizens must be able to read and interpret complex, and sometimes conflicting information (National Council of Teachers of Mathematics [NCTM], 1989, p. 5).

The significance of data handling skills for future numeracy has given it increased status in the mathematics curriculum, chance and data being described as one of the five key content strands in the publication *A National Statement on Mathematics for Australian Schools* (AEC, 1991a). This emphasis is justified by the following premises:

> A sound grasp of concepts in the areas of chance, data handling and statistical inference is critical for the levels of numeracy appropriate for informed participation in society today. Data provides us with a powerful means of forming opinions and reaching conclusions quite different to those we would reach if we relied upon, for example, hearsay... as the amount and variety of quantitative information confronting people have increased, however, so too has the need to understand the strategies for data collection and analysis... statistical inference underlies such diverse matters as weather prediction, economic indicators, medical and other research design, risk

> insurance, gambling and quality improvement. Ultimately it effects the lives of all people individually and collectively (p. 163).

Similar justification is provided by the American Statistical Association.

> Raw data, graphs, charts, rates, percentages, probabilities, averages, forecasts and trend lines are an inescapable part of our everyday lives. They affect decisions on health, citizenship, parenthood, employment, financial concerns, sports and many other matters...since the need to collect, organise, display, and interpret data is basic to our society, the...education system must place more emphasis on teaching statistics and probability (Burrill et al., 1991, p. 3).

Traditionally, the mathematics curriculum has focused on the development of data handling and statistics at the senior levels of schooling with little or no emphasis on the early teaching and learning in primary and early childhood mathematics programs (Reys, Suydam & Linquist, 1992). Some early childhood children experience making graphs or collecting information about the children in a given class, however the long term intentions of such experiences or provision of continuity of experiences are not always evident. This may be because teachers place an over-emphasis on the teaching of early number concepts or because they are not confident in their ability to extend children's statistical ideas, or it may simply be related to the limited emphasis previously placed on this area by policy makers and curriculum developers. It might also be suggested that some teachers avoid dealing with these areas of mathematics because they have negative attitudes towards areas with which they are personally uncomfortable (Greer & Ritson, 1993).

Russell and Corwin (1989) supported the introduction of data handling concepts to young children when they likened the introduction of statistical ideas to young children to the introduction of literature. They commented that:

> We introduce students to good literature in their early years. We do not reserve great literature until they are older - on the contrary, we encourage them to read it or we read it to them. Similarly we can give young students experience with real mathematical processes rather than save the good mathematics for later on (p. 1).

Data handling and interpreting skills are recognised as significant prerequisites for mathematical literacy and everyday functioning now and even more so in the future. As educators we have a responsibility to develop these skills throughout the schooling years beginning in kindergarten.

How data handling experiences can lead children to understand what it is to be a mathematician

When young children learn to read and write, teachers spend a great deal of time modelling and discussing what it is to be a reader and writer and what it is that adults do when they engage in these activities. These teaching strategies, combined with numerous opportunities to read and write, explicitly help the child understand what it is they need to do to enter the world of reading and writing.

So too in mathematics, it is desirable to help children work mathematically and function as a mathematician does, rather than seeing mathematics as a series of isolated tasks. A data handling investigation which involves posing a question, thinking of and sharing ways to find answers, collecting and analysing, then representing and interpreting data involves children in working together, dealing with uncertainty, suggesting and accepting/rejecting theories, and realising that there is not always a single clear answer. This replicates the work of mathematicians and scientists who "use information or data like snapshots to look at, describe and better understand the world" (Russell & Corwin, 1989, p. 2).

An investigation such as finding out which pets children in one class have and then comparing the information with which pets children in another class have involves children in a holistic mathematical experience, where they are using knowledge of mathematical ideas such as counting, adding, subtracting, predicting, using mathematical language, conjecturing and using problem solving strategies as well as working in a context. These are all processes which are identified by the AEC as significant features of working mathematically (1994, pp. 4-5) and noted as desirable outcomes for all children.

Data handling experiences enable us to capitalise on what we know about the way children learn best

An abundance of research in the area of young children's learning leads to the conclusion that children learn best when the experiences they are offered are embedded within a meaningful context (Vygotsky, 1962; Donaldson, 1978; Hughes, 1986; Fleer, 1992). The findings of these researchers have helped early childhood educators realise that young children can and do learn quite sophisticated ideas long before it was once considered appropriate, provided the ideas are presented in an appropriate manner.

Bruner (1971) suggested that:

> There is an appropriate version of any skill or knowledge that may be imparted at whatever age one wishes to begin teaching - however preparatory the version may be. The choice of the earlier version is based upon what it is one is hoping to cumulate (p. 35).

This suggestion implies that teachers of young children should not only build on what is known about the way their students learn best but should also have a good grasp of the key mathematical ideas for which these early experiences provide a foundation. Understanding the key ideas within data handling and representation leads to the realisation that these ideas can be dealt with by young children, since they can be presented in a personally relevant context.

Because of their egocentric nature, young children are intuitively interested in answering questions about themselves, their families and their friends. It is this intuitive questioning which can be capitalised on in considering how data handling may be introduced into the early childhood curriculum. The early processes of data handling may be considered particularly appropriate to young children because they can be used to solve problems which are:

> Often inherently interesting, represent significant applications of mathematics to practical questions, and offer rich opportunities for mathematical inquiry. The study of statistics and probability highlights the importance of

> questioning, conjecturing and searching for relationships when formulating and solving real world problems (NCTM, 1989, p. 54).

This means that, rather than presenting young children with a 'watered-down' version of statistics for secondary school, we should look for ways to ensure that early experiences are meaningful and personally relevant in much the same way that Bruner (1973) suggested when he proposed that:

> It is possible to draw up methods of teaching the basic ideas in...mathematics considerably younger than the traditional age (p. 419).

Teachers who adopt these approaches and hold these beliefs about young children's learning are able to use these contextualised experiences in data handling to help children confront and come to understand key mathematical ideas such as addition and subtraction. These ideas can be introduced and dealt with as a meaningful part of an investigation, rather than teaching them as separate skills to be mastered prior to the introduction of 'real' mathematical problems.

The work of the Russian psychologist Vygotsky has been influential in establishing that young children learn through social interaction and finding shared meanings with others (Baroody & Ginsburg, 1990; Fleer, 1992; Mannigel, 1992). Many mathematical tasks are however, currently presented as solitary tasks for individuals and allow little social interaction, either child/child or teacher/child. By its very nature, data collection, representation, discussion and interpretation cannot be easily done alone and can be an ideal vehicle to involve children in the process of collaborating together and learning from each other.

> Social interaction is a process by which individuals create interpretations of situations that fit with those of others for the purposes at hand. In doing so, they negotiate and institutionalise meanings, resolve conflicts, mutually take each others' perspectives and, more generally, construct consensual domains for co-ordinated activity...social interaction therefore constitutes a crucial source of opportunities to learn mathematics (Cobb, Wood & Yackel, 1990, p. 127).

Ideal opportunities for collecting data arise in the day-to-day functioning of a classroom, e.g., "How many people are here today?," "Who has a pet at home?", etc. and children can decide how they, as a whole class or in groups will collect their information and present it to others. School environments provide easy comparative studies, eg., "Are there more boys in Mrs Jones' class than in our class?", "How do the results of our family graphs compare to those in the class down the corridor?"

There is much evidence to support the notion of an integrated approach to curriculum provision at the early childhood level, acknowledging that young children do not see the world as a set of subject areas and they learn best through the integration of learning areas within the classroom program (DEA, 1994). Experiences with an in depth data analysis activity starting from questions and leading to representation and interpretation of findings, allows a number of curriculum areas to be addressed. Many of the outcomes listed by the AEC in areas as diverse as Studies of Society and Environment, the Arts, Technology, English and Mathematics can be achieved through one well-planned and thoughtfully considered experience with data handling. For example, an essentially Social Studies teaching unit focusing on 'Our Families' might incorporate asking questions such as "How many people are in our families?" This could be answered by collecting data, by representing it in a suitable format or by using suitable technology to present it for an audience, comparing information with other classes, writing about the results and considering how to display the final product, if there is one.

Data handling can, therefore, be an important aspect of the mathematics program in an early childhood classroom and should not be ignored as a potentially rich mathematical experience for young children. Through exposure to asking and answering questions about themselves and others using data collection, display and interpretation, young children are involved in a relevant and engaging mathematical context. Involvement in these activities enables them to gain not only an understanding of data concepts, so important to later mathematical literacy in an information rich world, but also experience with many other ideas in mathematics such as counting, measuring, communicating mathematically and predicting, which are a direct link to understanding early ideas about probability and chance.

Conclusion

This chapter has highlighted the importance of including experiences with data handling in the early childhood curriculum in a world where we are constantly confronted with quantitative information and the opportunities provided by these experiences make mathematics personally relevant and meaningful for young children. Further chapters in this paper provide a review of available research in this area, report on research into kindergarten-aged children's understanding of simple graphs and make recommendations for classroom practice in the initial school setting regarding the teaching of these important mathematical ideas.

Chapter 2

Literature Review

Introduction

This chapter presents a review of available research in the area of children's understanding of statistical ideas and more particularly what they understand about graphing concepts. A review of current curriculum recommendations for statistics education in the early years of schooling is also discussed.

The research component of this project focuses on establishing insight into young children's intuitive understanding of simple pictographs and bar graphs. This area was selected for investigation to inform future classroom practice in early childhood settings and to gain insight into what intuitive ideas children have prior to any explicit teaching of early data handling skills. Hughes (1986) showed in his research that young children bought with them many ideas about mathematics which are not acknowledged or probed on entry to school by kindergarten teachers. He suggested that if links between what children knew prior to school were made with teaching episodes in the early childhood classroom, more children would experience success in school mathematics. If we can determine what children know about simple graphs, recommendations can be made for teaching approaches which connect their knowledge with classroom-based experiences and extend their understandings.

This approach supports the constructivist view of learning, held by many mathematics educators which suggests that new concepts are learnt when existing concepts are challenged. Only by ascertaining what children already know can we challenge their misconceptions and lead them to make meaning from their experiences.

> Children must be given the opportunity to assimilate mathematical knowledge -to construct accurate and complete mathematical understandings (Baroody & Ginsburg, 1990, p. 63).

> It is important that teachers continuously strive to estimate the nature of children's representations. Teachers' knowledge of children's thinking makes it possible for them to challenge and extend students' thinking and appropriately modify or develop activities for students (Maher & Davis, 1990, p. 90).

Recommendations for classroom experiences in data handling concepts have been documented in detail in recent years, based on calls for a more mathematically literate and statistically capable population. It is interesting to note, however, that these recommendations, as discussed below, have not been based on or accompanied by a sufficient research base (Gal & Wagner, 1990, p.1).

Suggested experiences in data handling for young children.

A National Statement on Mathematics for Australian Schools (AEC, 1991a) articulates current views on appropriate experiences for students at various bands of schooling. In the years Kindergarten to Grade 4 (Band A) it is recommended that teachers provide experiences in data handling which enable children to:

> frame questions about themselves, families and friends and collect, sort and organise information in order to answer these questions
> and
> represent and interpret information to answer questions about themselves, friends and families (p. 167).

In the local context, Tasmanian state education curriculum guidelines recommend that the emphasis in the K-8 years should be on activities which allow children to:

> Systematically collect, organise and record data to answer questions posed by themselves and others
>
> Use particular data-handling processes and strategies that can help them:
>
> • question the appropriateness of the data they use as the basis for decision-making

• organise and present the information they have collected and sorted to communicate the conclusions drawn

• interpret and perhaps re-organise presented information to answer questions about themselves and others

• have opportunities to draw distinctions between a sample and a population, and explore the appropriateness of both through personal experience

• use calculators and microcomputers in their handling of data and analysis of chance situations

• use their data as a basis for conjecturing, describing and generalising and consider the social impact of technological change on the collection and handling of data.
(DEA, 1993a, pp. 6-7)

Similar recommendations are made in documents from around the world, highlighting the common agreement of mathematics educators in this field. For example, a recent document from the United States suggested that children in the years Kindergarten-Grade 4 should experience activities involving data analysis and probability which enable them to:

collect, organise and describe data
construct, read, and interpret displays of data
formulate and solve problems that involve collecting and analysing data.
(NCTM, 1989, p. 54).

These curriculum frameworks all emphasise the personal nature of data collection and statistics in the early years of schooling, with children being encouraged to collect information to answer questions they and their friends have posed. As children in the first three years of schooling are in the main egocentric and primarily interested in themselves, approaching the teaching of data handling through the collection of personal data makes classroom mathematics far more meaningful and contextualised. The collection of data about the children's families, pets, favourite foods and television programs for example, can help make connections between home and school and help children see that mathematics helps us make sense of our world.

Most curriculum guidelines suggest that the earliest experiences children have in their school data handling activities should involve representations using concrete materials to form simple pictograms and graphs and the interpretation of the same (AEC, 1991; NCTM, 1989).

These recommended experiences seem to be appropriate and useful in informing teachers about directions for their mathematics program in the area of data concepts. We may ask, however, on what basis they have been made and would be surprised to find that there is very little documented research evidence available. Hoeffner (1993) asked the question:

> ...why are there so few studies that validate appropriate curriculum materials for teaching concepts of measurement, probability, statistics and graphing? (in Bright & Hoeffner, 1993, p. 96).

Education systems around the world are increasingly focusing on expected student outcomes and explicitly documenting developmental sequences. The AEC (1994) publication *Mathematics- a curriculum profile for Australian Schools* describes eight levels of mathematical learning relating to each of the content areas described in *A National Statement on Mathematics in Australian Schools* (AEC, 1991). In the Chance and Data strand at level one (typically early childhood) a student can be expected to:

- With guidance, pose questions about collected objects and information
- Participate in classifying and sequencing objects and pictures
- Display objects and pictures and describe data in words and numbers

(AEC, 1994, pp. 32-33).

These expected outcomes have been complied on the basis of a 'best guess' by the writers. There is a limited research base on which they have been developed. It is hoped that they may be verified or rejected as appropriate or otherwise, as teachers explore a wider mathematics curriculum with children at different levels of schooling and further research is conducted on students' statistical understanding.

> There is much work yet to be done, both in the development of assessment instruments and their validation and referencing if any systematic comparative analysis using the profiles on a national basis is to occur (Willmott, 1994, p. 42).

These curriculum recommendations and expected outcomes assume a great deal about the teacher's ability to plan and implement a quality teaching program. In fact the outcomes listed in the curriculum profiles are based on the premise that with "good teaching" they will be observed. A literature search reveals that teachers are often uninformed about the mathematical ideas involved and uncomfortable with their ability to teach statistics. This has implications for the sorts of mathematical experiences children have in the classroom and by implication, influences their understanding of statistical concepts.

Research into Student's Statistical Understanding

Leinhardt, Zaslavsky and Stein (1990) in their comprehensive review of the available research into this area of mathematical learning acknowledge the importance of research into this area, commenting that there is an abundance of work focusing on the early acquisition of ideas of addition and subtraction, fractions and word problems (p. 2) and very little specifically focusing on graphs, particularly graphing in relation to functions. They found that "actual studies of teaching at either the elementary or secondary level are quite rare and, in general unconnected to the knowledge that a student develops" (p. 54).

Gal, Rothschild and Wagner (1989, 1990) highlighted the paucity of research into young children's understanding of statistical ideas, noting that this is surprising, given the plethora of curriculum documentation, as described earlier in this chapter, suggesting that statistical literacy is an important aim for school mathematics. They suggested that this may be because American children learn very little about statistics in school.

> Most are taught only how to mechanically read charts and graphs, and perhaps by 4th or 5th grade, the algorithm for calculating an average (1990, p.1).

We could undoubtedly generalise this finding to Australian classrooms.

Teachers' Understanding of Statistical ideas

It is also important to consider the understanding teachers have of the content and purposes of the mathematical ideas they are dealing with, as these factors will significantly influence the way in which the ideas are taught and the emphasis they are given in the classroom. The limited research findings available on teacher's understanding of statistical ideas indicate that there is a need for thorough pre-service training, continued professional development and the publication of suitable resources to assist teachers in this field.

> Few teachers (math teachers or generalists) have *any* statistical background or experience in teaching statistics (Gal & Wagner, 1992, p. 1).

> Little is known about (a) what knowledge and skills teachers have in this domain (research to date has so far looked only at teachers' knowledge of very specific concepts especially of the average (eg. Mokros & Russell, 1991) ; (b) what attitudes teachers have towards teaching statistics (motivational issues are especially relevant in the elementary and middle grades, where generalists without special math background may be those who teach statistical topics); or (c) what teachers know or believe about their students' statistical knowledge (Gal & Wagner, 1992, p. 6).

A recent survey of teachers in Northern Ireland found that many teachers, particularly at the primary school level find difficulty in fully understanding the issues involved in teaching this area.

> The picture that emerges is of teachers struggling hard to cope with something they find difficult. The difficulties they encounter are not of their own making and serious consideration needs to be given to how best they can be helped (Greer & Ritson, 1993, p. 6).

This study also found that teachers were much less confident in data handling and probability than in other areas of the curriculum, being less aware of what lies ahead and where the experiences they plan are leading to.

> Collecting and recording data are not new to the primary syllabus and bar charts have been in evidence for a long time, but relatively few teachers know what to do next after the graph is drawn (Greer & Ritson, 1993, p. 5).

Why investigate graphs?

> Numeracy requires more than just familiarity with numbers. To cope confidently with the demands of today's society, one must be able to grasp the implications of many mathematical concepts- for example, chance, logic, and graphs - that permeate daily news and routine decisions (Board on Mathematical Sciences and Mathematical Sciences Education Research Board, National Research Council, 1989, pp. 8-9).

Simple bar graphs, pictographs and tally systems represent the most basic representations of data we come across as adults through our experiences with the media and in our working and everyday lives. Pereira-Mendoza and Mellor (1993) suggest that graphical displays allow the reader to visualise and reason about data more easily and believes that "with the advent of computers and other associated technologies the use of graphical displays is likely to increase" (p. 3).

Curcio (1987) cited research which suggested that:

> Processing information in our highly technological society is becoming more and more dependent upon a reader's ability to comprehend graphs. Although a literal reading of data presented in graphical form is a resultant component of graph reading ability, the maximum potential of the graph is actualized when the reader is capable of interpreting and analysing the data presented (Kirk, Eggen & Kauchak, 1980, in Curcio, 1987, p. 382).

Research Focusing on graphs

Kosslyn and Pinker (1983) drew attention to need for research in the field of graphical understanding when they concluded that:

> Even a casual perusal of the literature immediately convinces one that there is a real need for research on charts and graphs, and that there is a real need for a systematic approach to the topic. Research on charts and graphs is, in a word, scanty (in Pereira-Mendoza & Mellor, 1990 pp. 150-151).

In the ensuing decade since Pinker and Kosslyn's call for action, little has been documented to indicate a growth in understanding of children's ideas about or ability to interpret graphs.

A literature search reveals very little research into children's understanding of graphs and much of that which has been done focuses on secondary school children (Curcio, 1981, 1987; Kerslake, 1977) or children already in the primary school (Pereira-Mendoza & Mellor, 1993).

> The research on understanding of statistics concepts (as opposed to probability concepts) has almost exclusively studied students older than those in elementary school , though there is so little of this research that few generalisations are possible about the knowledge of students of any age (Bright & Friel, 1993, p. 1).

Most of the available research cited suggests that many students have misconceptions about and inappropriately use statistical concepts in problem solving. These persist well into adulthood. While abilities to literally read graphs appears to improve with grade level, many students in late primary school and early secondary school have difficulty in interpreting graphs and drawing conclusions requiring higher order cognitive skills (Bright & Hoeffner; 1993, Curcio, 1987, Pereira-Mendoza and Mellor, 1993). Reading and interpreting graphs is a complex cognitive process and is dependent on several factors.

> For seventh graders, prior knowledge of mathematics (e.g. 1 centimetre is less than 1 inch), of the topic of the graph (e.g. understands that height refers to "tallness" rather than "oldness"), and of graphical form (e.g. the tallest bar in a bar graph represents the greatest quantity), are all important for comprehending information in a graph (Curcio, 1987, in Bright & Hoeffner, 1993, p. 91).

These conclusions have significant ramifications for the teaching profession, suggesting that more emphasis might be given to the development and explicit teaching of these skills in the early childhood years and that careful attention should be given to the way in which graphing ideas are presented to and discussed with students.

Pereira-Mendoza and Mellor's (1990, 1993) work is perhaps the most pertinent in informing this project, in that it has focused on primary -aged children and specifically their understanding of pictograms and bar graphs. In their study of students in grades three to six (using a sample of 400 students) they found that children develop quite serious misconceptions about both bar graphs and pictograms which may effect their ability to interpret and read graphs in later years of schooling. These errors fall into three broad categories: non-graph based (e.g., counting errors), graph-based and topic-based. The number of graph-based errors caused the researchers most concern and led them to suggest that teachers need to carefully examine the way they approach the teaching of graphing concepts.

Graph-based errors included children believing there must be a pattern in the graph. The researchers found that children consistently "look for a pattern, even when such a search is unreasonable" (1993, p. 12).

> The urge to force a pattern was so strong for some students that they found a "pattern", even in some cases where the data was not ordered in magnitude or when any attempt to search for a pattern made no conceptual sense (1993, p. 14).

Other children did not use or correctly read scale or misinterpreted the fact that some information was not shown on the graph. This involved children reporting that they could not make predictions because the information "is not on the graph" or interpreting the absence of a symbol on a pictogram as an indication that there is no information.

Pereira-Mendoza and Mellor (1993) suggest that these errors, particularly those with scale, decline with experience but the urge to find a pattern does not. They relate this to the emphasis in many classrooms on seeking and describing patterns, the use of pattern spotting as a problem solving strategy and the over-use of graphs which do have a clear pattern.

Based on Pereira-Mendoza and Mellor's work, Asp, Dowsey and Hollingsworth (1994) conducted research into Australian children's understandings of pictographs and bar graphs with similar findings reported.

> Younger student's showing a greater tendency than older students to use prior ('world') knowledge and a greater likelihood of sticking to incorrect conclusions despite what the data indicated (p. 64).

These findings have clear implications for the classroom teacher in planning a mathematics program which incorporates data handling and more specifically, graphing concepts. The findings of these researchers indicate that children should be exposed to a broader range of graphical forms and become involved in experiences which challenge their ideas about graphs.

> Students need to see data where there is no pattern and prediction is not possible; where patterns exist but prediction is not reasonable; and they need experiences in which they predict within a range and realise that a specific solution is not appropriate (Pereira-Mendoza & Mellor, 1993, p. 17).

With respect to the teaching of pictograms, which is a common classroom activity in early childhood classrooms, Pereira-Mendoza and Mellor (1993) suggest that more emphasis might be placed on helping children differentiate the graph from their knowledge of the topic, given that so many of the children in their study suggested answers to questions in a logical way which reflected reality but could not be answered by the representation in front of them. For example, in response to questions about a pictogram showing how children get to school, many children, when asked to predict how a new child to the class might get to school, told a logical story about parents bringing the child because he/she was new, etc. While these stories made sense to the child viewing the pictogram, they could not be inferred from the information presented by the graph.

Future Directions for Research

As has been indicated earlier in this chapter, there is very little research in the field of statistics education particularly in relation to young children's understandings; and there is much scope for future investigation of both students' and teachers' knowledge of the key ideas. Leinhardt et al. (1990) concluded that if mathematics educators are to further communal understanding in the area of graphing and functions they need to:

> Understand what students know and the power and utility of their intuitions at different age levels and after different kinds of instruction...we need to have studies of instructional sequences and how they affect the learner. We must also have emperical [sic] studies of the effects of computers as facilitators and as problems for the learner (p. 54).

It is also important to consider the need for further research into early childhood teachers' understanding of and attitude toward the teaching of statistical ideas, as these factors will significantly contribute to the teaching of these ideas in the classroom.

> It is essential to have a theoretical basis from which to analyse student and teacher understanding of constructs in probability and statistics (Watson, 1992, p. 10).

Conclusion

This chapter has indicated that there is common agreement as to the curriculum content and classroom approaches recommended in most western countries for young children in regard to the introduction of data concepts. There is, however, little research to support the claims made by curriculum developers. There is much to be gained from further research into the understanding of statistical ideas by both teachers and children particularly at the early childhood level, where documented research findings are virtually non-existent. Therefore, the research reported in this project is of particular value in providing insight into the ideas of very young children and suggestions for future classroom action, especially at the kindergarten level. If action is taken to ensure effective teaching of graphing in the early years of schooling, some of the misconceptions reported by researchers working with older children may be prevented.

Chapter 3

Research Methodology

> Teaching students to read and interpret graphs accurately may be more important than teaching them to construct graphs (Bright & Hoeffner, 1993, p. 91).

Little focus appears to be given to interpretation of data collected and represented by others in early childhood programs. Emphasis is given to classroom activities which involve collecting and representing data, however, it is equally important to develop skills in interpreting and reading data. Much of our day to day dealings with numerical information in situations such as reading the newspaper or watching a television news broadcast rely on an ability to interpret the information in whatever format it is presented.

As stated in previous chapters, the intention of this project was to determine what understandings young children have of simple graphs and other forms of data representation. In endeavouring to answer the questions "What do children understand about simple graphs?" and "How do they read data presented in different formats?", this research is very much exploratory work, as so little documentation is available in the area.

Method

In order to establish what the sample of children understood and how they read various forms of data representation, they were interviewed and video-taped while interacting with the researcher using a purpose made 'big book,' which illustrated information in simple graphical formats. A separate task required them to manipulate concrete materials to display data.

The justification for the use of the 'big book' lies in young children's intrinsic interest and familiarity with books of this kind in everyday classroom activity and the manner in which the mathematical ideas can be contextualised within the framework of a book. The introduction and exploration of mathematical ideas through the use of appropriate literature has been advocated by mathematics educators in recent years who suggest, for example, that:

> When sharing books teachers can provoke mathematical thinking through questioning or by just allowing time and opportunity for students to respond spontaneously to the ideas in the story (Lewis, Long & Mackay, 1993, p. 470).

> The combination of mathematics and literature, used in conjunction with opportunities for talk and discussion, allows children to grapple with mathematical concepts in a meaningful context (Griffiths & Clyne, 1988, p. 3).

The 'big book' format, used for many years in early childhood classroom language learning experiences, was first advocated by Holdaway (1979) who suggested that the enlarged format allows a whole class to share in the experience of reading a text, as they can all see the print and illustrations and the teacher can demonstrate and share significant information shown in the text as a key teaching strategy. This form of teaching has proven to be effective in language learning and there is much potential to use such approaches for the teaching of mathematical ideas, particularly to young children.

Sample

For the purposes of this research the sample included children of varied social background attending sessions in local kindergarten settings. The children were all aged 4 years at the time of interview. None of the children had encountered any explicit teaching of data handling skills during their time in kindergarten (approximately 7 months).

A sample of 25 children was used (13 girls and 12 boys). The researcher selected one school from each of the education districts in the south of the state of Tasmania. School A is in a rural setting in the Huon Valley, School B serves a middle class area with many professional parents and School C is situated in a semi-industrial area with a high migrant population.

In all cases, school and parental permission for interviews was sought and signed documentation returned to the teacher, then researcher, ensuring that ethics procedures were followed (see appendices 1 & 2).

Interview Technique

Individual children in the selected sample were asked a set of questions asking them to 'tell the story' of the data represented in the big book. While a standard set of questions was asked, where appropriate, further questions were asked to probe understanding or to clarify the child's thinking. This enabled the researcher to interpret the meanings the children were constructing from the information displayed in the book and gain insight into the ideas children have about various forms of data representation. Video-taped recordings of the interactions were used to interpret and analyse data gathered from the interviews. Full transcripts of each interview were made and are available from the author on request.

The interview method reflected a constructivist approach to assessing mathematical understanding, as advocated by Hunting (1983), Labinowicz (1985), Confrey (1991), Yackel, Cobb & Wood (1992), and others.

> Under this view of learning, students are rarely considered to have no understanding or no strategy when addressing a problem. Even beginning learners are considered to be engaging in an active search for meaning, constructing and using naive representations or models of mathematics. Rather than being 'wrong' these representations frequently display partial understandings and are applied rationally and consistently by the individuals who use them (Masters & Doig, 1992, p. 251).

In following such an approach it was important to seek to gain insight into children's thinking through observation, rather than seek only to determine whether or not the child could perform a given task, as traditional forms of assessment have been predominantly focused on. This approach was particularly relevant to work with children of this age, as tasks requiring pencil and paper responses or reading are inappropriate in a kindergarten setting, where most children are not independent readers or writers.

This clinical interview method has its origins in the work of Piaget and has been used by many researchers in identifying and describing the behavioural strategies exhibited by children in a wide range of learning areas.

> The clinical method takes the form of a dialogue or conversation held in an interview session between an adult, the interviewer, and a child, the subject of the study. Usually the discussion is centered on a task or problem which has been carefully chosen to give the child every opportunity to display behaviour from which mental mechanisms used in thinking about that task or solving that problem can be inferred...because of the dependent relationship between the child's responses and the investigator's questions, no two children will receive exactly the same interview (Hunting, 1983, p. 48).

A range of data representation formats was included in the book - bar graphs, pictographs, tally systems, spreadsheets and a pie graph, in accord with the recommendation that children at all levels of schooling be exposed to a range of ways to record data (DEA, 1993b, p.10). Each page of the book described a situation familiar to children of this age such as arrangements for lunch, cars in a car park, favourite foods and breakfast cereals and the types of pets people have at home. The representations on each page increased with complexity, from simple pictographs, through tally systems and bar graphs, to a more sophisticated and abstract pie graph and spread sheet, where information could not be obtained in a purely visual manner.

Item 1- Front Cover of the Book

When using 'big books' with children, the front cover can be used to help the reader predict what the story might be about. In this instance, children were presented with the front cover of the book (Figure 1) and asked "What do you think this book might be about?", in order to determine whether they were able to make any predictions or indicate any prior knowledge of graphs.

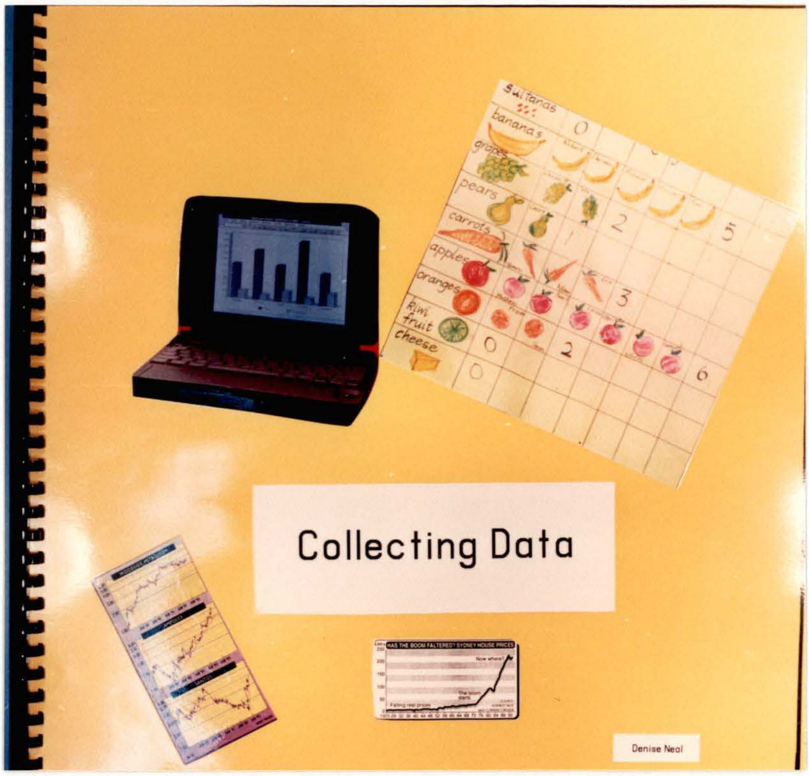


Figure 1 - Front cover of book

Item 2 - Pictograph about lunches

On this page of the book children were presented with three sets of photographs and told the following story - "The children in this class were finding out about what people were doing for lunch; they found out that this group had their lunch in their bags, this group were buying their lunch and this group were going home for lunch" (Figure 2).

Children were asked which group had the children most in it and which group had the least or the smallest number of children in it. As a way of determining whether they used numerical, visual or other information to reach a conclusion, they were asked how they knew which was the group with the most/least.

Figure 2 - Lunch Representation.

Item 3 - Car Park Data (Pictograph)

> Both quantitative and non-quantitative information can be represented pictorially, and the understanding and ability to use suitable forms of pictorial representation is a major mathematical skill which develops during the primary years... Symbolic figures (pinmen, cars, ships, pigs) make an effective means of showing comparable numbers of such things (Williams & Shuard, 1982, pp 313- 329).

On this page of the book shown in Figure 3, children were shown the information using symbolic figures and told "The children in this class went out into the school car park to look at the cars there - this is what they found out."

An open-ended question was asked of the children: "What did these people find out about the cars?" After an initial response was given, children were asked to indicate which sort of cars there were the most of and which sort of cars there were the least (smallest number) of in the car park.

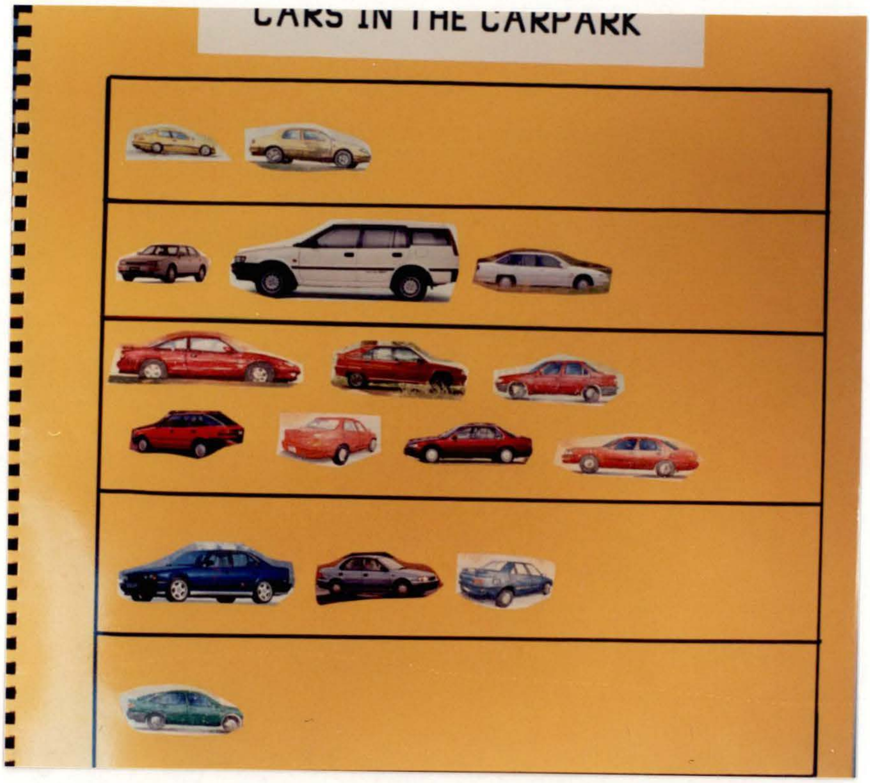


Figure 3 - Car Park Data

Item 4 - Food Chart

On this page of the book, children were shown a photograph representing the categories of food children in a kindergarten like to eat for morning tea (Figure 4). This information was collected and the chart made in a kindergarten earlier in the year. Children were told: "The people in this kindergarten bring food to eat for morning tea, just like you do. This shows what they liked to eat."

Once again an open-ended question was initially asked - "What did these people find out about the foods people in their class liked to eat?" They were then asked "Is there a fruit that lots of people in this class like to eat?" (How did you know?) and then, "Are there any foods that not many people in this class like?" (How did you know?).

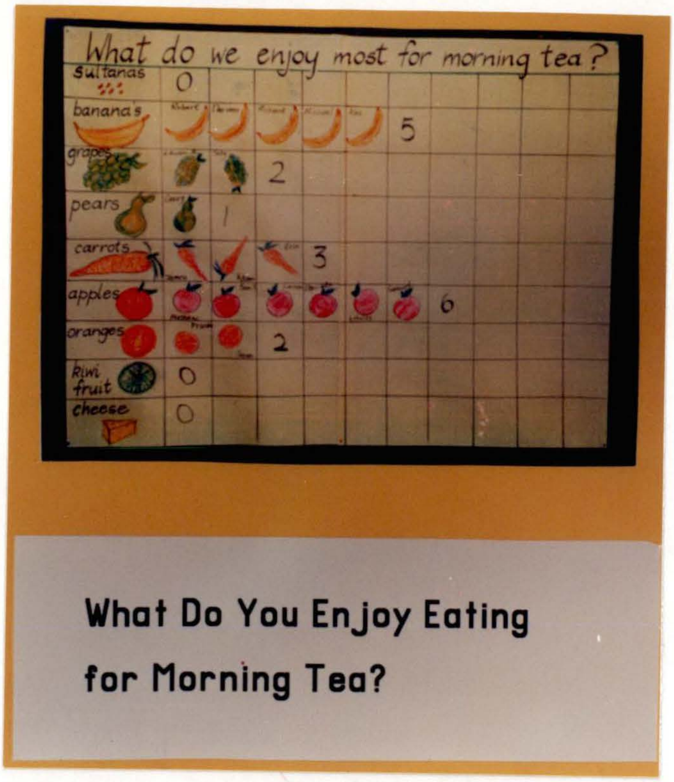


Figure 4 - Food Chart

Item 5- Shoe Types

On this page children were shown a simple tally system to represent the types of fastenings children had on their shoes (Figure 5). They were told: "The people in this class found out what sorts of shoes people were wearing- they found out that some people had laces, some people had buckles, some people had slip-on shoes and some people had other sorts of shoes."

Similar questions to those in items 1-3 were asked of the children: "Which sort of shoes did most people in this class have?" and "How did you know?"

Item 6 - The Pet Graph

This page of the book involved children in interpreting a simple bar chart showing the categories of pets children in a class had at home (Figure 6). Using the same format as used with earlier representations, children were asked to indicate which sort of pet most people in this class had. As a means of further probing understanding, the children were asked to move or change the laminated red squares of card to make the picture tell a different story, as shown in Figures 7 and 8. By asking the children to manipulate the red squares and providing them

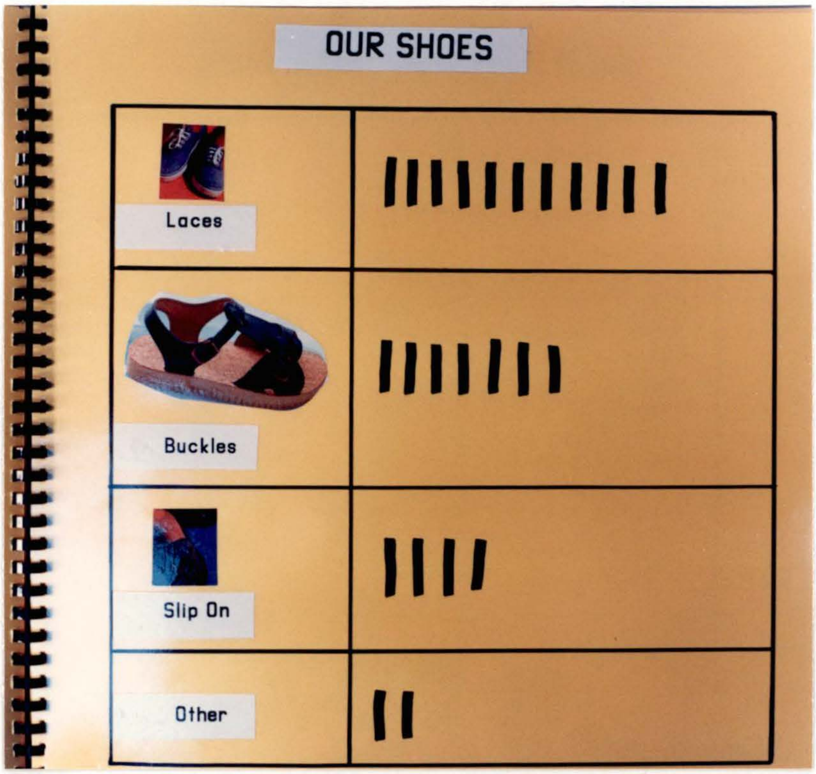


Figure 5 - Shoe Fastenings

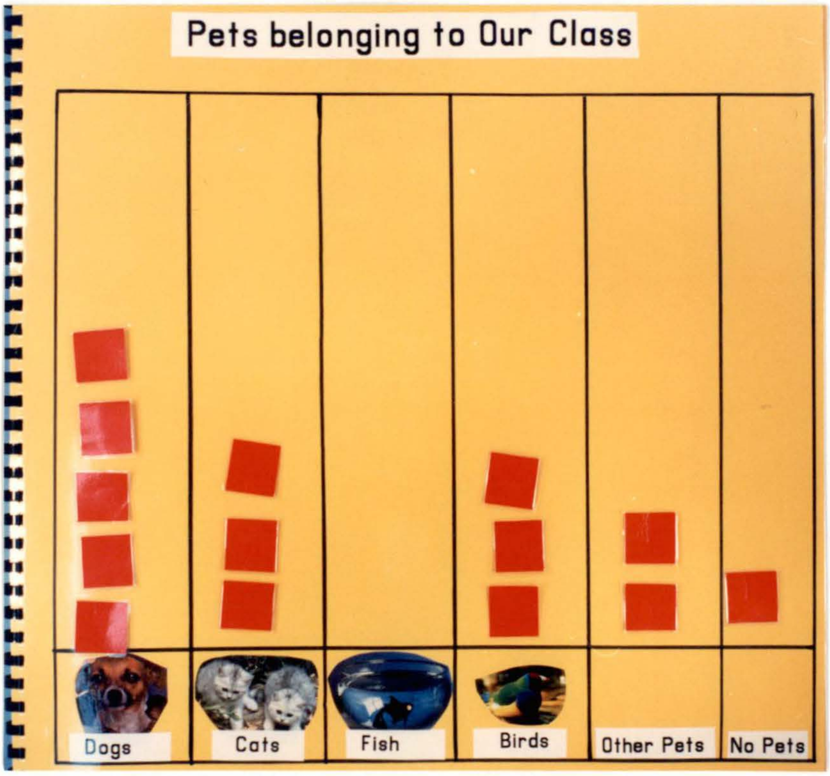


Figure 6 - The Pet Graph

Figures 7 and 8 - Manipulating the Pet Graph using movable red cards.

with the option to add more red squares to make a different story, greater insight is gained into their understanding of the purpose of the graph. Kamii (1982) suggested that more classroom activities should involve making and manipulating sets, rather than merely interpreting sets made by others, as many textbooks ask children to do.

> There are two ways of asking children to compare two sets: by asking them to make a judgement about the equality or inequality of sets that are already made , and by asking them to make a set. The second approach is far better for two reasons. First, when we ask a child to make a judgement about two sets that are ready-made, the child's reason for comparing them is only that the adult wants an answer. Second, comparing ready-made sets is a passive activity in which the child is limited to only three possible responses: the two sets are the same, one has more or the other has more...besides such an exercise easily elicits the right answer for the wrong reasons (pp. 36-37).

Item 7 - The Book Chart

This page involved children in interpreting a bar chart which indicated the favourite reading books of a class of children using laminated 'book' symbols cut from a catalogue (Figure 9), which included a well known

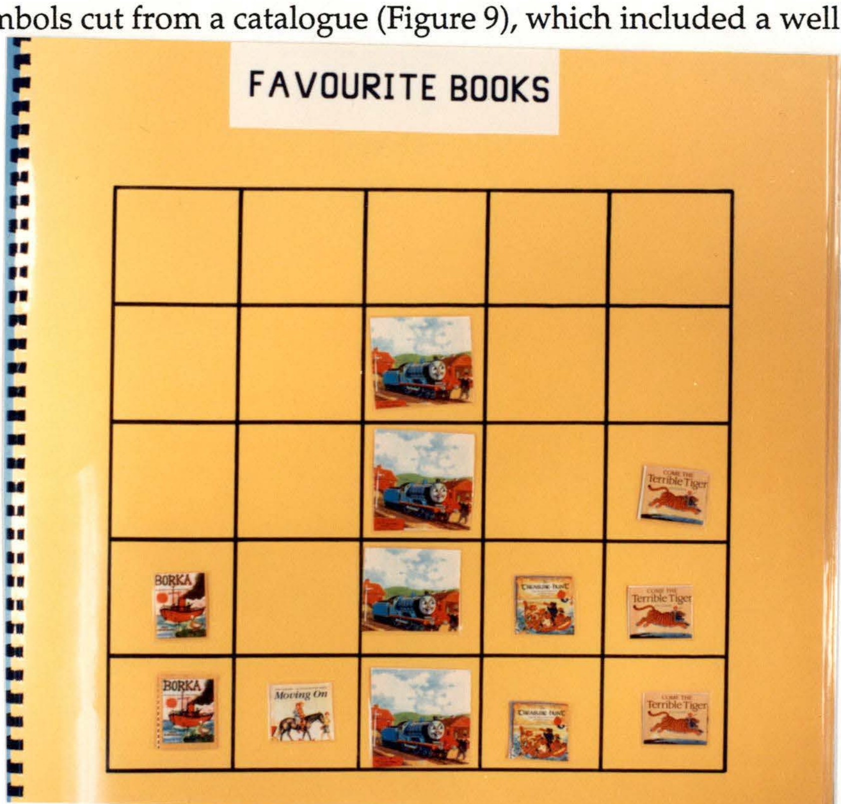


Figure 9 - The Book Graph

favourite *Thomas the Tank Engine.* As on the previous page, the task related to this page was two-fold; first, children were asked to interpret the information, when they were asked, "Is there a book lots of people here like to read?" The second part of the question was, "Can you move or change the page to show that not many people like to read *Thomas the Tank Engine* ?" (children were provided with the opportunity to add to the graph, as extra 'books' were available to them).

Item 8 - The Breakfast Pie Chart

While most curriculum guidelines would not recommend the introduction of pie graphs to kindergarten classes, it was considered worth investigating whether the children in the sample could in any way make sense of such a graph. As a means of ascertaining this, the children were presented with a pie-graph representing the percentages of children in a given class who preferred various breakfast foods (Figure 10).

An open-ended question, "What did these people find out?" was followed by a more specific question related to the graph, "Does this tell you anything?"

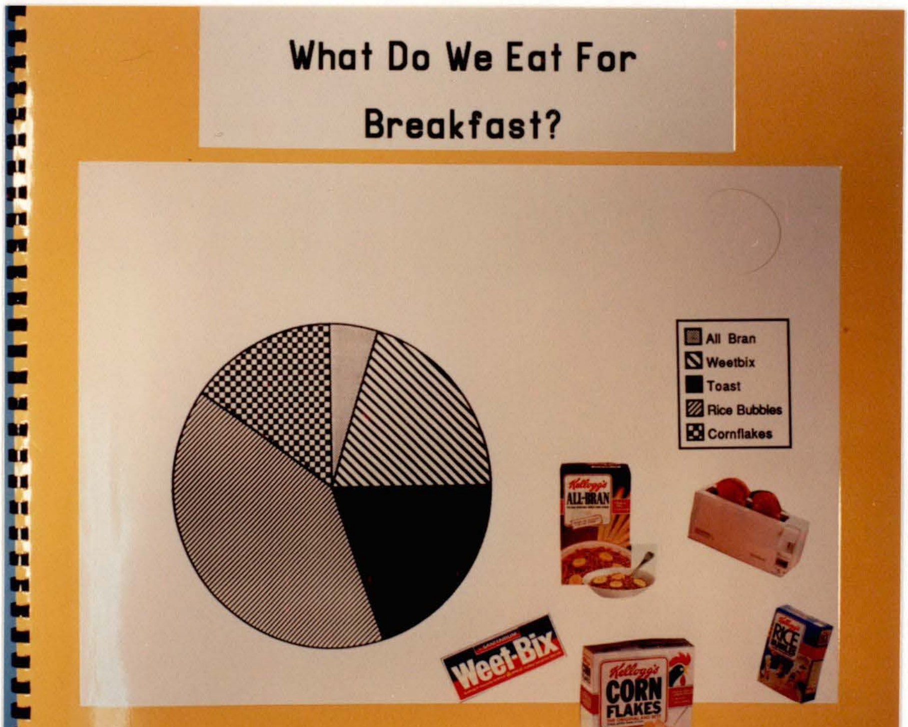
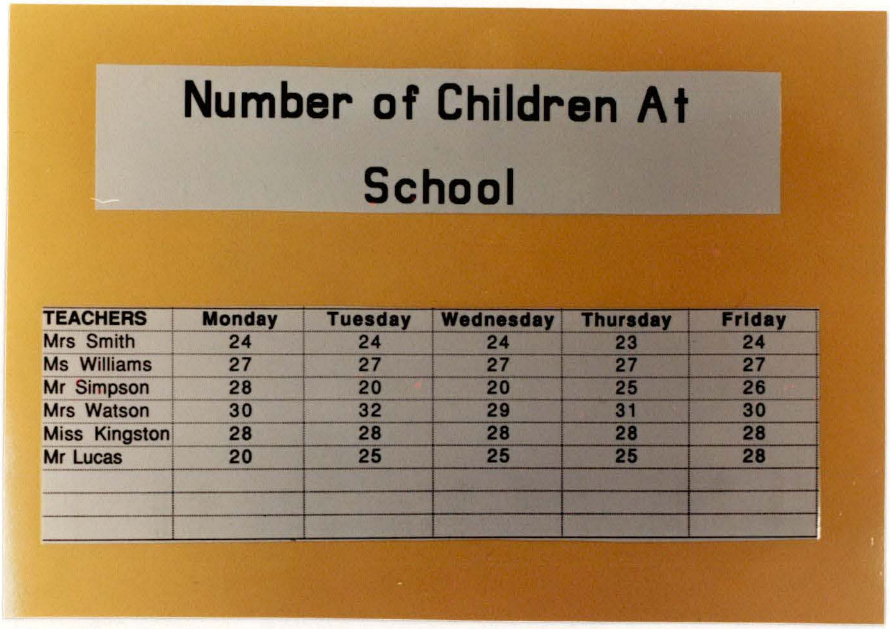


Figure 10 - The Breakfast Pie Graph


Number of Children At School

TEACHERS	Monday	Tuesday	Wednesday	Thursday	Friday
Mrs Smith	24	24	24	23	24
Ms Williams	27	27	27	27	27
Mr Simpson	28	20	20	25	26
Mrs Watson	30	32	29	31	30
Miss Kingston	28	28	28	28	28
Mr Lucas	20	25	25	25	28

Figure 11 - The Attendance Spreadsheet

Item 9 - The Spreadsheet

As a further form of data representation, children were shown a spreadsheet which recorded numerical information regarding the numbers of children at school over a week in different classes (Figure 11). It is recommended that all children in the K-8 years of school be exposed to appropriate technology (NCTM, 1989; AEC, 1991; DEA, 1993a). Computer-based forms of data representation such as spreadsheets and databases are examples of how we can utilise the technological tools now available in the classroom. While the use of such representation currently appears to be limited in early childhood classrooms, there is much scope for helping young children understand the efficiency of such representation methods. Findings of a survey in Northern Ireland (Greer & Ritson, 1993) suggested that "very few teachers make much use of spreadsheets because they are not fully familiar with their use" (p. 7) and that teachers need opportunities to build up their own computer skills if they are to fully utilise them in the classroom with children.

Item 10 - Manipulation of concrete materials

This task was quite different to those in the book in that it asked children to physically represent data rather than interpret data prepared by someone else.

One of the earliest experiences children have with representing data is the use of concrete materials including blocks, toys, or real items such as children themselves to physically represent information they have collected or had described to them. These initial experiences involve children in classifying and sorting objects and data according to different criteria.

> Students can group objects with a similar attribute to represent them by way of one-to-one correspondence with other objects (eg. cubes to make a tower graph) or by simply making a count of the objects in the group (DEA, 1993b, p. 8).

Later, children are introduced to the idea of representing or recording their information on paper in some way so that it may be shared with others or be referred to at some time in the future.

As an attempt to investigate the children's ability to represent data in a concrete form, they were given a task using some plastic farm animals. They were asked to make a picture to show that "I have some pigs, you have some pigs but the Teddy Bear has more pigs than we do." The intention of this task was to determine whether the children would use any pattern or system to physically represent the information supplied to them.

Conclusion

This chapter has described the research methods used to determine how a sample of four-year-old children read a variety of different forms of data representation. Children were exposed to pictographs, spreadsheets, pie-graphs, bar graphs, and simple tally recordings within the context of a 'big book' and asked questions relating to each representation.

There are many aspects of graph interpretation not dealt with in this project, such as reading beyond the graph to make predictions, which has been recognised as a key element in understanding data representations (Pereira-Mendoza & Mellor, 1993). For the purposes of this project, initial investigations of the intuitive meanings children were making was a focus. The clinical interview method was particularly useful for this project in that it enabled the researcher to assess the viability of the tasks used and gain information about the behaviours children are likely to exhibit when confronted with questions of this nature. Proponents of the clinical interview methodology suggest that in such constructivist research, where the investigator is seeking to understand the internal process learners use, one of its uses can be "the initial development of a task or set of tasks in preparation for formal investigation" (Hunting, 1983, p. 48). This is significant in this project, where there are no published accounts of similar research which could be used as a reference or to in any way replicate. There were no examples of appropriate tasks to elicit very young children's ideas about graphs. There is much scope for further formal investigation of young children's ideas about data representation through the use of more specific questions to further probe understanding. This will be discussed in chapter 5, following the discussion of findings in chapter 4, which describes some of the interactions between the researcher and individual children while sharing the book.

Chapter 4

Research Findings

This chapter reports results of interviews conducted to ascertain young children's intuitive understanding of various forms of data representation. From a pilot study such as this, with a relatively small sample, it is difficult to make generalisations. Findings of particular note may however, provide insight into how early childhood mathematics programs might further explore and extend children's data handling concepts. This may identify areas of interest for future research, using a much larger sample, a wider range of questions or a more specific focus on investigating children's ideas about one form of data representation, such as bar graphs.

In discussing the results of the interviews, it is important to establish a framework for considering responses. As a result of their longitudinal studies of kindergarten children, Herscovics, Bergeron and Bergeron (1987) have determined four levels in the construction of a mathematical concept which are useful in analysing responses to these interviews: intuitive understanding, procedural understanding, abstraction and formalisation. These levels are not unlike those proposed by Biggs and Collis (1991), which acknowledge the importance of intuitive understanding (ikonic functioning) as an early stage in informal thinking. Herscovics et al. (1987) define intuitive understanding in the following manner.

> The level of cognition which we call "intuitive" relates to informal knowledge acquired through life experiences, outside any formal instruction. For many mathematical concepts, one can find their embryonic presence in this informal knowledge...Intuitive understanding results from a type of thinking heavily influenced by visual perception. For pre-concepts of an arithmetic nature, this translates into visual estimation and primitive actions which do not yet provide a numerical answer (p. 345).

Procedural understanding, which can be a more sophisticated way of operating, relates to the gradual mastery of mathematical procedures as well as their appropriate use. For the purposes of analysing the results of this research, procedural behaviour will include counting and use of numerical information, rather than intuitive responses or visual estimation.

> Intuitive/informal mathematical knowledge can be used to initiate an ensuing stage of mathematization, that of the acquisition of relevant mathematical procedures. Relating these procedures to the learner's intuitive knowledge justifies their need and helps prevent meaningless memorisation. Conventional mathematical procedures are seldom discovered spontaneously by children. They are usually constructed by them following some socially transmitted information and convention, through school, television, parents, peers etc. (Herscovics et al., 1987, pp. 347-348).

As this project focused on an area of mathematics which children have had no explicit classroom instruction in or exposure to, the emphasis of investigation was essentially concerned with intuitive understanding, however, the researcher was interested in whether children used more sophisticated thinking involved in the procedural level or whether or not children operated in different modes according to the situation, as proposed by Watson and Collis (1994).

In reporting the findings of this project, each item used in the interview will be discussed in turn, with examples of dialogue between the researcher and the child provided to exemplify points being discussed (in each case, "I" will be used as an abbreviation for interviewer).

Item 1 - Front cover of book

One of the purposes of an effective cover of a 'big book' is to help children predict what the book may be about, to provide some visual clues about its contents and encourage the child to want to read it. Often, discussion of the front cover provides the teacher with insight into the children's experience of the subject matter of the book. The cover of the book presented to the children who were interviewed clearly showed that most of the children made little meaning from the information shown.

Few of the 25 children gained any clues from the pictorial information on the front cover of the book as to what its content may have been. Fourteen of the children interviewed responded by saying "Don't know" when asked what it might be about. Other responses tended to focus on particular pictures, such as the computer or the fruit chart with comments such as:

> "Daddy's going to buy us a computer."
>
> "It's a computer."
>
> "Computers, maps and things, fruit."
>
> "Computer games."

One of the children was asked about what he saw on the computer (which displayed a bar graph in 3d) and he suggested "Sort of buildings and stuff," which was a logical description, providing him with an explanation which fitted his experience and made perfect sense to him, providing an example of intuitive functioning.

One child whose reading skills were highly developed, read all the fruit names on the food chart and another focused on the written aspects, saying "I can't read that", another commenting "I don't know what all those words say." Only two children suggested that the book may have any numerical features, suggesting that it might be about "numbers" and "counting".

Item 2 - Pictograph

The pictograph was the most simple form of data representation presented to the children. Questions relating to the information shown on the page could be answered without any focus on numerical information, as this item dealt with quantity which can considered to be a pre-concept of number.

> For discrete sets, one can deal with notions of more than, less than, or the same without any counting process, by simple visual estimation (Herscovics, et al., 1987, p. 344)

Some of the children who were interviewed demonstrated visual estimation in determining the largest and smallest group commenting they knew because of the shape or other visual features. This illustrates the findings of Berenson, Friel and Bright (1993) who concluded that there is "a strong visual component in many decisions related to graphical representation" (in Watson & Collis, 1993, p. 369).

Child 8

> "It's biggest 'cause it's got the biggest sort of line around it and lots more pictures"

Child 9

> "Because it has a big one." (pointing to the boundary line)

Child 14

> CHILD: "Because it's longer than that one and that one"
> I: "How did you know this was the smallest?"
> CHILD: "Because that one's round and that one's big- that one's little to me."

Child 13

> "Because I just looked and I saw it."

It is interesting to note that some of the children interviewed did not rely on visual clues and used more sophisticated numerical strategies to determine the group with the most or the least in it demonstrating procedural functioning, for example:

Child 11

> Correctly points to the largest group.
> I: "How did you know?"
> CHILD: "Because it's got 1,2,3,4,5,6,7, 8 in it."
> Correctly indicates the group with the least in it.
> I: "How did you know?"
> Child: "Because its got 1,2,3 in it."

Child 23

Correctly indicates the largest group.
I: "How did you know?"
CHILD: "Because that one's only got 5 and that one's only got 3."
I: "And how many does the biggest group have?"
CHILD: "8"
Correctly indicates smallest group.
I: "How did you know?"
CHILD: "Because its only got 3 in it."

Child 18

When asked which is the largest group says "Getting their lunch out of they bags." (indicating that he has remembered the categories read to him by the interviewer).
I: "Which group is that?"
CHILD: Correctly points.
I: "How did you know that?"
CHILD: " 'Cause there's 1,2,3,4" (points to middle group) "1,2,3" (points to smallest group) "1,2,3,4,5,6,7,8" (points to largest group).
CHILD: Indicates the smallest group.
I: "How did you know?"
CHILD: " 'Cause there's only 3."

Child 12

CHILD: Points to correct group.
I: "How did you know it was the biggest?"
CHILD: "Because its got lots of people in it."
I: "Which is the smallest group?"
Child: Correctly indicates.
I: "How did you know?"
Child: "Because its just got 3."

Other children could correctly indicate the largest or the smallest group but were unable to articulate how they knew, making comments such as "I just did", "I don't remember", "Because it just was the smallest." As summarised in Table 1, more children could identify the largest group than the smallest group. These results are likely to differ because the difference between the smallest group and the middle size group is not as obvious as the difference between each of these groups and the largest group, which is obviously the biggest. Children who were using visual clues only were more likely to choose the middle size group as the smallest because they were not using numerical information or checking the numbers of children in the group to determine its relative size.

Can identify largest group	21
Uses visual/spatial clues	7
Uses numerical clues	6
Gives other explanation	4
Gives no explanation	5

Can identify smallest group	16
Uses visual/spatial clues	4
Uses numerical information	8
Uses numerical and spatial information	1
Uses other explanation	3

Table 1 - Summary of findings Item 2

A comment by one child illustrates the findings of Pereira-Mendoza (1993) and Asp et al. (1994) that children often extrapolate information from a graph or chart which is in not shown on the paper. When shown the pictogram one child's first reaction was "Those people who are buying their lunch are going to buy it from a cafe." While this may be true, it is certainly not evident from the data represented on the page. This pattern of response to graphs and other forms of data representation was also evident in relation to later items in the book.

Item 3 - The Car Park Pictograph

Responses to the open-ended starting question about what was found out regarding the cars included comments on colour and comments on size or shape, as well as comments on other information e.g. whether the car had snow on it or not.

1. Focus on colour

Child 1

> "They're all red, they're all yellow." (pointing to two groups)

Child 4

> "They're red."

Child 7

> "They're all different colours."

Child 14

> Points to various cars saying "red, red, red, red and white and orange, yellow..."

Child 18

> "Yellow ones, white , red."

Child 22

"White car, red, red, red, red, blue, blue, blue."

2. Focus on size or shape

Child 6

"Big, small, large and thin, fat, long, that's a small one..."

Child 16

Points to the largest picture says "That's a big one, points to another car, says "That's a small one."

Child 19

"Well, that one (the green car) that's very small, very small, tiny little and that one (the large van) that's a very big car."

Child 20

"Well, there's big cars and little cars."

These children had obviously had many experiences with sorting, classifying and describing groups of objects and did not see the black dividing lines separating the colour groups as necessarily important.

One child responded with a numerical question, wanting to find out how many cars there were:

I: "What did these people find out about the cars?"
CHILD: "All these cars, I'm gonna count them." (Counts to 16) says: "Mmm 16 altogether."

It is interesting to note how some children reacted to what to an adult appears to be superfluous information shown in the pictures. Several children commented on the fact that some of the cars had snow on them. For example, when asked what the picture was telling us the following responses were noted.

Child 2

"That one's got snow on it."

Child 5

I: "What can you tell me about this?"
CHILD: Points to one car says "That one looks pretty snowy and so does that one, that one looks OK."

Child 8

I: "What did these people find out?"
CHILD: "There's sort of snow everywhere."

Child 22

"They're all getting washed, some are and some aren't." (sees the snow as soap suds)

Once again, there was emphasis on concepts such as most and least in relation to this item, with children being asked to identify the groups with the most and least in them. The results of these questions are summarised in Table 2, indicating that more than half of the children could correctly identify the group with the most in it and slightly less children were able to identify the group with the least.

Able to correctly indicate group with the most in it	14
Able to correctly indicate group with least in it	11

Table 2 - Summary of findings Item 3

This particular item revealed some problems with the wording of the questions, the use of the magazine cut outs and the format of the page.

Because the cars used in the pictograph were varying sizes and one car in particular was much larger than the others, when asked "Which group is the biggest?", it was interpreted by some children as "Which car is the biggest ?" As discussed previously, the pictures of cars with snow on distracted many children. The third problem related to the way the page was set out. Because the pictures of the red cars were in two lines, some children saw them as two different categories, despite there being no dividing black line between them. These problems are worth noting as aspects of data representation for teachers to consider when making such graphs with children or presenting similar formats for children to interpret. They also identify important discussion points when teaching data concepts in the classroom, illustrating why teachers should explicitly discuss different forms of presenting data with children to avoid ambiguity caused by the presentation.

Item 4 -The Food Chart

This item produced more stories and information not shown on the page than most others in the book. This may be because it relates to an experience which is very familiar to the children: sharing fruit in a kindergarten. In most Tasmanian kindergartens, children bring a piece of fruit to the session to be shared with others and sharing and discussing fruit is a daily occurrence. This personal knowledge is demonstrated in the following examples.

Child 1

> I: "Is there something here that lots of people in the class liked to eat?"
> Child: "Well, I like grapes, I don't know who else does."

Child 10

> I: "Is there a food that lots of people liked to eat?"
> Child: "Well I like them." (pointing to bananas)

Child 19

I: "What did these people find out about the food their class liked to eat?"
CHILD: "Well, they had, we used to have banana for fruit but Kristy likes banana, but we didn't have grapes but we used to bring grapes..."
I: "What about this class here, what did they like to eat?"
Child: "Well I like these (points to each fruit, then becomes more specific) "Well, I like apples, I do 'cause they're red."
I: "Anything else that these people liked to eat?"
CHILD: "Well I like pears, but other people, my friend Kristy likes bananas."

Child 23

I: "Is there a fruit that not many people liked?"
Child: "Yeah, carrots."
I: "And how many people liked carrots?"
Child: "I like carrots, if you eat carrots you can go out in the dark without the lights on."

Identification of the food that most people liked to eat proved more difficult for the children than was expected. Many children could not identify that apples were the preferred fruit in the data presented, instead choosing bananas or another fruit. This may be because of a counting error or that bananas are the child's preferred fruit. These findings are summarised in Table 3 and indicate that less than half of the children could correctly identify apples as the preferred fruit.

Identifies preferred fruit correctly	10
Selects bananas as preferred fruit	7
Other explanation (Don't know, selects another fruit, no response)	8

Table 3 - Summary of findings Item 4

Children who used numerical information either relied on the numerals shown at the end of the rows of picture symbols or counted the individual fruits, for example children 8 and 18 described below.

Child 8

I: "What did these people find out about the food?"
CHILD:" How much they brang[sic]-we don't bring fruit any more.
I: "What did these people bring?"
CHILD: "Bananas, grapes, pears, carrots and oranges,...pink things, cheese, watermelon it might be."
I: "What did the most people bring?"
CHILD: "I think bananas (self corrects) no the apples"
I: "What made you change your mind?"
CHILD: " 'Cause I just saw there's 1,2,3,4,5," (points to bananas). Counts apples (including place holder on left hand side) says: "7" "So there's more apples."
I: "Is there anything that not many people bought?"
CHILD: "Only 2 pears, and they bought nothing here."
I: "How did you know that?"
CHILD: "Because they just look like zeros."

Child 18

I: "What did the people on this page like to eat most?"
CHILD: "Bananas, grapes, pears apples, oranges, kiwi fruit, cheese."
I: "What did they like to eat most?"
CHILD: Points to apples
I: "How did you know that?"
CHILD: " 'Cause there's more than the other ones"
I: "How many people liked apples?"
CHILD: Counts to 7
I: "Is there a food that not many people liked?"
CHILD: Points to cheese
I: "How did you know that?"
CHILD: " 'Cause there's a O there."

It was interesting to note one child's reaction to the question "What did these people find out?" She said "I'm not very good at guessing," indicating that she did had not made the connection that there was information on the page which might help her.

Child 20

I: "What did these people find out about the food they like to eat?"
CHILD: "I'm not very good at guessing."
I: "Is there something on the page that tells you something?"
CHILD: Silence
I: "How many people here like apples?"
CHILD:" 6"
I: "And bananas?"
CHILD:" 5" (makes no attempt to touch count, uses numeral clues at end of rows).
I: "Was there something that not many people liked to eat?"
CHILD: "Grapes, look only 2."
I: "What is the biggest group?"
CHILD: "The six group."
I: "And what is that?"
CHILD: "Apples."

The format of the chart used on this page revealed a problem which many teachers and text books may unintentionally cause for children when presenting information in such pictographs. As can be seen in Figure 12, the place holder for each fruit shown in the far left column gives the impression that there is one more item in each category than is intended. Several of the children counted the fruits and were perplexed to find that their total was not the same as the numeral displayed to the right of each set of pictures. For example, six children counted a total of seven apples when the chart shows six and three children counted six bananas when the chart shows five. This confusion may be overcome by presenting the information in another way such as that used in the book graph item. The confusion in itself and the difference between what the child counts and what the chart shows may however, provide a valuable conversation point for a class, enabling the teacher to demonstrate how we read such a graph.

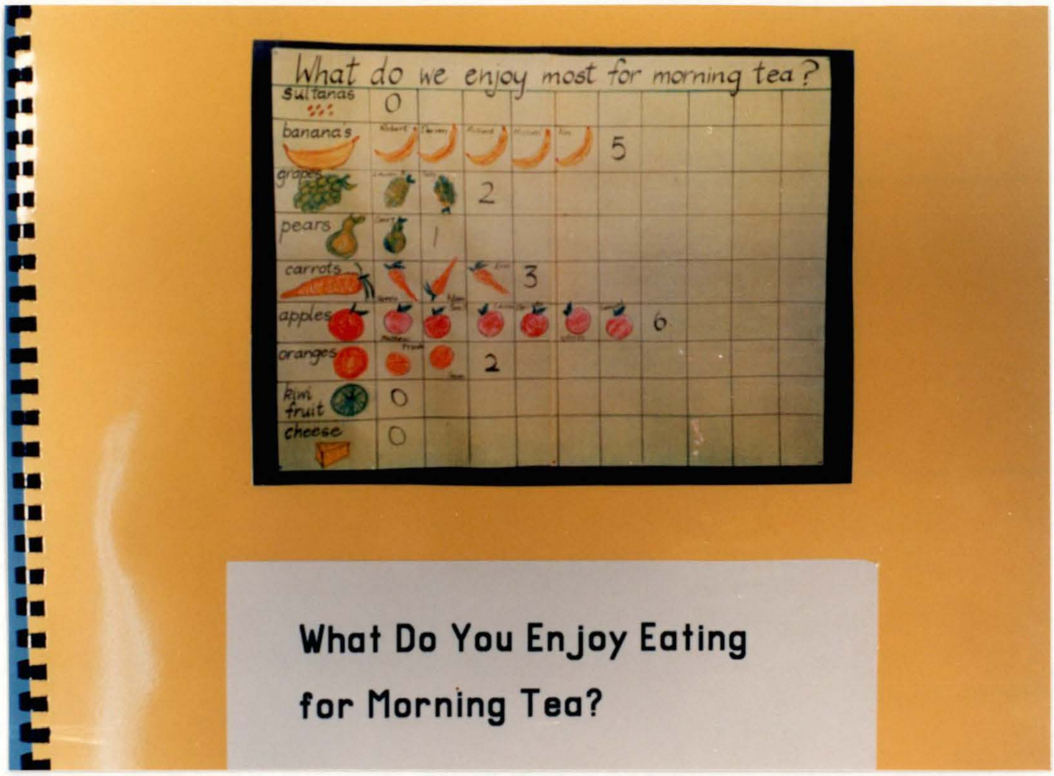


Figure 12 - The Food Chart

Item 5 - The Shoe Chart

This chart showed a tally system to record information about the sorts of shoes children in a class had. Once again, a problem was noted with the use of magazine cut outs to identify categories, as the picture representing shoes with buckles was larger than the other pictures, thus making it seem more important and causing some children to suggest that most people had this sort of shoe "because it was the biggest".

This form of data representation involved children in a more abstract concept than previous formats in that the tallies represented the number of children rather than an actual picture, as shown in the lunches, food and car park data. This is a complex idea which many children find difficult.

> The notion of one-to-one correspondence between real objects (for example, people) and some other physical objects to represent real objects (for example, cubes in a tower or tally marks in an appropriate column) is an important step in children making abstractions and working and manipulating information which no longer is in its original (real) form (DEA, 1993b, p. 8).

In interpreting this page, many of the children made no connection between the tally marks and the number of people wearing the various sorts of shoes. Instead they relied on the pictures used to illustrate the categories of shoes. For example, one child, when asked which sort of shoes the most people had pointed to "laces" and "slip-on", saying "I think these have got two shoes" (as compared with the "buckles" category which had only one shoe pictured).

Numerical information gained from the tally marks was used by only a few children.

Child 5

I: "What did they find out here?"
CHILD: Reads labels for categories of shoes.
I: "What did they find out about the shoes?"
CHILD: Points to tallies beside slip-on category and says "2, 4 people, 4 and 4=6, no it's 7 buckles, 4,4,3 (counts laces category) 11."
I: "So what did they find out?"
CHILD: "Well one of my best friends has these." (points to buckles)
"11 people have these." (points to laces)
Points to buckles counts 7, re-counts by saying "3 and 4 make 7 yeah."
"4 people have this one." (slip-on)
"3 people have other sorts."

Child 20

I: "What sort of shoes do the most people have?"
CHILD: silence
I: "Is there something on the page that tells you?"
CHILD: points to tally marks
I: "How many people have lace-up shoes?"
CHILD: "6" (looks at tallies, does not touch count)
I: "How many have buckles?"
CHILD: "4"
I: "Slip-on?"
CHILD: "4"
I: "Which group has the most?"

CHILD: "Laces."

This may be because the children have not experienced tally systems as a means of recording information or because they rely on the more visual forms of recording seen in earlier examples, where pictures provide much of the information.

One child used the tally marks in a spatial rather than numerical manner to determine which group had the most. After further probing her understanding through another question, she was able to provide numerical information as well.

Child 23

I: "Which group has the most?"
CHILD: "Laces."
I: "How did you know?"
CHILD: "Because that one's got the most."
I: "How many people have that sort?"
CHILD: "Don't know."
I: "Can you work it out?"
CHILD: "Because that one is over there." (Points to the far right hand tally marks).
I: "Can you find out how many?"
CHILD: counts 12
I: "Which is the smallest group?"
CHILD: Points to "others" category.
I: "How many people have that sort?"
CHILD: "2."

These findings are summarised in Table 4, indicating that, despite there being almost half the children who could identify the largest group, only three of them used the tallies to justify their answer.

Correctly identifies category which most people have	11
Uses tallies to justify answer	3
Gives other justification ("I just knew","My mum told me")	2
Provides no justification	6

Table 4 - Summary of Findings Item 5

Personal knowledge once again influenced some children's answers.

Child 19

> I: "What sort of shoes did the most people in this class have?"
> CHILD: " Well, my friend Peta has slip-on shoes and I have buckles on my shoes."
> I: "What about the people in THIS class, what sort of shoes did most people have?"
> CHILD: "Well some people have slip-on, these (points to her shoes with buckles) I have some shoes with laces."

Item 6 - The Pet Graph

This item allowed children to manipulate the data to tell a different story by moving or adding more red laminated squares to the graph after they had discussed the information presented to them in the prepared graph.

Once again the children relied heavily on picture clues to help answer questions. Only one child who had good reading skills discussed the categories 'other pets' and 'no pets'. When changing the red squares to tell a different story, few of the children made any changes to these categories, choosing to change the information in the columns easily identified by the pictures.

As illustrated in Table 5, almost half of the children identified the category with the most in it, using only numerical information (either counting or being able to say there were more in a particular column) to help them justify their choice.

Correctly identifies category with most animals	10
Uses numerical information	6
Uses spatial information	1
Uses other justification (e.g. "I just knew", "I don't know"...)	3

Table 5 - Summary of findings Item 6

Spatial information was used by only one child, who used the following justification.

Child 4

> I: "Which sort of pet did the most people have?"
> CHILD: Points to top of 'dog' column, says: "That's the biggest 'cause that goes right up."

Some children clearly demonstrated that they had made the connection between the red squares and the number of children who had the various pets.

Child 11

> I: "What sort of pets do the most people have?"

CHILD: "Dogs."
I: "How did you know that?"
CHILD: Touch-counts red squares and says "Because there's 1,2,3,4,5."

Child 12

I: "What sort of pets did the most people have?"
CHILD: "The dog."
I: "How did you know?"
CHILD: " 'Cause 1,2,3,4,5." (Touches each red square)

Child 13

I: "How many people had fish?"
CHILD: "None."
I: "How did you know?"
CHILD: " 'Cause there's no red things there."

Child 14

I: "What sort of pets do the most people have?"
CHILD: Points to dogs
I: "How did you know?"
CHILD: "Oh I don't know, yes I know how many squares 1,2,3,4,5." Then reads the totals from other columns.
I: "What does this show?" (points to fish column)
Child: "Nothing 'cause there's no squares."

Personal experience once again became evident during the interviews about this page.

Child 6

I: "What pet did the most people in this class have?"
CHILD: "It's hard to guess. The most- I think that one." (points to dogs)
I: "And how many people had dogs?"

CHILD: Starts to recite names of children in her class who have dogs.
I: "Does this tell us how many people in THIS class had dogs?"
CHILD: "5"
I: "How many people had cats?"
CHILD: "Me...." (recites names of friends who have cats).

Child 19

I: "What did these people find out?"
CHILD: "Well, some people have dogs, that's what Danny has, everyone else does too, some people I know have dogs."
I: "What other pets do people in this class have?"
CHILD: "Well, I have a cat and a goldfish, her name's Lisa."
I: "What sort of pets do the most people in this class have?"
CHILD: "Well, two places I've been have birds."
I: "How many people here have fish?"
CHILD: "Well, I have one and another place has one too."

In both of these instances, it is evident that the children have great difficulty in differentiating their class and knowledge of the children in their group from the information shown on the page. It was often necessary during interviews to re-state the question by asking "What about the people in THIS class (pointing to information displayed) what did they find out, or what was the favourite food/pets etc.?" Similar findings are reported by Pereira-Mendoza and Mellor (1993) who found that errors in graph interpretation are often the result of "a strong tendency to interpret the situation in term's of the student's own reality" (p 18).

Many of the children experienced difficulties with or ignored the fish column which, through the absence of a red square, indicated that no people in the class had fish as pets. This also parallels the findings of Pereira-Mendoza and Mellor (1993) who found that primary school children often interpret the absence of a symbol as meaning no information. For example, consider child 8.

Child 8

I: "Does this page tell us how many pets they had?"
CHILD: " Well ummm, they had 1,2,3,4,5,6- 6 dogs and three cats mmm hard to think."
I: (Points to fish column) "What does this say?"
CHILD: "Nothing."

Understanding of the purpose of the red squares became more evident when the children were asked to change the story. Although six children appeared to randomly move the squares around the page or made no attempt to make changes, others were quite deliberate in the changes they made.

Child 6

CHILD: Takes one square from birds category and adds one to dogs and one to fish.
I: "What does it show now?"
CHILD: "6 dogs.", Adds one square to cats, adds one to fish, says "I think I need some more." (squares)
I: "What does the story say now?"
CHILD: "6 dogs, 3 cats, 2 fish and one bird." (As with most children ignores other categories which do not have pictures to identify them).

Child 13

CHILD: (Asks interviewer) "Does one go here?" (the fish column)
I: "You can move them wherever you want."
CHILD: Places a red square in the fish column.
I: "What does it show now?"
CHILD: "1 fish."
(Adds more to fish column) Says: " That makes 2,3,4 people have fish- my mum and dad, their mum have fish [sic]. Adds more to fish column, says "1,2,3,4,5, people have fish and 6 people have fish, that's the mostest!!"

Child 16

CHILD: Makes several changes to columns
I: "What does the story say now?"
CHILD: Reads each column by counting eg. "1,2,3,4"; "1,2,3"; "1,2"
I: "So, which group is the biggest now?"
CHILD: (Points to dogs) "This one." (quickly self-corrects) "These two." (realising that she has made two columns the same size).

Child 19 (plans out her story but with personal experience in mind)

CHILD: "I'm gonna make another story up." (Moves three squares away from cats off the page, adds three to cats)
I: "How many people have cats now?"
CHILD: "Well, only Daniel has two so I take one away don't I?" says "I want 2 cats," takes all but one of the squares off dogs column.
I: "How many people have dogs now?"
CHILD: "Mine, I only have one so I'm gonna put one here. I'm gonna put 2 on, no I better leave one, that's my dog. What about fish?"
I: "How many people have fish?"
CHILD: "I do."
I: "How will you show that one person has a fish?"
CHILD: "I can put one down 'cause I have a goldfish. Now birds, I don't have a bird but do you know who has a bird?, David has one it's called a cockatoo."
I: "How will you show one person has a bird?"
CHILD: "I'm gonna make they [sic] only have one." Puts down a red square) says: "Like the goldfish and the dog."

Child 20

CHILD: (Takes one square off cats and places in fish column) Says: "How about I take them all off and then put them on, I'll leave this one on because this is how I want them to go (leaves one square in far left hand column) places 2 in fish column, 3 in cats etc. says "I'm putting them in counting order." Makes a staircase format (only using the columns with pictures at the

> bottom). When placing squares in the birds column says "We better put my square in here for when I get a bird."
> I: "Why did you put them in that order?"
> CHILD: "Just so it would be easy."

This child may have been attempting to make the graph fit a pattern. This was one of the common findings of Pereira-Mendoza and Mellor (1993) who believe that too often children look for or try to create a pattern in a graph when none exists. Asp et al. (1994) found similar results when they asked children to make a Smarties graph.

> Many children created their smartie pictograph and then re-arranged it so that the colours were sequenced from highest to lowest or vice versa, as if this was an essential component of such a graph (p. 64).

Once again, children suggested that the graph provided information which was not necessarily shown for example, the description of the interview with the following child, showed that even though he came up with the correct category in answer to the question "What pet do the most people have?", he did not use the graph to determine this.

Child 13

> I: "What did these people find out?"
> CHILD: "They found out that dogs are very good pets."
> I: "How did you know that?"
> CHILD: "I just knew it, I always did."
> I: "Is there an animal that most people in this class had?"
> CHILD: "Yep! the most people have these (points to dogs).
> I: "How did you know?"
> CHILD: "I just did."
> I: How many people had dogs?"
> CHILD: "About 8."

Item 7 - The book Graph

As shown in Table 6, while most of the 25 children quickly identified *Thomas the Tank Engine* as the most popular book, analysis of their answers shown below, indicates this may be because it is *their* favourite or it is a book they know and like, rather than them using the information displayed on the graph.

Identifies correct book most popular	Uses information on page	Other Justification provided	No justification
20	10	4	6

Table 6 - Summary of findings Item 7

Child 7

I: "Which book did the most people like to read?"
CHILD: Points to *Thomas.*
I: "How did you know that?"
CHILD: " 'Cause I like it."
I: "Is there anything on the page that shows you that lots of people like to read *Thomas*?"
CHILD: "No."

Child 22

I: "Which book did the most people like to read?"
CHILD: "I think train books."
I: "How did you know that?"
CHILD: "I just did."

Child 25

I: "Which book did the most people in the class like to read?"
CHILD: (points to *Thomas*) "That one."
I: How many people liked to read it?"
CHILD: "Don't know."

Child 6

I: "Which book did the most people like to read?"
CHILD: "I think that one." (points to *Thomas*).
I: "And how many people liked that one?"
CHILD: "I don't know, I think all of them did."

Children who did focus on information shown in the graph provided answers in a numerical or spatial manner, for example:

Child 23

I: "What did these people find out?"
CHILD: (seems to anticipate the question "Which book did they like the most?") says " *Thomas the Tank Engine* I think 'cause its got the most."
I: "What else did they find out?"
CHILD: (point to columns) "That one's only got one, that's got 2 and that's got 4."

Child 20

I: "What did these people find?"
CHILD: "They were all different but some was the same"
I: "Which book did most people like to read?"
CHILD: Points to *Thomas*
I: "How did you know?"
CHILD: "There's lots of them."

Child 11

I: "What did these people find out?"
CHILD: "They like to read boats and horses and trains and a treasure and a tiger."
I: "Which book did the most people like to read?"
CHILD: Points to *Thomas*.
I: "How did you know that?"
CHILD: Counts and says "Because there's 1,2,3,4."

Child 17

I: "What book did the most people in this class like to read?"
CHILD: "That book." (points to *Thomas*).
I: "How did you know that?"
CHILD: "' 'Cause there's 4 of them."

Child 16

I: "What did these people find out?"
CHILD: "Well, they found out *Thomas the Tank Engine* and riding horses and riding on boats and trips on islands."
I: "Is there a book lots of people like to read?"
CHILD: Points to *Thomas*.
I: "How did you know that?"
CHILD: "Because there's lots of pictures and lots of stories."
I: "How many people liked *Thomas the Tank Engine* ?"
CHILD: "1,2,3,4 - 4 people."

When children were asked to manipulate the 'books' (laminated cut outs of the book covers) some demonstrated that they had not used the graph to answer the first question, thus illustrating Kamii's (1983) claim that children, unless challenged with an active task which demonstrates understanding, can give the right answer for the wrong reasons.

Child 1

(Had said that *Thomas* was the favourite book)
Randomly moves books around the page, then begins to swap one for another in deliberate moves.
I: "What does the story say now?"
CHILD: "Don't know."

This was also illustrated by Child 7, who quickly stated that *Thomas* was the favourite book, yet when asked to change the page, moved the symbols in a random fashion, indicating that she was basing her decision on factors other than the placement of the book symbols or their number.

Several children moved the books to other columns, not realising that their presence on the page gave the reader information, one child seemed to realise this and took the books right away from the page after initially placing the symbols on the graph.

Child 8

> CHILD: Says "Put 'em somewhere else, take 'em away." (Places 2 *Thomas* symbols on top of *Borka* column) Says: "Move Thomas away."
> I: "What does it show now?"
> CHILD: "2 people liked *Thomas*."
> I: "What about these?" (pointing to *Thomas* symbols in *Borka* column)
> CHILD: "Oh well, there must be a, well if we changed it, if I just took them away they would still be there, so let's take them right away from the book and put them here." (places them on the table)
> I: "What does it say now?"
> CHILD: "2 *Thomas*', 2 of these and there'll be three of these in a minute." (as he places an extra symbol in *Borka* column)

As summarised in Table 7, almost half of the children were in some way able to show that not many people liked to read *Thomas the Tank Engine*. Those children who could not do so fell into two clear groups: those who simply moved the book symbols in a random manner and those who made deliberate moves but did not show the information they were asked to.

Makes graph show that *Thomas* not read by many people	Random moves	Other
12	7	6

Table 7 - Responses to task of changing data

As with the pet graph, some children wanted themselves to feature in their changes.

Child 13

> CHILD: "Well do I take them off?"
> I: "You can move them if you want."
> CHILD: Starts to remove *Thomas* symbols saying "Well they don't like it, they don't like it, they don't like it, three people don't like it."
> I: "How many people like it now?"
> CHILD: (Points to symbol) "That's me."

Child 19

> CHILD: Removes 2 from Thomas column.
> I: "How many people like Thomas now?"
> CHILD: "Daniel and I, guess what else, I like that story I do." (pointing to Treasure Hunt).

Item 8 - The Pie Graph

Limited responses were gained to questions related to this and the following item (the spreadsheet). This was expected, as these were the more abstract and complex forms of data presentation used in the book. Because of this it is difficult to summarise the findings of these items in a table but some responses are worth discussion. Many of the children discussed the pictures of the breakfast foods and what they eat at home. Some responses specifically relating to the pie graph are worth noting however for example, one child was able to interpret the graph using his reading and comparing skills.

Child 5

> I: "What do you think this might be about?"
> CHILD: "Cereals."
> I: "What does it tell us about cereals?"
> CHILD: "There's All Bran, Weet Bix, Rice Bubbles, toast."

Looks carefully at the key and makes a connection between it and the graph. Points to All Bran in key and says "All Bran and what is cornflakes? It must be that one and Rice Bubbles, that one is toast, that one is All Bran, that one."
I: (points to graph) "What did this tell them?"
CHILD: "There's five cereals."
I: "What did the most people like for breakfast?"
CHILD: "I think All Bran."
I: "Does this tell us what the most people like?"
CHILD: "Mmm." (points to largest sector) Says: "I couldn't count all these lines." (starts to count fine lines shading sector) "That one looks the biggest."
I: " And which one is that?"
CHILD: "Rice Bubbles."
I: "And which is the smallest?"
CHILD: "All Bran."
I: "And where is that on here?"
CHILD: Points to smallest sector.

Other responses of note included children who provided logical explanations which made sense to them.

Child 8

I: "What did they find out?"
CHILD: "Which is good for you- I don't know that. They're just showing you the totals of Weet Bix there, toast, Rice Bubbles..."

Child 12

I: "What might this be about?"
CHILD: "Weet Bix and All Bran and toast and Rice Bubbles. We've got those at our house."
I: "What does this show?" (points to graph)
CHILD: "About their plates."
I: "What did it show?"
CHILD: "About all sorts of colours."
I: "Which part of the plate was biggest?"
CHILD: Correctly indicates.

I: "Which part of the plate was the smallest?"
CHILD: Points correctly.

Child 22

I: "What might this be about?"
CHILD: "Making breakfast I think. Some people like to eat Weet Bix (points to picture) some people like to eat cornflakes- that's what I have at home, some people like to eat this and what is this?"
I: "That's All Bran." "What does this tell you?" (points to graph).
CHILD: "Just about nothing, about circles."

Child 23

I: "What might this be about?"
CHILD: Points to rice bubbles- "Well some people could like that - I like that. It's Rice Bubbles."
I: "Does this tell you anything?" (Graph).
CHILD: Points to smallest segment, says: "Well they're Rice Bubbles," points to another segment, says: "They're that (All Bran), that could be that." (points to cornflakes and segment shaded black).
I: "What do you think people like the most?"
CHILD: "Some people like that." (points to Rice Bubbles)

Child 14

I: "What do you think this might be about?"
CHILD: "I eat that, my mum eats that." (pointing to different cereals)
I: "What does this tell you?" (pointing to graph)
CHILD: "Patterns- black, white, black, white, black..."
(This class has had a major focus on repeating patterns during the year.)

These responses fit with the suggestions of Donaldson (1978) and Hughes (1986) who believe that in their daily interactions, children are seeking meaning, trying to understand events and ideas in ways which make "human sense" within their experience of the world. The description of the pie graph as a plate makes perfect sense to the child and enables her to answer the question to her satisfaction while the emphasis on patterns fits with experiences the child had encountered earlier in the school year.

Item 9 - The Spreadsheet

Few children constructed any understanding of the information shown in the spreadsheet, most giving responses such as "I don't know." Some children attempted to make sense of the numbers shown on the page in an attempt to relate what they saw to something they had experienced at school.

Child 5

> CHILD: Reads the days of the week says "I know what all of these say."
> I: "These people were finding out the number of children at school each day."
> CHILD: Reads the numbers in each cell. Says "That's on Tuesday, that's on Monday." Reads: "Mrs Williams."
> I: "Is there anything interesting about the numbers in Mrs William's week?"
> CHILD: Points to a cell says "That one's got the most in it", reads downs the Tuesday column, says "That one's got the most numbers in it." (This was incorrect.)

Child 16

> I: "What do you think this might be about?"
> CHILD: "Counting, there was 1,2,3 (searches for a 4) 4,5,6,7."

Child 20

> I: "What do you think this might be about?"
> CHILD: "It might be about counting, they're all in a mix so I can't count them."

Child 22

> I: "What do you think this might be about?"
> CHILD: " I think it's about special numbers, I think it was going to be about 24 degrees."

Item 10 - Manipulation of concrete materials

Of the 25 children interviewed, twelve found this task relatively simple and quickly moved the objects to illustrate the information given to them, which asked them to show that "I have some pigs, you have some pigs but the teddy bear has more pigs than us". There were limited attempts to in any way organise the materials in rows, lines or columns to show the information, however, children were able to show the information by grouping the objects in distinct groups, one child piling pigs on top of the teddy bear.

Children who did not represent the information given appeared to either forget the task because they were involved in playing with or looking at the characteristics of the pigs, such as colour or whether they were baby pigs or mother pigs, or because they wanted to show that *they* had the most.

Child 12

> CHILD: Lines up 6 pigs in front of self, gives interviewer 4, gives bear remainder (3).
> I: "What does it show now?"
> CHILD: "The bear has 3 and you have 4 and I have 7."

Child 14

> CHILD: Gives interviewer 3, self 7, bear 4.
> I: "Who has the most now?"
> CHILD: "Me."

Developmental levels of responses

While the preceding discussion of each individual item and responses by individual children provides much valuable information, it is also worth considering how individual children respond over all items, to identify any patterns in the levels of their response. Using the levels identified by Herscovics et al. (1987), it is possible to classify responses

Response Totals

Child	No resp.	Intuitive	Transition	Procedural
1	2	6	0	0
2	2	6	0	0
3	0	7	1	0
4	3	4	1	0
5	0	3	4	1
6	1	6	1	0
7	2	5	1	0
8	1	3	3	1
9	3	2	3	0
10	4	4	0	0
11	1	0	4	3
12	0	6	0	2
13	0	7	0	1
14	0	7	0	1
15	4	3	1	0
16	0	5	2	1
17	0	4	3	1
18	3	2	0	3
19	0	7	1	0
20	0	3	2	3
21	7	1	0	0
22	0	5	3	0
23	1	2	2	3
24	2	6	0	0
25	3	5	0	0

Table 8 - Total responses according to levels.

as intuitive or procedural. Some children, however, provide a blend of intuitive and procedural informal, in what appears to be a transitional stage, as suggested by Bergeron et al. (1987) when they describe their model.

> ...it would be a mistake to perceive it as a linear model in the sense that a given level can only be achieved after all the steps of the preceding level have been covered. As our case study has shown, the child evolves simultaneously at many levels (p. 359).

An analysis of responses reveals interesting results for some children. As illustrated in Table 7, some children operate entirely on an intuitive level, some children are sometimes in a transition and three of the children (Child 5, Child 11 and Child 20) respond at a more sophisticated level, with few intuitive responses. No children appear to be operating only at a transitional level, where most responses include some elements of intuition and story creation and some use of procedural knowledge, such as counting. Some responses were limited or non-existent and thus classified as no response.

In summary, as shown in Table 9, it may be concluded that of the children in this sample, sixteen appear to be responding in an intuitive manner, with a maximum of one transitional response (Children 1, 2, 3, 4, 6, 7, 10, 12, 13, 14, 15, 16, 19, 21, 24 and 25). Four children (Children 5, 11, 22 and 17) more frequently provide a transitional response with elements of both procedural and intuitive knowledge and might be classified as transitional in their thinking. Five children are difficult to classify into one of the levels as their responses are spread across the levels (Children 8, 9, 18, 20 and 23); for example, Child 8 provided one procedural, three transitional, three intuitive and one no response answers. As might be expected of children of this age and experience,

Intuitive	Transition	Procedural	Not classified
16	4	0	5

Table 9 - Number of children at each level

no children could be classified as entirely procedural in their responses.

An analysis of each item according to levels of response also reveals some interesting patterns, as shown in Table 10. Item 1 has been excluded, as so few responses were obtained and item 10 excluded because of the differing nature of its requirements. This item will be discussed separately.

Item Number	No Resp.	Intuitive	Transitional	Procedural
2	4	12	4	5
3	1	18	5	1
4	2	15	5	3
5	5	15	2	3
6	4	10	8	3
7	4	13	4	4
8	5	16	4	0
9	15	10	0	0

Table 10 - Responses to each item according to level.

As indicated in chapter 3 the items used in this research generally increase in sophistication as the book progresses (for example a pie chart is more sophisticated than a pictograph). The results of the study show that as the items increase in sophistication, children generally respond with intuitive responses, with no procedural responses to items eight and nine (the pie chart and the spreadsheet) as might be expected. Item six (the pet graph), which appears to be very much like items four and five, produces more procedural and transitional responses than either of them, indicating that it was easier for children to deal with than the simple tally system shown in item five. Similarly item seven (the book graph) seemed easier than the tallies. This raises questions as to whether the familiar context of pets and books helps the children focus on these items.

Item five (the shoe-type tallies) produced a high number of intuitive responses in comparison to item six. Few children used any procedural knowledge of counting or comparison to determine the sort of shoes most people had. This may be because of an unfamiliarity with tally systems or because they have been unduly influenced by information provided by the pictures. As discussed in earlier in the case of child 23, some children rely more on size not quantity to determine which group has the most. This is consistent with Piaget's theory that young children are unable to conserve number, basing their judgements only on perceptual features.

> To them, "going spatially beyond the frontier" means "more" (Kamii, 1985, p. 14).

Item ten, which involved children in manipulating materials asked them to represent data in a concrete form, rather than interpret data prepared by others, as the items in the book had done. This item produced more procedural responses than most (11). This may be attributed to children's familiarity with such materials and ability to see the data in front of them, as they move the materials around. With many experiences of counting such items in a kindergarten, it may have been more natural to use familiar procedures such as counting in completing this task.

General Discussion

The ten items presented to the children in the interviews revealed some common outcomes in response to the various forms of data representation shared with them.

Generally, children attempted to make some sense of the book which was shared with them, often relating the data displayed to events or people they were familiar with or activities they had engaged in as part of their classroom program.

> Children, like adults, will always perceive a situation from a framework that is uniquely theirs. Furthermore, any situation can only be seen in the light of individual interpretations (Pengelly, 1990, p. 357).

The children rarely failed to give any response at all, with the exception of child 21, who spoke English as a second language and seemed to have difficulty in interpreting many of the questions.

It appears that these children have difficulty in separating information they know about the topic or about people they know from information presented in a graph. They are able to supply personal ideas, experiences and information for example, about the pets they or their friends have. Even with reminders about the graph being about another class, many children still see their knowledge of the topic as important in answering the questions, even if their information conflicts with what is on the page in front of them. This was particularly evident with one child (Child 19) who could rarely disassociate herself from the information on the page. In almost all items she either told a story about herself, a classmate or a family member in relation to the subject matter on the page; for example, in relation to the pie graph:

> CHILD: "Well I have Weet Bix at home I do but I used to have cornflakes but they all gone, Daddy ate the last bowlful."
>
> CHILD: "I have a Corona I do." (describing the family car in relation to the car park pictograph).

In relation to the book graph, she gave the following explanation.

> I: "What did these people find out?"
> CHILD: "Well I like, my brother has *Thomas the Tank Engine*, he likes it."
> I: "What about these people, how many in THIS class liked *Thomas*?"
> CHILD: "Well, Daniel and I like *Thomas*, that's two people like Thomas, me, Daniel."

Many children rely heavily or exclusively on visual information and ignore or mis-read graphical presentations where they have to use numerical, rather than purely visual information. This was evident in the lunches pictograph, where children who relied on visual clues alone often incorrectly identified the smallest group and in the pets graph where children ignored information without visual clues in the form of pictures. This leads to the conclusion that these children are operating at an intuitive or ikonic level of cognitive functioning and rely on either informal life experiences or visual information to make sense of the graphs, rather than on any procedural or formal knowledge gained in school. Others were obviously successfully attempting to use procedural knowledge of counting, addition and reading to answer question about the graphs shared with them. This conflicts with what has been believed about four and five year old children, who have been classified by Piaget as "pre-logical and intuitive" (in Labinowicz, 1985, p. 15).

Some responses were influenced by the questions asked or by misleading information shown on the graphs. For example, the foods chart presented difficulties with counting when the place holder/category identifier picture seemed to be representing information it did not. Similar problems were noted with the car park data and the shoe type chart which had one picture which was bigger than the others, causing many children to think it was more important than it was. It is therefore important that future research using a similar approach takes into consideration the sorts of questions and tasks which are framed and that the forms of data representation are carefully developed to avoid unnecessary confusion for children.

There are some clear implications for classroom practice which emerge from these results. Teachers and curriculum writers have tended to hold views about what is and is not appropriate for different ages. This has in some cases placed ceilings on children's learning and limited what they have been exposed to. This research has found that while these kindergarten children are mainly operating at an intuitive level, some are capable of procedural levels of thinking in relation to graphs. This finding is similar to that of Bergeron and Hersovics (1990) who found that in relation to number concepts kindergarten children were more capable than assumed.

> The overwhelming majority of kindergarteners have informally acquired a very extensive knowledge of the preconcepts of number, far more than most teachers realise. Our results also bear out the fact that at this age level, much of the children's thinking is influenced by their visual perception. But this does not imply that one should delay many of the more challenging activities, for it is by gradually having to cope with them that children arrive at some cognitive conflict (p. 133).

Many teachers would not assume kindergarten child were capable of such thought, having set ideas about what four-year-olds can and cannot do; and therefore not expose them to experiences with graphs. The findings of this project challenge teachers who hold these beliefs to re-examine their views on appropriate data handling experiences for kindergarten children and to find out what children can do rather than assuming what they cannot do.

> It is pre-school children who have been most seriously underestimated... We should devise tasks which make sense to children so that we can look at their strengths rather than their weaknesses, at what they can do rather than what they cannot (Hughes, 1989, p. 23).

Opportunities for further research

The results of these interviews indicate that there is much to be learnt through further research into young children's ideas about graphs. Using a larger sample it would be useful to investigate social/geographical differences in children's ideas, as there appear to be some differences between the schools used in the sample (school A has a majority of children who only use intuition). A focus on children's understanding of one type of graph may also provide some useful information. Because of the interesting responses to the bar graphs of pets and books and the tally system, it would be worthwhile to probe more deeply into ideas about what the graph tells us and how we might read beyond the graph in order to make predictions. It may also be interesting to investigate gender differences in graph interpretation, as an initial analysis of responses of children in this sample shows that there are some differences, with girls more likely to 'tell a story' about the information shown.

While the levels of operation provided by Herscovics et al. (1987) have been useful in analysing the results of this research, it may also be worthwhile using other frameworks such as SOLO Taxonomy with multimodal functioning (Biggs & Collis, 1991) to gain further insight into children's cognitive functioning regarding graphs in future projects of this nature.

Conclusion

The findings of this research indicate that very young children have the capacity to read and interpret simple graphs, particularly those with a high visual impact. They attempt to make sense of graphs using information they have gathered about themselves, their families and the members of their class and use strategies they have not been taught in school, building on prior experiences in informal settings. These findings mirror those of researchers who have focused on the abilities of older children to understand graphs.

Classroom activities to develop children's understanding of data concepts should build on these connections between what the child understands and the tasks planned by the teacher. If this can be done well at the early childhood level, it may be possible to prevent common misconceptions which researchers have found prevalent in older children being established.

> The second type of rich linking that appears for constructing robust mathematical knowledge lies at a more global level. It involves connections that need to be established in the learners' minds between their worlds of meaning and purpose, the learning tasks that teachers devise or select and the knowledge that is created because it is used in performing tasks. There is a need for these links to become explicit to the learners and for them to not only develop a capacity, but also to know what capabilities they possess and their potential uses (Denvir, 1990, p. 82).

Chapter 5 discusses ways in which teachers might make these explicit links and help children construct meaningful understandings of data handling processes.

Chapter 5

Recommendations for approaching the teaching of data handling in early childhood settings.

This chapter outlines suggestions for classroom approaches which may assist teachers in making data handling skills meaningful and relevant for young children. It has been established by many researchers who propose a constructivist view of learning, that children attempt to make sense of the experiences they have in the light of what they already know through intuitive understandings of the world. Classroom approaches should build on and challenge these ideas, through activities which make sense to the child.

Teaching statistical ideas in a constructivist manner

As a result of this research, it is evident that teachers should ascertain what individual children know in order that they can plan classroom experiences which build on their intuitive knowledge and help move them toward other more sophisticated levels of cognitive development.

> One of the key tasks of the teacher is to ascertain existing knowledge and beliefs each student brings to the learning situation. This can perhaps best be done by talking with the students as they engage in mathematical activities and by listening to and observing them as they interact with each other and act on the materials and ideas with which they are engaged (Mansfield, 1990, p. 384).

This research has shown that children vary a great deal in their individual understanding of the information presented to them in graphical format. Some children could benefit from extension activities, challenging their ideas and building their understanding, while others could benefit from more explicit teaching of ways to read a simple graph. Unless childrens' original understandings are investigated, the teacher has no real starting point for planning classroom activity. Textbook and curriculum guidelines may provide some insight into what children may be capable of but it is only through interactions and careful observation that an accurate picture can be gained. Graphing and other statistical ideas can be made far more meaningful for students and their misconceptions identified and challenged if teachers adopt such a constructivist approach in the classroom.

> Ordinary graphing activities can be enriched so that students have opportunities to construct their own meaning from data and to use data to solve problems...We've learnt that the true art of teaching data analysis lies beyond collecting and graphing data. It is in considering, interpreting, predicting and developing theories about the data (Corwin & Russell, 1991, p.16).

Appropriate Classroom activities

Seven key aspects of classroom activity have been identified by the author as a result of reflection on the research findings, available documentation on teaching data handling skills and what is known about the ways in which young children learn best. Each of these are important in the provision of an effective learning environment for data handling skills in early childhood settings. They will be discussed in turn but are not intended to be seen as any particular sequence, instead, all should operate together to ensure that children fully engage with the experience.

1. Explicit demonstrations of data handling and interpretation

In language teaching, it has been established by researchers and practitioners that explicit demonstrations by more competent others significantly contribute to learning how to read and write.

> I've come to believe that demonstrations are the raw material of almost all learning, not only language learning. Potential bike riders need demonstrations of how a bike is ridden before they can begin bike riding. The same applies to shoe lace tying, singing, reading, writing and spelling. Demonstrations can also be provided through artifacts. A book is an artifact. It is also a demonstration of what a book is, what print is and does, how words are spelled and how texts are structured. Demonstrations are necessary conditions for learning to occur (Cambourne, 1988, p. 34).

Teachers do this in early childhood classrooms through demonstrating on a whiteboard or easel how we form letters, where we start on the page and in which direction we write. In reading sessions, the teacher will work with a whole class using a 'big book' to demonstrate which marks on the page tell the story, in which direction we read and strategies we can use to decode the messages in the text. Similar demonstrations can be used in the mathematics classroom in introducing and becoming familiar with data representation. Purpose made 'big books' such as that used in this project, provide an ideal vehicle for class sharing and discussion. Other published formats can be collected by the class or by the teacher to initiate discussion, using a range of questions to encourage children to share their theories about what the graph/table etc. is telling us. Specific forms of data representation such as tally systems can be demonstrated to children as an efficient means of recording information in classroom contexts for example, keeping scores in a game. Sharing sessions or class discussions resulting from planned demonstrations allow the teacher to introduce the specific language and skills of data handling within a context, particularly if a book, poster or graph developed by another class is used for the demonstration.

Such demonstrations also enable the teacher to encourage children who clearly understand an idea to share with their peers and demonstrate their ideas, thus allowing children to learn from and challenge each other. Social interaction is important in developing cognitive conflict within the learner, challenging existing beliefs and confirming or rejecting theories. Using the examples shown in the 'big book' used for this project, the children who understood the purpose of the tally marks in the shoe chart could be encouraged to share how they worked out their answer and what they thought the tally marks were for, so that their classmates could hear a different interpretation from that which they had made.

2. Recording in meaningful ways

While it is important to demonstrate how adults record information in conventional ways, we should not expect that children replicate these formats instantly. Just as we allow young children to approximate adult writing, we should encourage children to initially record their information in ways which are personally meaningful to them, rather than insisting on a standard algorithm for graphs and tables before the child understands the purpose of the recording. Hughes (1986) suggests that children are forced too quickly into using conventional symbolism which conflicts with their concrete knowledge of the world when they enter school.

Allowing children to record data they collect and wish to represent in their own ways will provide them with understanding of the purposes for recording and eventually allows them to see the inadequacies of some idiosyncratic systems. It also allows teachers to highlight why some forms of recording are more appropriate than others and why it is important to consider the audience in presenting information. While the child may make sense of the information they present, the audience may not and they need to gradually develop an awareness of clearly represented, unambiguous information.

3. Using Real life experiences

Hughes (1986) suggested that the abilities of young children are most likely to be elicited by problems that arise naturally in a context which children find interesting. As Donaldson (1978) has pointed out, children's difficulties frequently start when they are required to move "beyond the bounds of human sense" (p. 121). When they are dealing with 'real-life' meaningful situations, they have no difficulty in understanding or seeing other's points of view and are not nearly as egocentric as was once believed. Sumio (1990) supported this view and suggested that early childhood mathematics experiences should all stem from real life experiences.

> For younger children, mathematical guidance should be made dependent on their real-life activities and experiences. One should not attempt to construct a formal mathematics curriculum separate from such activities and experiences (p. 377).

Therefore, statistical ideas and data handling skills need to be taught in a way which uses 'real-life' examples from children's lives, such as that presented in the 'big book' used for this project. Examples such as pet graphs, book graphs and finding out about our morning tea encourage the collection of real data by the children, rather than the use of contrived data as shown in many textbooks.

> Elementary school children should be actively involved in collecting "real life" data to construct their own simple graphs. They should be encouraged to verbalise the relationships and patterns observed among the collected data (eg larger than, twice as big as, continuously increasing). In this way, the application of mathematics to the real world might enhance student's concept development and build and expand the relevant mathematics schemata they need to comprehend the implicit mathematical relationships expressed in graphs (Curcio, 1987, p. 391).

As suggested in chapter 2, such experiences can involve children in answering questions about themselves, their friends and their families. This gives children ownership of the learning experiences and of the data they are working with.

For these activities to be purposeful and meaningful for both children and teacher, they should be more than 'one-off' lessons. An in depth investigation may take several lessons, each lesson building on what has gone before and further extending the children's understanding.

4. Helping children focus on the graph

The research findings reported in this project and the conclusions of others (Curcio & Burke-Smith, 1982; Pereira-Mendoza & Mellor, 1993; Asp et al., 1994) suggest that young children often mis-use prior knowledge in interpreting a graph. Children in this study, for example, often answered questions in terms of their experiences or knowledge of the topic rather than what was shown on the pages of the book. It seems vital then, that teachers talk with children and demonstrate how we focus on the graph in interpreting it, rather than using other extraneous information. Encouraging children to discuss and share their differing answers to questions about the graph can encourage them to critically analyse why their answers are different and which might be more appropriate, based on what is shown on the graph. Children can be encouraged to share their experiences about the topic and should have their contributions valued, as they were in the responses to many of the questions in this study. Yet they should also be challenged through questions such as "Can we really tell that from the information we have here?", "Is that shown here on the page?" etc.

> There needs to be exploration of alternative answers in order to differentiate the graph from the students' knowledge of the topic. They need to see that their answers are not incorrect per se, but are not derivable form the graph. This may involve more time on discussing the nature of the relationship between the graph and one's own knowledge than is now assigned (Pereira-Mendoza & Mellor, 1993, p. 18).

5. Helping children read beyond the graph

Reading beyond the data to make predictions is an important objective in statistics education, linking data handling to probability (Pereira-Mendoza and Mellor, 1993). Questions about data which encourage prediction might include, "If a new person came to this class is it likely they will have blue eyes?", "How can our graph help us predict?", "Is Mrs Brown's class likely to have as many people with buckles on their shoes as we have in our class?" etc.

> To improve students' ability to interpret, analyse, and extrapolate from graphs they must be given appropriate tasks which require them to notice trends in the data, to make generalisations, or predictions; that is to read beyond the data (Curcio, 1978, in Curcio & Artzt (in press)).

6. Ensuring that all data handling processes are dealt with

There is a tendency in many classrooms to focus on the collection and representation of data and to forget the important aspect of interpretation. It is important that even young children are exposed to questions which encourage them to critically reflect on the findings of a data handling activity and to be given experiences in interpreting data which has been processed by others, enabling them to compare results. While the whole process of posing a question, collecting data, representing data and interpreting findings does not need to occur on every occasion (for example, the teacher may bring in a published graph made by another class to initiate discussion, without emphasis on the collection of data) it is desirable that some units of work focus on all the steps in the process.

It is also important to expose children to a wide range of data representation methods. If they only have experience of bar graphs for example, they may find it difficult to interpret tally systems, as the children in this study did, most probably through their lack of exposure to such forms of recording. Representation need not mean putting something on paper; initial experiences may include use of blocks, toys or even children to show information about the class for example; all the children with white socks on might sit in one place, all the children with blue socks in another and all the children with other coloured socks in another. A class discussion might then take place about which group has the most in it, which group has the least and what coloured socks the next person who walks in the room might have on.

7. Allowing opportunities for talk

Talk is vital in early learning and teachers should provide opportunities for children to debate and exchange ideas, question each other and reach shared understandings while engaged in data handling activities.

> Infants and primary school children can discuss problems around data collection in many of the same ways as professional statisticians discuss and debate ideas...The heart of mathematics is discussion, exchange of ideas, questioning and analysis. Students often want to discuss their ideas about data at all phases of the analysis process. Just as in a social studies class, or when talking about an interesting story, students profit from exchanging and comparing ideas with others. Ideas are refined and polished when they have to be interpreted and presented (Corwin & Russell, 1991, p.17).

Books such as that used in this project, which have an interactive component, where children are able to manipulate and move symbols to make the graph tell a different story, provide a starting point for valuable talk. As children describe their story and discuss with a group or the class how it might be altered to provide different information interaction can occur and the teacher can gain insight into the children's understanding by 'listening in' on their conversations.

Interaction between the child and the teacher is a vital component of meaningful learning. Some early childhood teachers have in the past beieved that they should not intervene in children's learning and that young children learn through interaction with materials. Recent research suggests that adult-child interaction helps children make connections and develop new insights through challenging their beliefs.

> Within a socially meaningful context that encourages not just a resource rich environment, but extensive adult- child interaction, young children are able to cognitively excel beyond present theoretical expectations, which have, unfortunately, become cemented as a basis for early childhood practice (Fleer, 1992, p. 148).

The development of appropriate resources for early childhood classrooms

If teachers are to use these effective teaching approaches, they can be assisted by the availability of appropriate resources and ideas. Many resources are currently available or are being developed for the teaching of statistical concepts at the secondary level. There is a need for more developmentally appropriate classroom materials, teaching and assessment ideas for the early childhood classroom. Resources such as *Used Numbers* (Russell & Corwin, 1989) are an available exception but in some cases suggest examples which are not culturally relevant to Australian settings. Lovitt and Lowe's *Chance and Data Investigations* (1993) suggest some useful ideas but once again is biased towards the upper primary and secondary classroom. Resources may include books such as that used in this research, games and suggested formats for lesson sequences.

Professional Development for Teachers

No amount of suitable resource material or curriculum documentation will change the teaching of data handling concepts if teachers are uncomfortable with their understanding of the ideas or hold a negative attitude towards teaching the topics which are recommended.

While teachers can adopt the ideas discussed above and learn from action research in the classroom, it is also important that they have opportunities for professional development to build their own ideas and confidence with data handling.

Research conducted in 1993 indicated that elementary school teachers in North Carolina "may not be very familiar with, and may not be able to understand fully the goals and objectives of emerging national and state curriculum frameworks" in the area of statistics (Bright & Friel, p. 5). While teachers were familiar and comfortable with the idea of making graphs, the posing of questions and interpretation of graphs featured very little in discussion of classroom practice. Similar findings have been reported in Northern Ireland (Greer & Ritson, 1993) and similar results would undoubtedly be found in Australians schools. It is therefore important to address the key processes of 'pose a question, collect data, analyse data and interpret data' in an explicit manner in focused professional development sessions. Recognition of the relationship between these ideas is crucial if teachers are to help children form a holistic view of how, why and when we use statistics.

Teachers' own understanding and attitudes towards key ideas in data handling will impinge on their teaching of these, as has been briefly discussed in chapter 2. Without clear understandings of the mathematics involved, teachers will often limit their teaching to the most basic ideas.

> Teachers make a serious mistake if they believe that they need little knowledge to teach young children. If their knowledge is limited or they stick to what the children's textbooks offer, they may unwittingly put a ceiling on children's learning...If you understand the mathematics they are dealing with, you will be able to help them in just the right way (Mannigel, 1992, p. 2).

Some work has been done in particular areas of the United States such as Gal and Wagner's Project STARC (Statistical Reasoning in the Classroom), based in Philadelphia aimed at ascertaining what elementary school teachers know and building their statistical understandings. Since the publication of national directions for mathematics curriculum in Australian schools, funding has also been available to conduct research and develop materials for Australian teachers. The Australian Association of Mathematics Teachers [AAMT] has developed teacher development materials on chance and data in their *Maths Works* series. Australian Research Council [ARC] funded research into students' and teachers' understanding of chance and data concepts is being undertaken by the University of Tasmania (Watson, 1992). This project, still in its early stages, is investigating teacher's confidence, beliefs and needs in this area to assist with planning appropriate professional development programs.

Conclusion

This chapter has described some classroom approaches to the teaching of data handling concepts for children in the early years of schooling, stressing the importance of finding out what children know and using this as a starting point for classroom activity and the need for explicit demonstrations of and discussions about various ways to record and interpret data. It has also suggested that it is important to provide teachers with appropriate professional development and resources to enable them to teach data handling in an effective and purposeful manner.

Conclusion

> Until recently statistics and probability would have been considered out of place in most elementary school mathematics programs. That is no longer the case! (Reys, et al. , 1992, p. 257).

This project has provided a rationale for the incorporation of data handling skills in the early childhood program and has addressed the question "What do young children intuitively understand about simple representations of data?"

The sample of four-year-old children who participated in this study showed that they understood far more about these representations than some teachers might have been expected. In some cases they have quite sophisticated understandings, using procedural knowledge of counting addition, comparison and spatial clues to describe the data presented to them.

The children showed a tendency to interpret the data in terms of their own reality, something which has been noted as carrying through to older children's graphical understanding (Pereira-Mendoza & Mellor, 1993; Asp et al., 1994). There was also a heavy reliance on pictorial or visual cues in interpreting the information. There is a need for teachers to plan classroom activities which recognise and incorporate children's intuitive knowledge, yet at the same time, help them differentiate their reality from what is shown on a graph, moving them towards a more sophisticated level of thinking.

As indicated in the literature review discussed in chapter 2, there is much scope for further research into children's ideas related to data handling and their ability to interpret graphs. This is particularly pertinent in the current context, where data handling has been given increased emphasis in curriculum documents and policies as a significant mathematical strand for all students to study.

There is also a need to assist teachers in their work with young children in relation to data handling skills. There is much to be gained from studies of teachers' ideas about statistics to ensure that professional development meets teachers' needs. There is also a need for the production of quality materials and teaching resources to ensure that the ideas are introduced within a meaningful context for children, enabling them to relate classroom activity to their own experiences.

This project has shown that, even though they have not been taught about these ideas at school, kindergarten children can deal with simple forms of data representation. To facilitate future learning of data skills, so important to numeracy in our modern society, they should be introduced to and immersed in a range of data handling skills in an explicit manner during their initial years of schooling in order to build on, extend and challenge the intuitive knowledge they have. Opportunities to experience data handling concepts arise naturally in the context of a classroom and can assist children develop a wide range of mathematical ideas in a holistic manner as they ask questions, collect, represent and interpret data about issues important to them and their friends.

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Appendix 1 - Parent Permission Form

Denise Neal,
Lecturer Early Childhood Education,
University of Tasmania,
GPO Box 252C Hobart.
August 8 1994

Dear Parent/ Guardian,

I am currently enrolled in a Masters Program through the University of Tasmania School of Education under the supervision of Dr. Jane Watson, Reader in Mathematics Education. Part of my requirements for this program is the completion of a research based project.

I am particularly interested in gaining an understanding of what young children know about simple graphs. I hope to use the information I gain to make recommendations for classrooms teaching in the area of graphing, which is an important early statistical idea.

In order to gain insight into children's ideas about graphs I plan to share a book with them which illustrates graphs and ask questions of the child. I will video tape each interview for later analysis but will not use children's real names or video footage in my final paper, which will be assessed.

I am writing to seek you permission for your child to be among the children interviewed during this research phase of my work. Please complete the section below and return to your child's teacher as soon as possible.

Thank you for your co-operation. If you have any questions or concerns about this research or wish to read the completed paper at a later date, please contact me on 002 202561.

Denise Neal.

I am happy for my child...to be interviewed by Ms. Denise Neal as part of her research on children's ideas about graphs. I understand that my child's name will not be used in any published paper and that video footage of my child being interviewed will remain confidential.

Signed.....................................

Date..

OR

I do not wish my child ....to be interviewed by Ms Neal.

Signed.......................................

Appendix 2 - Letter to Principals

Denise Neal,
Lecturer Early Childhood Education,
University of Tasmania,
GPO Box 252C Hobart.
August 8 1994

Dear

I am currently enrolled in a Masters Program through the University of Tasmania School of Education under the supervision of Dr. Jane Watson, Reader in Mathematics Education. Part of my requirements for this program is the completion of a research based project.

I am particularly interested in gaining an understanding of what young children know about simple graphs. I hope to use the information I gain to make recommendations for classrooms teaching in the area of graphing, which is an important early statistical idea.

In order to gain insight into children's ideas about graphs I plan to conduct interviews with a sample of kindergarten-aged children in three southern schools and I am writing to seek your permission to conduct interviews with , if possible, ten four-year-old children from your school. These interviews will take the format of a video taped sharing of a big book I have prepared which shows various formats of simple graphs. I do not envisage that the interviews will be in any way intrusive into the kindergarten program and would take no more than ten minutes each.

I have gained ethics clearance for this project from both the Department of Education and the Arts and the University of Tasmania and enclose for you perusal a form seeking parent approval.

I would appreciate your contacting me as soon as possible to inform me of your decision so that I can begin planning my visits to the school. In anticipation I thank you for your co-operation.

Yours Sincerely,

Denise Neal