PARTNERS IN PROBLEM SOLVING

CHILDREN COLLABORATING IN PAIRS

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Abstract

The extent to which children's collaborations with their peers affects their learning is an area which merits scrutiny due to the complexities of such collaborations, the nature of the tasks children focus on, and the dynamics of peer discourse.

This study focuses specifically upon pairs of children of similar ability during problem solving in mathematics. Current research on collaborative peer dyads (children working in pairs) indicates that these small groups are relatively non-threatening and provide the opportunity for a child to elaborate his or her ideas with a peer. Debate surrounds the quality of collaborations within dyads and the extent to which these interactions influence children's learning.

This qualitative study closely examined the processes of collaboration between children in peer dyads as they engaged in problem solving. The 16 children in the study ranged in age from seven to 10 years. The problems they investigated varied in type from closed (with one "correct" solution) to ill-defined (with a range of possible solutions and strategies). The methodology draws upon grounded theory and incorporates a number of central grounded theory methods. These methods were used to analyse the data and build a conceptual basis for this analysis, rather than to build a grounded theory. Methods of data collection included observation, interviews, video-recording, audio-recording, children's work samples, recourse to relevant documents and discussions with teachers.

The findings suggest that the notion of a problem "type" in enhancing collaboration is less relevant than the cognitive demand of the problem. The cognitive demand of problems was crucial for encouraging children's engagement with each other.

The presence of a partner appeared to maintain persistence with problems which were challenging. This persistence was quite subtle, yet effective, in that one child did not overtly encourage another to stay on task but merely continued with a line of reasoning or exploration. Often, this was all that was required to re-engage a reluctant or discouraged child.

Collaboration was not a constant feature of any dyad during any one problem. The children often moved from individual musing to peer collaboration in an iterative fashion. The roles that the children assumed within a dyad did not remain static. This appeared to be a corollary of similar ability dyads wherein the power relationship is relatively mutual and reciprocal. There was evidence to suggest that children would often borrow each other's strategies, language and ideas to pursue the problem solving.

While the children's talk was utilised as the prime focus for analysing the data it is acknowledged that any study which examines talk is limited by the imperfect and incomplete way that spoken language represents thought. A further limitation is

determining the extent to which children learnt from each other and the residue that any learning may have left for children's future problem solving.

The implications of this study include the potential of collaborative peer dyads for developing children's persistence in problem solving. Such persistence can encourage children to persevere when experiencing difficulty and consult with a peer rather than abandon a problem or rely upon a teacher's intervention. Such a finding does not assume that teachers should relinquish their role as challengers, facilitators and supporters of children's learning. Children's misinterpretations should not be left unchallenged and dyads are not always sufficient for clarifying such confusions. Teachers' decisions about curriculum and pedagogy could, however, consider the potential for collaborative peer dyads in developing persistence in problem solving when a problem is sufficiently challenging and engaging for children.

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Chapter One

Introduction

1. Learning and Teaching Experiences

This study has its inception in my own schooling and teaching experiences. For many people of my generation and older, learning in school was a highly individualistic enterprise. Children, for the most part, were not required or expected to work with others. In fact to do so was tantamount to cheating. The few exceptions I recall were instances where we were required to test a partner during spelling or mathematics, and the performance of sport, singing and plays. In the testing the onus was very much upon marking your partner right or wrong. For cultural activities we were grouped together but rather than being encouraged to interact with each other we were required to follow the instruction of the teacher to us as a whole class.

Peer collaborations were, however, initiated informally for study purposes. Such collaborations were hidden from the teacher so that we would not be penalised and admonished for working with another person. I attended Teachers' College from 1979-1981 during a time when behaviourism was particularly popular at the tertiary institution I attended. For example, we were instructed to use only performance objectives when planning lessons and these had to specify clearly observable behaviour. Children were evaluated in terms of their ability to reach the objectives that were set. These objectives focused mostly on the acquisition of skills (which were easier to observe) and incremental gains in knowledge made evident through some activity which purported to show that children had grasped a particular concept. The focus on group work and peer collaboration was minimal. We studied friendship patterns, grouping children by ability (three groups for mathematics and three groups for reading) and seating arrangements in the classroom. These aspects of grouping were studied in order to assist a teacher's classroom management, including his or her organisation of resources and use of time. While groups were encouraged for mathematics and reading, there was no guidance provided on teaching children the skills of collaboration. Furthermore, it was not suggested that children could or would learn anything from each other. Groups were dominated by the teacher who instructed each group one at a time while the other children worked individually, even if they were seated in groups.

My own teaching experiences included a number of these group work arrangements. I also incorporated pair (or dyad) collaboration amongst children for spelling, mathematics testing of times-tables, measurement activities and "buddy" reading. These dyad collaborations freed me as the teacher to circulate amongst the

children to observe, assess children's progress, or attend to other tasks. It was evident that the interactions between children were low-level, with the spelling and mathematics testing comprising mostly of checking answers. Group work was also used for discussions in social studies and activities in science and physical education. The focus of such groups, however, tended to be on their convenience for accessing resources and for teacher assessment purposes rather than on the processes of interaction and learning that occurred between children. Occasionally I had pairs of children working together on projects and I noticed that when a dyad collaborated well, and were of similar ability, the two children involved appeared to stimulate and challenge each other. In particular, I wondered what the potential for children's learning in dyad collaborations could be and suspected I was making limited use of pair work.

Since my time as a primary (elementary) school teacher, dyad collaborations have started to be used by some teachers for a wider range of purposes such as technology investigations, mathematics problem solving and for jointly composing stories and other texts in language. There is also greater use of dyads for peer tutoring purposes wherein a more able child assists a less able child. While peer tutoring is based upon an established research base, there is much less foundation in the literature for dyads which are comprised of children of similar ability. The predominance of peer tutoring in the literature is reflected in this use of dyads in the classrooms. From my observations, the purpose for most of the pairings of children by teachers seems to be for peer tutoring, peer mentoring and for assisting a new child with adjusting socially to a classroom culture and milieu. Occasionally I have observed teachers in classrooms pairing children of similar ability, for example, when teaching small ball skills and jointly writing stories on a computer. When I discussed with the teachers their reasons for pairing children of similar ability they often stated it was an "intuitive" decision. They stated that children of similar ability will engage each other because they are well suited but that they will often become frustrated when working with a partner of considerably less ability. The teachers sometimes sought to match the children so that they would be at the same level. They thought that this enabled children to challenge each other. They also commented that when children were invited to choose their own partners they invariably chose someone of similar ability. In addition, teachers often commented on pairing children with scepticism, stating that sometimes one child would not do his or her share of the work in a dyad. In relation to this, many very able children commented to me that they preferred to work alone and noted that they often ended up doing the majority of the work or that they became frustrated with the slow pace of their partner.

These experiences and observations highlighted a number of factors for me. First, there was little use of dyads of similar ability in the classrooms I have observed over

the years. Second, teachers often recognised that similar ability pairs were likely to challenge each other. Third, this challenge would depend upon a fair distribution of work load in a dyad. Fourth, children would often choose a partner of similar ability. And fifth, very able children were likely to prefer to work individually. These factors were reiterated with my experience of dyad collaboration in tertiary teaching. In the university, students are for the most part, expected to work individually and are assessed on their own achievements. Pairing students for collaborative tasks is not widespread and it is not common practice to assess students as a dyad. I have used pairs for seminar presentations and the students involved commented that they usually enjoyed working this way as it was less intimidating when presenting a seminar to a class. The students did not have to work together but most chose to do so. There were a few who had difficulties with dividing the work load evenly which tended to affect their overall seminar presentation and their relationship with their peer. Interestingly, as evidenced with the children, the students tended to choose a partner of similar ability.

The most beneficial experience I have had of pairing students was for peer writing and editing purposes. Students commented on the supportive and helpful process of having someone else (an editing partner) read and give feedback on their written drafts. Many commented that it was the first time that anyone had read their work and given feedback, other than a lecturer for assessment purposes. They also commented that the feedback process required guidance (which was part of the course), diplomacy and trust. As they were not grading each other's work they felt they had considerable latitude to explore ideas and concepts (see Fraser & Spiller, 1996, for a full account). The peer editing appeared to be successful for most students.

These learning and teaching experiences raised questions for me regarding the use of dyad collaboration in the classroom. The potential for opportunities to learn in similar ability pairs did not appear to be explored in considerable depth by practitioners nor by the research literature. Various practices I observed or implemented indicated that dyad collaboration can be educationally and emotionally beneficial for many students, but perhaps not for all. From this experiential starting point it seemed salient to investigate what has already contributed to the understanding of peer and dyad collaboration.

The problem which is central to this thesis is outlined in this introductory chapter. We need to know more about the processes of collaboration in order to ascertain the potential of pair groupings in primary school classrooms. This problem is clarified through the brief discussion of my teaching and learning experiences above, contributions from the past regarding the use and understanding of peer collaboration, curriculum emphases, and related issues and concerns. A brief outline of each chapter's contents is also presented.

2. Contributions from the Past

The willingness of children to interact with each other in schools is readily apparent in classrooms and playgrounds the world over, yet didactic teaching methods flourished in the face of children's proclivity to engage with each other. Such methods actively avoid any peer collaboration as knowledge is transmitted from the teacher as expert, to the children as passive recipients. Interaction of peers (except for covert whispering and clandestine communications) in such environments is rare as discussion is expected to be channelled through the teacher, generally in the form of questions and answers. Even among education researchers, children's interactions with their peers has (until recently) been largely regarded as unnecessary, distracting and a nuisance (Cazden, 1988).

It would be easy to assume that when I was teaching children little was known about peer interaction and the potential of children's collaboration for their learning and development. This, however, is not the case. Despite teacher-centred traditions, the recognition of the benefits of peer collaboration is not new. Centuries ago the Talmud stated that readers should have a "learning partner" to study the meaning of its contents. Similarly, the Socratic method promoted "dialogue" between learners who were encouraged to generate and discuss ideas amongst themselves. Aristotle is also reported to have actively encouraged peer tutoring amongst groups of young men. And in the 17th century Comenius broke with tradition by advocating accessible education for all which included encouraging peer interaction and the communication of knowledge between learners regardless of their social status or gender (Wagner, 1982).

The influential US educator Dewey (1916) discussed the importance of peer interaction in cooperative groups. The writing of Dewey and others influenced a number of curriculum reports and documents in Britain, the United States and New Zealand which have long recommended the educational use of peer groups (e.g., Department of Education, 1961; Hadow, 1926; Pepitone, 1980; Plowden, 1967). In addition, Taba (1969) lamented that peer interaction was a most under-utilised resource in the classroom. She argued that learning difficulties could be addressed by using group work more efficiently. Encouraging children to help each other and work together was also promoted by Bloom (1976) who stated that peers can dispense reinforcement, feedback and corrections.

The influence peers have on children's cognitive development, however, has only relatively recently become a serious subject for enquiry by psychologists and education researchers. Developmental psychology no longer defines the child as an individual scientist, testing out hypotheses in isolation to make sense of his or her world, although this was the view that held precedence in cognitive development during much

of Piaget's time. Piaget (1967) himself acknowledged that the different points of view provided by peers could challenge a child's thinking and create the need for a child to alter his or her thinking to accommodate the different perspective a peer afforded. He believed that a child's cognitive development is influenced by social interaction and stated that "without interchange of thought and cooperation with others the individual would never come to group his [*sic*] operations into a coherent whole" (p. 163). He regarded the cognitive conflict children can experience when confronted with an opposing opinion as essential in confronting egocentrism. He argued that the extent to which a child can learn from others is determined by his or her level of cognitive development.

In addition to cognitive development, Piaget argued that peer interaction can be instrumental in fostering moral, social and personality development. Children's relationships with their peers, he stated, have the advantage of equality and reciprocity in that it is easier to have similar status with another child than with an adult. He claimed that peer relationships can enable a child to take the perspective of another. Perspective-taking and "decentering" becomes possible in peer interaction, Piaget believed, as children are more likely to retain their autonomy instead of acquiescing to an adult. He acknowledged, however, that inequalities still exist amongst children and autonomy of thought and action may also be thwarted during peer interaction. It was not until the establishment of social psychology in the 1970s that Piaget's theories on peer influences began to be systematically explored (Light & Littleton, 1994). Piaget's views on this issue are discussed in more detail in the following chapter.

The other seminal theoretical position which has contributed substantially to the current study of collaboration is Vygotsky's (1934/1962, 1978) theories on language and learning. Vygotsky explored the relationship between language and thought and explained how meaning can be developed through social discourse and how it can be internalised as inner speech. He emphasised the key role of collaboration in constructing meaning and developing thinking. He emphasised the importance of social interaction in understanding thinking and its development. As Moll (1990) stated "he viewed thinking as a characteristic not of the child only but of the child-in-social-activities with others" (p. 12).

His theories have also influenced subsequent research from sociocultural and social constructivist perspectives. Some of this research and its relevance to collaborative problem solving, will be discussed in the literature review.

3. Curriculum Emphases on Collaboration

Group work, peer collaboration and problem solving are currently emphasised internationally in a range of curriculum statements. The presence of these factors

signifies the influence of social constructivism on curriculum development and is relevant to dyad collaboration. For example, in England the Cockcroft report (1982) recommended discussion between peers and the opportunity for children to explain ideas in their own words. Similarly, in Australia the Australian Education Council (1991) stated that, "Asking children to talk about how they solved problems should help them to learn from each other and come to realise that there is often more than one way to deal with a situation" (p. 40). And, in the United States, the National Council of Teachers of Mathematics (1989) stipulated that, "Interacting with classmates helps children construct knowledge, learn other ways to think about ideas, and clarify their own thinking" (p. 26). Each of these documents conveys an understanding of how children learn and a serious regard for children learning from interacting with their peers.

While collaborative learning is not new, and there appears to be persuasive reasons for continuing the practice, there are a number of issues yet to be addressed. Of import to New Zealand and a number of other countries is the increased focus on group work across the school curriculum. At the same time, there are calls for the return to formal whole class teaching by some groups who are sceptical about the benefits of children collaborating with their peers during lessons (Hillgate Group, 1987; "New Orthodoxies", 1998). Furthermore, even the advocates of group work stress that collaborative learning is not a replacement for whole class teaching or individual work, but is one option in a pedagogical repertoire. Nonetheless, curriculum documents such as *Mathematics in the New Zealand Curriculum* (Ministry of Education, 1992) support and encourage group work. Higgins (1995) noted that

> In official curriculum statements in New Zealand, group work is being promoted both as a means and as an end. There are changed curriculum emphases on mathematical processes over content, active rather than passive learning, and the locating of mathematics learning in the everyday context. (p. 2)

There is a particular need to investigate the processes of collaboration in New Zealand as these processes seem to underpin the purpose of grouping children in pairs. *The New Zealand Curriculum Framework* (Ministry of Education, 1993), which is the basis for teaching in primary and secondary schools, emphasises (inter alia) the importance of social and cooperative skills. These are considered "essential skills" and are intended to be developed across and within all curriculum subject areas. *The New Zealand Curriculum Framework* describes social and cooperative skills as including taking "responsibility as a member of a group for jointly decided actions and decisions" (p. 19) and developing "the ability to negotiate and reach consensus" (p. 20). Both of these processes can occur when children collaborate in a dyad.

What *The New Zealand Curriculum Framework* overlooks, however, is that it is misleading to define cooperative ability and social development as a set of "skills" to be acquired. Irwin (1996) stated that the term skills pertains to those specific performances that are improved with practice such as ball skills, handwriting skills and map reading. It seems inadequate to consider social and cooperative development as skills, even if they can be improved through practice. As Irwin pointed out, there is a difference between those mechanical skills which require repeated practice and higher level capacities such as critical and creative thinking. Furthermore, he argued that such higher level capacities (which may include social and cooperative abilities) "are not generic but are intrinsic to distinctive forms of knowledge" (p. 12). There may be some transfer of ability from one context to another but this is not automatic. His argument begs a number of questions. To what extent is social and cooperative ability a generic skill? Does the context and subject matter influence the extent to which children may cooperate? And can it be claimed that a child who cooperates well in mathematics will transfer this skill to other subjects? The broad claims of the *New Zealand Curriculum Framework* require scrutiny, including the issues of nomenclature (skills) and meaning (essential generic skills).

Each curriculum subject document, however, attempts to specify how such essential skills as social and cooperative ability can be developed within the context of a particular discipline. Social and cooperative skills are acknowledged and stipulated within each of the curriculum documents which support *The New Zealand Curriculum Framework.* For example, in *Mathematics in the New Zealand Curriculum* (Ministry of Education, 1992), peer discussion and group work is recommended through statements such as, "Students should be...working co-operatively as part of a group by listening attentively, generating ideas, and participating in reflective discussion" (p. 29). Similarly, *Mathematics in the New Zealand Curriculum* (Ministry of Education, 1992) lists under "Mathematical Processes" that students should be given the opportunity to "become effective participants in problem-solving teams, learning to express ideas, and to listen and respond to the ideas of others" (p. 23).

In addition, *English in the New Zealand Curriculum* (Ministry of Education, 1994) places considerable emphasis on the development of oral language, which also includes the "interpersonal functions" of listening and speaking to others with coherence and confidence. Furthermore, *Beginning School Mathematics* (Department of Education, 1985) is a widely used classroom resource with young children in New Zealand. This resource consists of teacher-led activities, extension activities and independent activities. The latter two types of activities are intended for children to work on in groups (including pairs), independently of the teacher. Higgins (1995) pointed out that the structure of the *Beginning School Mathematics* resource is designed to encourage peer collaboration and independent group work.

Some research in mathematics in primary schools suggests, however, that peer collaboration is not encouraged in the classroom. For example, Young Loveridge (1992) studied the attitudes towards mathematics of 68 nine year olds as part of a longitudinal study of children's number concepts. She found that when the children had difficulty with their mathematics they were more likely to ask their teacher for help than to seek assistance from their peers. Some children thought it was acceptable to ask their peers for help but not to be told the answers. For another group of children the thought of obtaining help from peers was deemed inappropriate and they "regarded this as cheating" (p. 101). One able child expressed frustration with being asked to help others and ended up telling them the answers in order to get on with her own work. Young Loveridge concluded that collaborative learning during mathematics is not encouraged. She summarised that

> Even talking to peers during mathematics seemed to be discouraged or prohibited in many of the classrooms. It appears that the children were expected to work individually on mathematics all of the time. In some classes, children who finished their own work quickly were allowed to help others. Not one child mentioned working in groups on a shared mathematical activity. (p. 101)

It should be noted that this study was published in the same year as *Mathematics in the New Zealand Curriculum* (Ministry of Education, 1992) and a year before the publication of *The New Zealand Curriculum Framework* (Ministry of Education, 1993). Furthermore, the data were collected in 1989. Therefore, it could be predicted that the influence of the curriculum since that date may have resulted in more peer collaboration in classrooms during mathematics in the last few years. Both the *Curriculum Framework* and *Mathematics in the New Zealand Curriculum* place emphasis on social interaction and peer assisted learning, as evidenced earlier. The methodology of the Young Loveridge study consisted of open-ended and structured interviews with the children. Without classroom observations, or some other method of data collection it cannot be claimed with certainty that what the children reported was an accurate reflection of what always occurred.

4. Concerns and Issues

It has been argued that even when teachers organise groups they tend to dominate group interaction by setting all the boundaries and not allowing sufficient time for children to reflect on the ideas discussed (Prisk, 1987). Such teacher dominated interaction is often of educational use and to children's cognitive benefit but it seldom affords children the opportunity to develop and extend their social and communicative

ability. Prisk stated that children's talk in groups is vital as it can promote both their thinking and their ability to reflect on their learning. Moreover, such talk and collaborative problem solving can develop children's independence, interdependence and self-evaluation. She added that

> Sharing responsibility in a group for methods of tackling a problem appears to give practice in skills important for future success in learning. If teachers do not provide opportunities for children to structure their own thinking the pupils, by becoming over-reliant on externally imposed structure, may find it progressively more difficult to monitor and evaluate their own strategies. (p. 92)

With the current emphasis on social and cooperative skills in groups, it seems opportune to know more about what contributes to, and influences, collaboration. While the word "cooperative" is used in the documents mentioned above, the research on cooperative groups is not sufficient to gain a full picture of the processes that contribute to collaborations in the classroom. The processes of problem solving, and listening and responding to others, can occur in various groupings which do not adhere to, or exemplify, a cooperative learning model (e.g., Johnson & Johnson, 1974, 1994). Furthermore, the corpus of research on cooperative groups focuses on groups larger than two, whereas this study focuses exclusively on pairs.

In New Zealand it seems likely that the flexible grouping of children for various purposes creates a number of ways in which they have the opportunity to collaborate with others. The underlying assumption is that such opportunities are beneficial for children's learning and development. Only recently have researchers questioned this assumption and recommended a close examination of small group processes (Higgins, 1996; Irwin, 1996; Thomas, 1994). This critical appraisal of small group processes in New Zealand is matched by a similar concern in Britain (e.g., Dunne & Bennett, 1990; Stables, 1995) and America (e.g., Cohen, 1994; Linn & Burbules, 1993; Tudge, 1990). This international movement conveys scepticism about the generalised claims that small groups are preferable to whole class teaching, and explores what learning occurs for children in group settings. For example, some group interactions provide few opportunities for children to learn and some interactions may impede children's development. Nonetheless, group work is encouraged internationally for both educational and economic reasons. For example, as Westgate and Hughes (1997) noted

> Communication, collaborative learning and group problem-solving are becoming more firmly established among the 'transferable skills' on which employers place emphasis and which figure ever more explicitly in curricular documents for every stage from pre-school to higher education. Over the past 20 years, the exercise of

> such skills has gained recognition as central not only to language development but also to learning more generally - even if some dangers in overstating the case need to be acknowledged. (p. 129)

Communication, collaborative learning and problem solving are pertinent factors in the facilitation of dyad interaction. The ways in which these processes can occur and the significance of these for children's learning requires investigation.

5. Summary and Outline of Chapters

This study focuses on children's collaboration and problem solving in dyads (small groups of two) to examine their interactions and what these may indicate about children's learning. Since collaborative group work is emphasised in the curriculum we need to know more about what occurs when children collaborate, how the interactions affect them, and when the use of collaborative dyads is appropriate. It is also useful to know where and how the literature may be "overstating the case" in claiming benefits from collaboration in pairs. While peer tutoring appears to be well established, there still remains many unknowns about the use and purpose of similar ability dyads.

Chapter 2 reviews the related literature pertaining to this thesis. This includes distinguishing collaboration from cooperation, relevant findings from group work research, collaborative peer dyad research, related analytical and theoretical issues, and problem solving. The review raises questions about some existing methodologies, outlines gaps in the literature and highlights a range of issues of import.

Chapter 3 explains the methodology of the study, drawing upon a number of central methods and principles in grounded theory. This study utilises these methods to guide the way in which data were collected, coded and analysed. The research process is described and reflected upon. In addition, the limitations of the method used are discussed.

Chapter 4 outlines how the data were analysed in terms of coding and categorising to build the theoretical framework of the study. This chapter also outlines some of the issues and debates in using grounded theory and explains the stance taken for this study. The selected grounded theory methods of analysis are made explicit with some examples.

Chapter 5 presents both the results and discussion of the study. It shows how this thesis generated a series of themes which relate to the categories outlined in Chapter 4. The results are presented in terms of these emergent themes. Each theme is illuminated by extracts from the data. Discussion of each theme is compared and contrasted with the existing literature and also highlights new insights that emerged. In addition, the initial research questions are returned to and addressed in the light of the results.

The final chapter, Chapter 6, concludes with implications for theory, classroom practice, curriculum, and further research. It includes discussion of the limitations of the study and liberty is taken to extrapolate some suggestions for the future.

Chapter Two

A Review of the Related Literature

1. Introduction

The literature which is reviewed for this thesis comes from a range of sources, all of which make significant mention of an aspect related to children's collaborative problem solving. While many are qualitative studies with a focus on interaction and process, a few are experimental studies within a positivist paradigm. Most of the studies selected are based on empirical classroom research and the few laboratory studies mentioned have some feature of significance for this research. Some of the literature relates to general classroom interaction studies and some of it has a specific curriculum focus. Mathematics, science and computing feature frequently as these contexts have a strong problem solving focus, and because mathematics is the curriculum context for this study. Also included, however, are studies in language and social studies which pertain to children's collaborative problem solving. Of particular note is the literature related to children's talk and the ways in which their discourse affects and conveys their thinking and understanding. These qualitative studies draw primarily upon classroom observations, interviews and tape-recordings.

Studies have been selected which focus on three major areas:

- collaboration and cooperation
- peer interaction and group work
- analytical and theoretical issues

The words "collaboration" and "cooperation" are sometimes used synonymously in everyday usage and in the research literature. There are instances, however, where a distinction is made between the two terms. The first part of this review defines cooperation and collaboration, explores the overlaps between these terms and justifies the use of collaboration for this study.

The second part of this review explores a range of findings from peer interaction and group work studies which raise issues about children's collaboration. There are pertinent implications from these studies which have significance for children working in pairs. This is followed by a specific focus on research related to collaborative peer dyads and problem solving. While some of these studies examine outcomes, the focus is also on the processes which characterise dyad collaboration. A section on recent New Zealand research on group work and problem solving is included. Studies which

support contrasting theoretical positions are deliberately chosen to provide an overview of the issues in the area of collaborative problem solving.

Issues and theories which pertain to the analytical and theoretical debates in the literature forms the content of the third part of this review. This includes theories from a cognitive perspective, particularly the contributions of Piaget and his intellectual successors, and some which focus on social constructivism, sociocultural issues and the influence of Vygotsky. The ways in which these theories have contributed to an understanding of children's collaboration and cognitive development is discussed. Analytical issues of coding and the role of children's talk in collaboration and problem solving are included as this study codes and categorises children's discourse during problem solving. This section also reviews issues in problem solving and defining problems.

Omitted from the review are studies which examine issues of gender, class, race, disability and ethnicity in collaborative work as these factors are beyond the scope of this study. There is a plethora of cooperative group studies which (inter alia) compare cooperative groups with competitive and individual work but they are not included, as this study is not concerned with comparing group work with other arrangements for learning. Research on the use of rewards and resource interdependence in groups is also excluded.

The sections to follow on collaboration and cooperation draw largely from empirical studies undertaken in primary (elementary) school classrooms and include definitions on these processes of interaction. Some of the literature reviewed here is intended as guidelines for teachers in developing a pedagogy of groups.

2. Collaboration and Cooperation

What is meant by collaboration? The term implies a joining together of people, usually focused upon a common goal. Collaboration is unlikely to take place when individuals have different goals and are not committed to a shared purpose. Some effort may be required to pursue a joint enterprise. Such effort is directed at an outcome that the individuals have decided is worthy of pursuit. Some value judgement therefore seems inherent on the part of the individuals as to the purpose of the collaboration. Increased collaboration may result from the individual's personal investment in the nature of the task. Conversely, the process of working on a shared task may engender collaboration as the individuals become increasingly absorbed in the nature of the task itself (i.e., individuals may reluctantly face a group task and have little enthusiasm for it at the outset, but become increasingly absorbed and intrinsically motivated as a result of the joint investigation). Their increased motivation may accrue from the task itself, or from the act of working together, or from both.

Collaboration requires an interaction between at least two individuals. This interaction occurs between individuals engaged both with the task and with one another. Interaction with the task alone appears insufficient in achieving collaboration. Individuals may take turns or work in parallel rather than truly collaborate. For example, a competitive game where one individual is pitched against the other requires the players to interact with the task and take turns, but they are not working together in the sense of aiming for a shared goal. Some engagement with each other beyond the waiting for one's turn is required (Light & Littleton, 1994). In order to study the relationship between collaboration and children's learning, it appears expedient to focus on both the children's engagement with the task and with each other. This issue will be returned to later in the section on peer interaction effects on children's thinking. Definitions from the group research literature which distinguish between the terms collaboration and cooperation are discussed in the following section.

2.1 Cooperative and collaborative groups: Distinguishing the two

The literature does not always clearly delineate the terms cooperative and collaborative. Furthermore, there appears to be some distinct differences in the way the term cooperation is explained. While Johnson and Johnson (1974) emphasise face-to-face interaction and regular group processing, other writers emphasise different aspects of cooperation. Kutnick and Rogers (1994), for example, defined cooperation as individuals working on *separate* (but related) sub-tasks which are brought together as a joint outcome. They defined collaboration as individuals working on the *same* task with a joint goal. Kutnick and Rogers appeared to base their definitions on the work of Galton and Williamson (1992) whom they cited in their own work. Galton and Williamson (1992) defined cooperative work as situations when "pupils work on the same task but each have individual assignments which eventually are put together to form a joint outcome" (p. 10). They distinguished collaborative work by defining it as involving "all children contributing to a single outcome and often involves problem-solving activities, particularly in cases where the group has to debate a social or moral issue and produce an agreed solution or recommendation" (p. 10). They emphasised the process of debate in their definition of collaboration, in contrast to the somewhat less interactive and more consensual process of cooperation.

The preference in this study is for a focus on collaboration for the following reasons:

- Cooperation denotes a sense of compliance. Challenges to thinking may not be welcome in an environment which does not seek to challenge and change existing boundaries, but rather, achieve harmony.

- Cooperation denotes a sense of concurrence-seeking. The purpose of the group in cooperative learning is usually to seek resolution of a conflict or problem by working together and pooling resources, ideas and strategies. While collaboration also has an emphasis on working together towards a goal, there may be less agreement during the process.

From an analysis of the cooperative/collaborative literature, the distinction outlined above appears to be warranted.

For the purposes of this study the following descriptions exemplify this distinction:

Cooperation

Two children have been assigned the task of depicting and explaining the cycle of the seasons. They divide the task so that one child works on summer and spring while the other child works on winter and autumn. One draws large crayon pictures with bold captions underneath. The other makes fine sketches with arrows and labels on her drawings. When their drawings and captions are complete they present their work to the class together but take turns explaining each child's contribution to the project.

Collaboration

Two other children have been assigned the same task. They sketch out their ideas. They discuss how they will depict the seasons and consider a range of possibilities including a poster, a picture strip, and a mime. After much debate and a few false starts they decide on the mime. Eventually, the mime is presented to the class and they are both actively involved in the mime sequence.

Collaboration, as illustrated by the latter example, is more likely to result in children working together, rather than in a parallel fashion. It also requires more negotiation between the learners and may result in more disagreement about the actual processes used. The concepts of "negotiation" and "disagreement" are evident in some theoretical concepts which will be discussed under the analytical and theoretical issues later in this review. When children are engaged in their own separate tasks there is little need for them to alter their intentions in the light of others' opinions or ideas. As such, cooperative work may be more appealing for the child as a learner can retain their autonomous approach within the general group goal. Cooperative work,

however, may also engender more complacency as the child need not be challenged or come into conflict with opposing points of view which require resolution.

Although the terms cooperation and collaboration are often used interchangeably they refer to distinctly different processes and principles. Further clarification of the distinction between the terms is offered by Barnes and Todd (1977) and by Davidson (1994). Theories about language and learning devised by Barnes and Todd are related to collaborative learning where the focus is on the creation of meaning between peers through dialogue. In contrast to the corpus of literature on cooperative learning, collaborative learning does not emphasise the direct teaching of social skills, the use of rewards, nor the need for resource interdependence. Instead, the collaborative approach described by Barnes and Todd, and by Davidson, is one in which a task is jointly investigated. This contrasts with cooperative models wherein a task is often broken into its component parts and roles for group members are specifically delegated. There is also less emphasis in collaboration on the key cooperative components of interdependence and individual accountability, although these aspects are still of some relevance.

Collaborative learning can be less "orchestrated" and encourage more peer negotiation and flexibility rather than prescribe roles and responsibilities. Lester (1992) made a clear distinction between the two terms and argued that "cooperative learning is imposed structure with preset goals and explicitly defined and rigidly adhered steps for attaining those goals" (p. 200). This process makes the learning outcomes largely predictable. In contrast, she claimed that collaborative learning is "a process of discovery, a process of meaning making where knowledge is constructed over time through collaborative exchanges" (p. 202). The collaborative process aims to encourage learners to question, to challenge, and to transform their thinking through a democratic approach to education.

Such an approach has direct relevance for this study which is concerned with ways in which children's engagement with each other and the task at hand affects their collaboration and problem solving. This study is not focused on teaching children how to practice interaction skills or process these skills as outlined by a number of approaches to cooperative learning. Rather, the purpose of this study is to investigate the processes of collaboration when children are involved in problem solving. The preference for the term collaboration is justified by recourse to the literature and exemplars cited above.

2.2 Summary

The terms collaboration and cooperation are not used consistently in the literature. Cooperation is often used in the sense of working together but some group work

researchers postulate that cooperation is the sharing of separate but related work with a joint goal. Therefore, collaboration is the preferred term for this study because of the limits and connotations of the word cooperation regarding group work and problem solving. This review has led to the adoption of the following definitions:

- cooperation refers to individuals in a group/dyad working separately on agreed goals and sharing their work as a joint outcome;

- collaboration refers to individuals in a group/dyad working together on agreed goals and sharing their work as a joint outcome.

2.3 Research needs

The interchange of ideas that occurs in collaboration which may affect children's learning bears further examination. A close examination of peer collaboration should assist with understanding more about the potential of dyads for problem solving. It would also be fruitful to know more about the nature of collaboration as a process.

It is well established that children affect each others' thinking. Under what conditions this occurs and in what ways, is the focus of the following section.

3. Peer Interaction and Group Work

The types of interactions that children can have in classrooms vary considerably and underline the complexity of human interaction in social and educational settings. The literature on group work is burgeoning and takes many different perspectives. For example, group work research may focus on on-task behaviour, or interpersonal dynamics between group members, or peer tutoring, or problem solving processes, or a host of other features. The setting or structure of the group studied can also vary and may include the following types of interactions:

- with other children on an informal basis
- with other children on an informal but reciprocal basis (e.g., friendship, asking for materials, asking questions)
- with one other child in a pair or dyad where the relationship between the two children is "expert" and "novice" (i.e., an asymmetrical dyad such as peer tutoring)
- with one other child in a pair or dyad where the two children are of similar ability (i.e., a symmetrical dyad)
- with the teacher in an asymmetrical (expert-novice) dyad

- with the teacher in a symmetrical dyad (co-learners)
- with two other children in a triad
- with other groupings from four children upwards
- with the whole class
- in heterogenous curriculum instruction based groups
- in homogeneous curriculum instruction based groups

For the purposes of the following sections of this review, studies have primarily been chosen that pertain to children's interaction in small groups during problem solving. The first part focuses on group work research where the numbers of children in a group are larger than two. The findings from these studies are included as they signal issues that also have relevance for dyads. The subsequent section (3.1) then focuses specifically on studies of collaborative peer dyads and, in particular, symmetrical dyads since pairs of children of similar ability are the focus of the present study. Research in school rather than experimental settings is seen as more relevant for this investigation although it is acknowledged that some aspects of experimental studies can have significance for the classroom setting and that not all classroom settings yield reliable or unambiguous findings. A few experimental studies have been chosen as they present features of relevance for this research. Studies have also been deliberately selected which present contrasting findings to this thesis. Most of the research selected for review, however, took place in classroom settings with children working on tasks related to their school work.

While many studies attest to the advantages of group work and peer interaction, there is evidence to suggest that group work does not necessarily contribute to group members' learning. For example, Higgins (1995) stated that

> ...the extent to which peers can guide each other's thinking and promote each other's cognitive development remains in question. The quality of that assistance will vary. Some forms of peer interaction will assist learning while others will clearly not. (pp. 2-3)

The group dynamics of children working independent of a teacher are often different from those that exist when a teacher is present in the group (Alton-Lee & Nuthall, 1992; Prisk, 1987; Rogoff, 1990). When children work in groups independent of a teacher there is the opportunity for off-task behaviour. Bennie, Henry and Ratcliff (1990) claimed that during independent group work in mathematics, children are less likely to be on-task compared to times when they interact with a teacher. Dunne and Bennett (1990) also warned that group work and peer collaboration is not necessarily beneficial for the group or the individuals

concerned. They identified some of the negative behaviours which can be manifested in groups:

- "Free riders": those who contribute verbally, appear supportive but do not actually provide their share of the work, and they show no qualms about taking credit for the group assessment.

- "Suckers": those who initially contribute a lot but who suddenly lose interest and do not complete tasks.

- "Ganging up": when individuals pressure group members to prematurely agree to an idea in order to get the assignment finished, rather than engage in debate, research or deep learning.

Such findings illuminate pitfalls of group interaction and are a reminder that groups often need training in how to work together equitably and guidance on how to facilitate positive interaction.

A further study argues that small group work can be counterproductive (Stacey, 1992). Achievement in mathematics problem solving was found to be no better with pairs and threes than for children working individually. According to Stacey, children often dismissed important ideas or doubts in favour of easy and often erroneous answers to a range of problems. While she found that groups generated a range of ideas, they often had difficulty in comparing ideas and carefully choosing an appropriate path for problem solving. She cautioned against the widespread use of small groups for problem solving, arguing that such an arrangement did little or nothing to enhance children's understanding.

The common classroom practice of seating children in groups of four to six children seems to maximise the use of space in classrooms, but it may do little to facilitate educative peer collaboration. It seems apparent that teachers do not necessarily want children to interact when they seat them in groups, which can convey contradictory messages to children (Hastings & Schwieso, 1995). Children are often expected to sit together but work individually, which can be difficult for even the most resolute and self-controlled child (or adult) to avoid the temptation of interacting with their neighbouring peers. At other times, teachers do encourage group members to interact and may provide group tasks, but such interaction is not always perceived by children as permissible or useful if the teacher does not explicitly develop group interaction skills (Dunne & Bennett, 1990). In addition, Galton, Simon and Croll (1980) found that children in classroom groups spent most of their time working independently. For one-sixth of the time, children did interact with their group peers

but only 5% of that portion was task-related talk. Dunne and Bennett commented that such a finding shows that children may work in groups, but not necessarily as a group.

A greater incidence of task-related talk between children in groups was observed by Bennett, Desforges, Cockburn and Wilkinson (1984), but the quality of the talk they recorded was deemed "low level" in that it mainly consisted of children stating how much they had completed, how capable they were, and what they would do at play time. Dunne and Bennett concluded that this study shows that "although a good deal of their talk was task-related, it was rarely task-enhancing" (p. 11). They defined task-enhancing talk as conversations where children explain, demonstrate, discuss and make joint decisions. In contrast, Clarke and Helme (1997) argued that peer discussion during mathematics problem solving can be educationally beneficial. They found considerable evidence of children appealing to peers during times of uncertainty and evidence of resolving uncertainty through collaboration. The children's talk was largely task-related and typified by what they termed, "negotiative events". This issue of the nature and role of talk in groups (e.g., Higgins, 1995; Thomas, 1994) is discussed in more detail later in this review.

In the "best case scenario", group work has a number of benefits. The question of who benefits and how they might benefit continues to be a focus of group work research. For example, Holton, Anderson and Thomas (1997) observed a number of groups (pairs and fours) in primary and secondary mathematics classrooms. From their analysis of the various group interactions (see section 3.2), they concluded that there are some advantages for both the teacher and children in fostering group work. The advantages for the teacher included that groups save the teacher time and enable the teacher to more freely monitor and assess children's learning. The advantages for the children included that groups provide opportunities for talking about their ideas and for supporting each other. They also claimed that children generally enjoy group work and that groups give children's work status by reinforcing "that what students do is important" (p. 52). Holton et al. added that it is hoped that group work also benefits children's learning and understanding but conceded that this was not the focus of their study.

Peer instruction (ways in which children inform each other) was the focus for Damon and Phelps (1989) who identified three major categories of instruction. They distinguished between peer tutoring, cooperative learning and peer collaboration, the distinction between the latter two being akin to the delineation of these terms mentioned in the previous section. They used the term "mutuality" to refer to the amount of interaction which takes place in groups and the source of the interaction. Kutnick (1994) added that, "Mutuality is not a simple matter of assigning two pupils a joint problem to solve; it is the development of an underlying sense of closeness or

trust that allows for sensitive interaction between partners" (p. 23). A group with high mutuality would have regular input from all group members. Low mutuality is when one person dominates discussion. Damon and Phelps used the term "equality" to refer to the degree of control that one person may have in a group. In peer tutoring, for example, there may be less equality as one person has more knowledge, power and control, at least initially.

Peer interaction covers a range of forms of communication. Weissglass, Mumme and Cronin (1990) noted that peer communication in the classroom involves children in both giving and receiving "ideas, messages, feelings, or information" (p. 273). This reciprocity is identified as indicative of "effective" talk between peers (Westgate & Hughes, 1997). Weissglass et al. clarified, however, that communication between children is not only verbal but includes body language, drawing and writing, and using concrete materials. They promoted peer communication in the classroom for the following reasons:

- it clarifies children's thinking
- it empowers children as learners
- it reduces anxiety and alienation
- it establishes some common understandings
- it assists the teacher in thinking about the child as learner

These educational and philosophical claims seem evidently desirable. When children have the opportunity to discuss their ideas with others, they can clarify and sharpen their own thinking. When peer interaction is valued in the classroom, learners may feel that their ideas are important or at least, that they are heard. Weissglass et al. claimed that peer communication can encourage useful metacognitive capacities as children have the opportunity to think about their thinking. The building of a community of learners is evident in the claims that peer communication can reduce alienation and establish common understanding. Finally, Weissglass et al. posited that a focus on peer communication gives the teacher a window on the children's world and on their particular ways of thinking.

The challenge is to identify those situations and contexts in which peer communication engenders positive effects. Peer communication can be destructive, harmful and demeaning, producing the opposite effects that Weissglass et al. claimed. Their study (1990) focused upon teachers and their pedagogy in facilitating positive peer communication in mathematics. They found that the teacher's philosophy remained crucial in ensuring peer communication was beneficial for children's learning. While a focus on teachers' pedagogy is important, it is also necessary to know more about how children perceive and make sense of peer collaboration.

The literature on peer interaction and group work produces contrasting findings. On one hand, there appears to be considerable opportunity for being off-task in groups, especially if a teacher is not present. There can be inequitable work-loads and power relationships that may be harmful or limiting for some children. There may also be a reluctance to pursue difficult issues and a preference instead for choosing easy answers, or the path of least resistance. While discussion in groups may be task-related, it is not necessarily task-enhancing. On the other hand, some studies suggest that groups provide opportunities for children to resolve uncertainties through discussion which can be of educational benefit for the children concerned. There is also the opportunity for children to provide support for one another. Issues of mutuality and equality are also highlighted in the literature. Some groups may have an imbalance of these qualities which, in turn, will affect the group dynamics.

These findings have relevance for dyad interaction as the issues mentioned can also impact on groups of two children. This review now turns to studies of collaborative peer dyads, the major focus of this study.

3.1 Collaborative peer dyads

> There have been few studies of the process which make collaborative dyads so effective. It is safe to speculate that there is a high level of elaboration between members with little potential of threat or dominance between pupils. (Kutnick, 1994, p. 22)

Collaborative peer dyads (hereafter referred to as cpds) have been the focus of various cognitive studies. Cpds can be asymmetrical, as in peer tutoring where one child is more advanced than another, or symmetrical, as in peers of similar ability. The asymmetrical cpd is significant in Vygotsky's (1978) social learning theory of the zone of proximal development (ZPD). Through social interactions with a more capable partner, a child can be assisted through scaffolding towards independent mastery of new learning. The asymmetrical cpd also forms the basis of peer tutoring programmes which are largely concerned with incremental learning towards specific skills or processes.

Vygotsky's notion of the ZPD also has relevance for symmetrical dyads. Forman (1986) claimed that such a dyad is, in effect, a bidirectional ZPD. This notion is explored further by McCarthey and McMahon (1995), who drew upon the work of Damon and Phelps (1989) to aid their analysis of children's symmetrical dyad interactions during writing. McCarthey and McMahon claimed that peer collaboration engendered the most equality and mutuality, compared with cooperative learning and peer tutoring. They argued that the peer collaboration of two children jointly composing a text provides a site for the construction of new knowledge and the

opportunity for children to support each other. They hastened to add that peer collaboration should not be considered as superior to cooperative learning or peer tutoring, but rather, as different from these interactions. When two children collaborate, McCarthey and McMahon also argued that knowledge is bidirectional, passing back and forth from one child to the other, rather than in one direction. This claim is also supported by Lyle (1996) who stated that "it would seem that ZPD development can occur in a situation in which the participants have equal status, and in which all of them are struggling to understand" (p. 29). Lyle asserted that children do not always need more experienced, expert others to assist and extend their learning but can develop their understanding with peers of similar ability.

McCarthey and McMahon claimed that the peer tutoring model, where the relationship between children is asymmetrical, would exemplify unidirectional knowledge transmission as the more able partner is conveying knowledge to the less able partner. Peer tutoring, however, also benefits the tutor who can gain cognitively from the process of helping another (Topping, 1994).

Peer collaboration provides opportunity for fluid and dynamic knowledge construction and power relations, as each partner has input and makes decisions during the discourse. McCarthey and McMahon argued that peers of similar ability can assist each other in developing within the zone. Although there is not one expert assisting the novice to learn a new concept, both children in a cpd can share and exchange roles. They claimed that children can achieve more in a cpd than they might individually, suggesting that both children benefit cognitively. Furthermore, both children in a cpd have the opportunity to give explanations to each other. Pryor (1995) also argued that different children can take the role of expert in a group situation, as they advocate for their ideas. He conceded that some children may take more of a leadership role in this regard, but that there is the potential for each child to exchange roles and be both the expert and the novice in collaborative work.

A child can be an effective explainer to a partner in collaborative problem solving as he or she can also be new to the problem and can empathise with their partner who may be having difficulties (Vedder, 1985). Children usually employ language that their peers understand and in a cpd they can be a source of immediate help (Webb, 1991). Forman (1981) suggested that cpds provide the opportunity for children to take complementary roles. She found that collaborators solved more problems that those who worked alone and that the cpd that showed the most collaborative actions also solved the most problems. This pair gave each other support, correction and guidance in a complementary fashion. There is also evidence to suggest that the act of giving explanations is beneficial for the giver as they have the opportunity to clarify their thinking and can enhance their understanding (Forman & Cazden, 1985;

Topping, 1994). The benefits of giving explanations, however, depends on a number of crucial factors identified by Vedder (1985):

- whether the receiver needs the help
- the relevance of the explanation
- the timing of the explanation
- whether the explanation is understood
- whether the receiver has a chance to use the explanation
- whether the receiver then uses this opportunity

It seems that there are clear benefits for giving explanations but such a conclusion needs to consider the above conditions for beneficial explanation giving. Webb (1991) stated that content related explanations are beneficial in peer collaborations but other types of explanations might actually be detrimental to learning. For example, Webb (1991) claimed that the evidence is overwhelming that being told a correct answer with no explanation is negatively related to achievement. Zack (1996) also stated that children's explanations to each other are not always helpful. She found that some explanations added another layer of confusion. She differentiated between different levels of response to peer explanations ranging from children who merely copy their partner, children who reflect on, adapt or incorporate what is said, through to those who simply ignore the explanation. Zack claimed that a certain amount of abstraction is required for a child to understand another child's explanation or idea.

Inspired by the experimental designs of Piaget and the possible effects of peer interaction, Doise and Mugny (1984) reported a number of studies wherein they examined cpds in laboratory situations. They compared children's performance when they worked alone and in pairs on a number of tasks including a Piagetian "points-of-view" task which used a model village as a context and conservation of equal lengths. Although their studies did not take place in classrooms, they invariably had children from the same class and in pairs of the same gender. Their findings, after numerous studies (with 100 children in one case), are of interest regarding the alleged benefits of peer collaboration.

Doise and Mugny emphasised that peer interaction during problem solving does not always favour cognitive growth. Any benefits for individuals from peer interaction depends upon the nature of those interactions. According to their experimental designs, however, they found that children in dyads performed better than those who worked alone. There were no substantial differences on simple tasks between pairs and individuals but they claimed significant differences when the task was more complex. Furthermore, they posited that the cognitive levels of the children in a pair influence the performance of the dyad. A very able child paired with a novice

may impose his or her ideas and impede cognitive collaboration. They believed that unilateral dominance of ideas by one child over another does not contribute to progress for the dyad. Doise and Mugny conceded that progress can occur when a child is paired with a significantly more advanced partner. They postulated, however, that the "less advanced" child in the pair may merely imitate their more able peer which can give the appearance of improved performance.

When the cognitive levels of children are different but not too different, Doise and Mugny stated that progress can occur for both children in a dyad. Even children at the same cognitive level can benefit cognitively from dyad interaction they claimed, if they are not too compliant to each other's views and if they "execute the task together but from different viewpoints" (p. 135). While they conceded that differing viewpoints, or conflict, will not automatically engender cognitive progress, Doise and Mugny's central thesis is that sociocognitive conflict forms the basis of dyad efficacy. Their contribution to this theoretical position will be discussed later in this review.

Doise and Mugny did not make the distinction of "similar ability" in cognitive development. They claimed that the children can be at the same cognitive level, and they contrasted these children with those who were at different levels, which they believe aided their comparative data. It is not guaranteed that their findings are transferable to classroom settings. It is still unclear what types of performance are improved through peer collaboration. Furthermore, the nature of the task itself and who posed it can make a difference. For example, Donaldson (1978) criticised Piaget's original studies (including the points-of-view and conservation tasks) which she believed did not take cognisance of the child's possible misinterpretation of the adult's meaning. She stated that the children's performance on a task had less to do with their actual ability and more to do with how the task was interpreted. Cpds appear to provide greater opportunity for clarification of the task and this in itself may account for the results of Doise and Mugny. Conversely, cpds can also provide greater opportunity for reinterpretation of the task in ways that were perhaps not intended by the presenter. There is also the potential for greater mutual expectation to perform by each child in the dyad, especially in an experimental situation where tests are given prior and afterwards. Studies which investigate peer dyad interaction and learning in the classroom setting are therefore of import in this review.

The significance of the composition of a dyad appears in a number of further studies. For example, Yackel, Cobb and Wood (1991) reported on a three year project on children's mathematics learning in the classroom. In their study children were paired for problem solving at the request of their classroom teacher who liked the children to work in dyads before attempting to work in larger groups. The formation of pairs was found to be appropriate for the study and therefore dyads were retained. Children were paired as symmetrical and asymmetrical in ability. Yackel, Cobb and

Wood conceded that in retrospect, they preferred symmetrical dyads as this grouping was deemed more "productive". Ussher (1997) also found that symmetrical dyads made more gains (in terms of increases in the number of story elements used) in collaborative story writing, than asymmetrical dyads. In addition, Pryor (1995) commented on dyad composition stating personality, gender and ability factors have an influence on how pairs of children work together. In his pilot study of dyads working on computers he found that similar ability "assertive" girls worked together well, but similar boys did not. He stated that dyads require "balance" (like a pair of scales) and this balance is best achieved when the factors of ability, assertiveness and gender create some equilibrium, rather than an imbalance between partners.

It has been claimed that cpds are particularly effective in open-ended problem solving (Damon & Phelps, 1989) and in brainstorming (Doise & Mugny, 1984). Open-ended problem solving and brainstorming have been consistently identified as aspects of creative thinking (Maker, 1993; Torrance, 1977). The cpd studies cited above, however, scarcely provide an extensive research base for such claims. Conversely, it has been claimed that individuals outperform pairs and groups and that claims of improved learning through peer collaboration should be treated with caution (Stacey, 1992).

One problematic aspect of this and other findings in the cpd studies, is what is interpreted as "working together". The previous discussion on collaboration defines this as individuals working on the same task with joint purpose in mind. Closer analysis of children's dyads reveals that they are often working in parallel, or taking turns, rather than actively engaged in the same task concurrently. Joint commitment to the task appears to be significant in collaboration. Simply seating children in pairs to work together does not guarantee that this will happen. Furthermore, when children are seated together but pursuing their own individual line of enquiry they are what Pryor (1995) called task-focused, but not partner-focused. Kutnick (1988) termed this parallel pursuit of the task as "co-acting" (see also the earlier discussion about seating children in groups, e.g., Dunne & Bennett, 1990).

Light and Littleton (1994) reviewed a number of studies which explore this contrast between working in parallel and working together. For example, Glachan and Light (1982) studied dyad interaction using the puzzle, the "Tower of Hanoi". They found that whilst children were sitting together and ostensibly collaborating, they were more often than not working in parallel (see also Bennett, 1987; Galton, Simon & Croll, 1980). When the Tower of Hanoi task was amended by the researchers to include a collaborative component that required children to work together, the dyads' performance improved. The Tower of Hanoi task was trialed also with computers by Light, Foot, Colbourn & McClelland (1987) who adapted software so that children were required to use the keyboard together to make moves on a computer. Such

adaptation was deemed necessary as their initial trials revealed that children were taking turns, rather than collaborating. There appeared to be no gains for children working together when they were merely waiting for their turn. With the software adaptation they claimed there were cognitive benefits as a result of the collaborative work. Working together collaboratively is defined as interacting with each other and the task concurrently, so that decisions are negotiated and actions are jointly agreed upon.

How cpds might enhance learning remains an area of conjecture. Dunne and Bennett (1990) claimed that when children get on well together, or are accustomed to working together, their relationship contributes to their ability to problem solve and learn collaboratively. The need for negotiation and joint decision-making, however, may lead to greater conformity or quick answers to resolve a problem or complete a task. Perhaps cpds simply work faster than children alone, and therefore seem to have improved performance. Webb (1991) came to the predictable conclusion, from a review of peer collaboration research, that off-task behaviour is detrimental to learning. It is not clear, however, what influence peer collaboration has upon on-task or off-task behaviour.

Some research indicates that arguments during collaboration are crucial for children's cognitive development. Dyads with the best performance (according to pre-test and post-test results) were those engaged in frequent arguments which meant "sequences where the children were offering differing suggestions as to what move to make next, and where at least one of them was offering some kind of justification" (Light & Littleton, 1994, p. 96). If arguments are required to stimulate cognitive development in cpds it may be that dyads based upon friendships are less effective than others, as the social need for acceptance and positive relationships may mitigate against the need to assert and debate one's point of view. This may become particularly significant in the middle school years of childhood wherein the peer group becomes a strong centre of influence. The role of such arguments is discussed under "conflict" in more detail later in this review (see section 4.4).

The effectiveness of dyads is the central focus of a number of studies which attempt to explain what contributes to children's collaboration. For example, Schwartz, Black and Strange (1991) argued that dyads are more successful than individuals at higher order thinking as they need to negotiate a shared representation of a problem in order to communicate about it. This need to represent a problem, in a way that is accessible to both partners in a dyad, is claimed to develop the thinking of the individuals involved. In addition, Yackel, Cobb and Wood (1991) claimed that cpds provide opportunities to learn in mathematics problem solving which are absent from traditional classrooms. They posited that these opportunities result from children's interactions.

> As the children work together and strive to communicate, opportunities arise naturally for them to verbalize their thinking, explain or justify their solutions, and ask for clarifications. Further, attempts to resolve conflicts lead to both the opportunity to reconceptualize a problem and thus construct a framework for another solution method, and the opportunity to analyze an erroneous solution method and provide a clarifying explanation. (p. 401)

They clearly subscribed to the benefits of discussion during problem solving as a tool for developing and negotiating thinking. Similarly, Palincsar (1986), and Palincsar and Brown (1986) claimed that peer dialogue enables children to rehearse and develop their thinking and communication skills. They added that such discourse between children shifts the control of talk from the teacher, to groups in the classroom, and ultimately, to the individual.

It is interesting to note that many of the cpd studies focus on peer collaboration in mathematics, computing or science. It seems that these subjects emphasise problem solving and therefore provide a helpful context for fostering joint endeavour. Perhaps there is something about these disciplines which encourages collaboration, although the traditional mathematics classroom, for example, is not an environment renowned for encouraging interaction. The contemporary focus on the process of problem investigating and solving has transformed the pedagogy of science and mathematics in particular and therefore made it opportune to study peer collaboration in these areas. Furthermore, there is evidence to suggest that many of the greatest achievements in scientific endeavour have been collaborative ventures (e.g., Watson & Crick's model of the structure of DNA). Similarly, Bruner (1996) argued that

> Your chance of winning a Nobel Prize, interestingly, increases immeasurably if you have worked in a laboratory with somebody who has already won one, not just because of "stimulation" or "visibility" but because you have shared access to a richer distribution network. (p. 132)

Such a claim also has implications for children's learning and it is a reminder that collaborative learning in the pursuit of knowledge occurs beyond the walls of classrooms and business board rooms.

Children bring a number of experiences and skills to any interaction in a classroom. This can include their understanding of the problem they are working on, their understanding of classroom culture, their communication skills and the ways in which they have learnt to negotiate their world (Graves, 1996). In addition to this, they endeavour in cpds to understand and learn from each other's partial knowledge.

Graves acknowledged that such communication is not always easy or straightforward. Nor is it easy or straightforward to research.

The New Zealand perspective on peer collaboration, and in particular, its role in the learning of mathematics, is outlined below.

3.2 The New Zealand context

In considering the New Zealand context it is appropriate to begin with the innovative and progressive work of Sylvia Ashton-Warner (1963), one of New Zealand's foremost teachers, writers and educational philosophers. Decades ago she recognised the prevalence of peer interaction in classrooms and came to the realisation that it was futile to ignore or try to extinguish children's engagement with each other. Instead, she identified ways to harness children's interactions through dyad collaborations which were intended to encourage children's learning. She stated that children's interest in each other was one of "the worst enemies to what we call teaching" (p. 103). It seemed, therefore, that she was not exactly enthusiastic about the potential of peer collaborations but she indicated a major shift in the way she regarded how such collaborations could benefit children. She explained that peer interaction

> ...plays the very devil with orthodox method. If only they'd stop talking to each other, playing with each other, fighting with each other and loving each other. This unseemly and unlawful communication! In self-defence I've got to use the damn thing. So I harness the communication, since I can't control it, and base my method on it. They read in pairs, sentence and sentence about. There's no time for either to get bored. Each checks the other's mistakes and hurries him [*sic*] up if he's too slow, since after all his own turn depends on it. They teach each other all their work in pairs, sitting cross-legged knee to knee on the mat, or on their tables, arguing with, correcting, abusing or smiling at each other. And between them all the time is this togetherness, so that learning is so mixed up with relationship that it becomes part of it. What an unsung creative medium is relationship! (p. 104)

Ashton-Warner understood the inevitable fascination children have for each other and adapted this to form cpds as sites for learning. She was teaching over half a century ago and such an attitude and practice was considered highly innovative (and somewhat suspicious). Her ability to transform peer interaction into cpds indicated her regard for what children could achieve together. Although it appeared that she initially found cpds a convenient way to group children so that they would concentrate more on their lessons she eventually recognised that the children often learnt from each other. Furthermore, she claimed that the children's relationship with each other was inextricably bound up with their learning in cpds.

The issue of control in the classroom was also explored by Ashton-Warner. Rather than struggle against children for control of the classroom (at a time when didactic, teacher-controlled classrooms were the norm) she gave children opportunities to have control of their learning and behaviour through cpds. Teachers who insist on total control in the classroom are unlikely to encourage cpds which are independent of the teacher. Yet the purpose of many cpds as described by Ashton-Warner, is to work together without a teacher for the most part. This does not preclude that children cannot consult with a teacher during their collaboration but the decision of when to consult with a teacher, and why, is largely left up to the children themselves. This again emphasises the control and ownership that children can have in cpds. The quality of learning that occurs in cpds, however, remains an area of conjecture and debate.

Recent New Zealand research on group work and cpds is not extensive, but a few studies make significant mention of group and dyad interaction (Higgins, 1995; Hohepa, McNaughton & Jenkins, 1996; Holton, Anderson, & Thomas, 1997; Holton, Spicer, Thomas & Young, 1996; Thomas, 1994). Each of these will be discussed in turn.

The teacher can be pivotal in ensuring purposeful group interaction. In Higgins's (1995) study of 198 five and six year olds in eight New Zealand schools, she found that teachers who took an active role in facilitating activities with children were more successful with engaging children with the mathematical purposes of the activities. Children who worked in groups independent of the teacher were more likely to be distracted by the social demands of group interaction. Furthermore, when children were left to their own devices she found that they often adapted their mathematics activities into familiar games such as "dominoes" and "memory" with an emphasis on low level skills and winning, rather than on learning or consolidating mathematical concepts. Notwithstanding this finding, there are times in any busy classroom where children will be expected to work collaboratively, independent of the teacher, and times when teachers have not taken an active role in preparing children to undertake independent tasks. In particular, the opportunity for children to work in pairs is common in a number of classrooms. What occurs in these pairs when children are asked to collaborate bears further examination.

Group-based learning of a collaborative nature is claimed to be culturally preferable and appropriate for Maaori children (Hunkin, 1985). Recent research on Maaori pedagogy (Hohepa, McNaughton & Jenkins, 1996) disputed this generalised notion and claimed instead that groups are important settings for learning, but that within this setting there is the opportunity for both collaborative dyads and individual learning. Hohepa, McNaughton and Jenkins noted in their study of language interactions in a koohanga reo (Maaori immersion early childhood setting) that dyad interactions and

personal conversations by the children were common in the centre. The larger group settings provided an ideal context for one-to-one interactions between an adult and a child, or between a child and a child. Furthermore, they found that when children interacted with a peer, the role of expert in the dyad did not always remain static but was often exchanged.

Further mention is made of dyad collaboration in recent studies of mathematics problem solving. Thomas's (1994) study of young children's talk in junior mathematics did not solely focus on pair work but looked at a variety of groupings. When children worked together on tasks independent of their teachers, there was considerable time spent attending to their tasks, much to the surprise of their teachers. The nature of the children's interactions related to the tasks, however, were low-level. She found that in larger groups, considerable time was spent on the social demand of the task (e.g., whose turn is it, who is winning, who has more or less), rather than on the problem itself. The larger the group, the greater the social demand (see also Higgins, 1995, above). Holton, Spicer, Thomas and Young (1996) summarised this finding and argued

> At one extreme is individual work which presents little encouragement for children to engage in cognitive talk. At the other extreme the high level of social talk interferes with the opportunity for talk about cognitive aspects. In the middle there appears to be an optimum level of social demand in which there is a need to talk about the task, because it is shared, but not to the extent that it interferes with cognitive talk. (p. 113)

It could be surmised from this that a cpd can provide a setting in which cognitive talk is maximised and the more distracting elements of social talk are minimised. During the action research stage of Thomas's study some of the teachers participating in the project commented on their preference for having children work in pairs. For example, a teacher named "Jane" stated

> I'm trying to encourage them to work with a partner or in threes rather than to work with big groups. There were just too many children to work cooperatively. All those arguments about turns. But if they've chosen someone to work with then they tend to work with that person better than being told to work with the whole group. (1994, p. 110)

Two types of cpds were developed in Jane's classroom: symmetrical dyads (children of similar ability) so that "one child was less likely to dominate the activity" (Thomas, 1994, p. 112) and asymmetrical dyads for cooperative work such as measurement. Thus, the choice of symmetrical dyads for collaboration in problem solving was regarded as an appropriate and preferred arrangement.

Some further evidence of teachers' preferences for cpds was noted in Holton, Spicer, Thomas and Young's (1996) research project on problem solving which involved two teachers at the primary school level. Both of the teachers preferred having the children work in pairs for problem solving because

> They felt that this allowed both children the opportunity for participation which was sometimes lost in groups of larger size. They also believed that working with another child encouraged the children to progress further on the problem than if they were working individually. (p. 39)

Cpds were deliberately chosen by these teachers who believed that pairing children is advantageous for problem solving. At the intermediate level there was some evidence in their study that the children themselves preferred to work in pairs. The reason given by one dyad for this preference was that in larger groups "you get a bit more embarrassed if you make a mistake" (p. 109). This self-consciousness may be particularly pronounced as children near adolescence. The extent to which this attitude persists with younger children bears further consideration.

Also at the secondary level, Holton et al. (1996) suggested that problem solving was most effective when the students worked in small groups (two or three children at most) and was least effective when the groups were four or greater. From an analysis of the video-recordings they took during the study, the children who worked in pairs were invariably more successful with their problem solving than any other sized group. When children were grouped to work in fours, they often formed parallel pairs within the group. When summarising the optimum number in a group for problem solving they stated

> The groups of size two have almost always seemed to be the most successful. Fours have tended to break up into two lots of two or one or two people have been left out of the group in some way. Similarly in groups of three, one person inevitably is set apart and tends not to be involved in the discussion as much as the other two. (p. 109)

They noted that their findings only indicate a preference for dyads in group problem solving and that such a claim needs to be researched further. Of significance in the work of both Thomas and Holton et al. is that neither study deliberately sought to study dyads. Thomas researched the use of discussion in junior mathematics and Holton et al. researched the benefits of problem solving. It is interesting that both studies seemed to discover the importance of cpds within their broader frameworks.

A subsequent study of mathematics problem solving found that primary school children tended to work in pairs or fours while secondary students generally worked in groups of four (Holton, Anderson & Thomas, 1997). Within the groups of four there

was a variety of interactions ranging from children working individually and consulting occasionally with the other group members, the group dividing into two pairs, through to the group of four working together. They reported that the most able students in the secondary classes preferred to work as individuals and "then consult with other group members for confirmation of direction and answers" (1997, p. 51). This finding implies that the group played a role in checking and giving feedback but the students did not work together to process problems or devise strategies. Holton et al. pointed out, however, that the interactions in any one group did not remain static and that different behaviours occurred within and between tasks.

The variation of interactions noted in groups of four were also noted in dyads. The four types of dyad interactions observed by Holton et al. (1997) were

(i) The two students work as individuals with little or no interaction
(ii) One student does the whole problem with little or no interaction from the other student
(iii) The students work alternatively on separate parts of the task
(iv) The pair work together as equal partners (p. 49)

Again, the types of interactions noted were not permanent within any one dyad and, in fact, would vary from task to task and even during one particular task. This caveat underlines the complexity of group interactions and the need to attend closely to the processes of interaction.

In terms of group interaction processes they found that complex and varied interactions occurred within groups. They categorised the interactions they observed into four types. These were not "fixed" in that the interactions between children would vary during a task and across tasks. The categories they devised were: expert/novice, expert and assistant, joint ventures, and supportive environments. The expert/novice interaction typified asymmetrical relationships where a more able peer scaffolds the learning of a less able. The expert and assistant arrangement was also asymmetrical in that a brighter child dominated the discourse in a dyad. The contrast with the expert/novice arrangement was that the "assistant" did take an active role from time to time, including correcting the brighter child. With joint ventures a dyad or group worked together throughout the problem solving, negotiating ideas and collaboratively pursuing lines of inquiry. One child may propose an idea which was then investigated further by another child. This often occurred in homogenous high ability groups. Supportive interactions also occurred in homogenous high ability groups. In supportive groups, the children largely worked independently, except for the occasional comment or question to each other. These comments or questions appeared to be an opportunity to think aloud, or confirm their direction, in the problem solving. Holton et al. acknowledged that these four types of interaction are attempts to

categorise highly complex and dynamic interaction patterns. This suggests that the study of group interactions is challenging and resists the notion that group processes conform to some constant structure. They did suggest, however, that there are patterns in and across group interactions that can be identified. These patterns have implications for how children in dyads learn and collaborate during problem solving.

3.3 Summary

A number of studies conclude that cpds are particularly suitable for problem solving but not enough is known about why this might be the case. Traditional studies of cpds have tended to compare pairs with children working individually. More recent research has also compared cpds with larger groups. While the studies reviewed here tend to find favour with cpds over other arrangements, it depends upon the types of interactions occurring within a dyad. There is a concern that on-task behaviour is affected when children work in groups and this may also be pertinent for dyads. Of particular import is the balance between the social and cognitive demands of a task. It is also important to know more about what might thwart dyad collaboration and what influence the particular task might have. There are a number of ways in which dyads may collaborate revealing different patterns of interaction and engagement. The processes that enhance both collaboration and problem solving in dyads, remain unclear.

3.4 Research needs

An examination of what happens during dyad collaboration will assist with understanding what contributes to the efficacy of cpds. It seems that a balance of the cognitive and social demand of the task is important. It would also be useful to know more about what frustrates and halts dyad collaboration. It is not clear how collaboration appears to affect the thinking of individuals in a dyad. Little is known about what happens in collaborations to assist learning and what occurs to detract from it.

The previous reviews on both collaboration and peer interaction lead now to a review of related analytical and theoretical issues outlined below.

4. Analytical and Theoretical Issues

Of significance for this study is a review of studies that focus on children's interactions, particularly peer interactions. The following discussion reviews issues on coding schedules, starting with the early focus on teacher-child interactions and

then outlining the emergence of a more contemporary focus on peer interactions. Theoretical issues related to talk, social constructivism, sociocultural perspectives, sociocognitive conflict, problem solving and problem type are also examined.

4.1 Coding classroom interactions

A large number of coding schedules have focused upon teacher-child interactions as the context for discourse (see Edwards & Westgate, 1994, for an overview). These observation schedules were attempts to reduce the complexity of classroom interaction to focus upon significant patterns of interaction. While such schedules reduce and simplify what occurs, their use is intended to order, and make sense of, a plethora of data. Researchers are faced with the challenge of imposing some order or structure on data, whether it be in the form of case study, narrative, statistical tables, observations schedules, or some other alternative. Prescribed observation schedules for teacher-child interactions are one way in which classroom researchers have endeavoured to make their data manageable.

No form of recording interaction is complete, however, and the categories used may obscure important aspects of interaction by their very structure, that is, a coding schedule which determines what should be noted is making clear what to attend to and what to ignore. Furthermore, Walker and Adelman (1986) argued that such a priori coding systems "force a fit" as classroom talk does not neatly fall into prescribed categories and there is an even greater mismatch when the classroom talk is intimate, informal, and mainly generated by children. The challenge for any coding system is to capture denotative, as well as connotative, meanings and to explore the shared and covert meanings that lie hidden from the observer.

Up until the mid-1970s, the study of classroom talk was restricted to teacher led interactions and performances (Edwards & Westgate, 1994). The coding schedules that were developed, therefore, reflected this focus on the teacher and their discourse as a stimulus for the children's responses. In contrast, Tough's (1976) classification was an early attempt to focus more upon the language that children used rather than the interaction between the teacher and students which had been the focus of most earlier classroom language studies. She identified seven main uses of language (self-maintaining, directing, reporting, logical reasoning, predicting, projecting and imagining) with attendant supporting strategies. She claimed that the use of directing and reporting language by children indicate their early attempts at language use and that their use of predicting, projecting and imagining represent more sophisticated language use which emerges in a developmental sequence.

Tough's classifications were intended to be transferable to a range of settings and as such, provide a systematic schedule for employment by classroom observers. She

focused first upon surface features of children's language (the forms) and later the functions which formed the basis of her categories. Although her original intention was to investigate children's development of meaning, her work soon became a rather prescriptive category system which teachers were encouraged to use as a guide in assessing children's needs and to provide a language enhancing environment. Criticism of Tough's schedule included scepticism of the claim that her categories cover the range of language a young child employs. Also, Edwards and Westgate (1994) argued that the lack of naturalistic settings for the collection of data and the limited range of recordings taken limit the validity of her claims regarding children's language performance. The scrutiny of children's peer discourse has continued since Tough's pioneering work. The subsequent coding schedules which have evolved, however, tend to be less prescriptive and seldom claim transferability to many settings.

4.2 Coding peer verbal interactions

Since the 1970s there has been an increasing focus upon talk between children in classrooms by sociolinguistics, ethnographic studies, linguistic-pedagogic and linguistic-developmental traditions. Talk amongst peers in the classroom came to be regarded as more than just background noise and distraction. It emerged as a valuable source of information about how knowledge is constructed (Cazden, 1988). The shift in focus from the teacher as the central pivot for communication created the need to design ways of capturing children's talk so as to reflect their interaction with each other, and the context, not just their interactions with the teacher. Studies which focus on children's talk and code verbal interactions cover a range of subject areas such as social studies, writing and literature.

Classification frameworks are less evident in research which has been developed since the mid-1970s which focuses upon capturing children's talk in the vein mentioned above. Analysis of talk among peers in early childhood and school settings has largely emerged from scrutiny of transcripts alongside observations. These studies are typified by line-by-line open coding which attends more to the quality and intention of talk rather than to the quantity of a certain type of utterance (e.g., Alton-Lee & Nuthall, 1992, 1993; Barnes & Todd, 1977; Hughes & Westgate, 1990; Lazarus, 1984; Phillips, 1985; Wade & Wood, 1980). These studies also derive broader, more generalised categories from the initial coding which provide less specificity pertaining to individual acts and more cognisance of peer and task interaction. For example, Hughes and Westgate (1990) coded their transcripts with terms such as "directing" and "informing", but they also made judgements about the language used as being collaborative, assertive or protecting rights.

Learning in small groups was the focus of a early seminal study which continues to influence the research field today (Barnes & Todd, 1977). They recorded conversations between 13 year old children engaged in problem solving tasks. They transcribed conversations between children in groups of four working on problems outside of their normal classrooms. The 32 children in total were drawn from two different schools. They developed a two level analysis of children's talk which attended to both the cognitive (content frame), and social (interaction frame), functions of language. They believed that there is constant interplay between the two frames which provides a broader view of peer discourse. Barnes and Todd generated descriptors for each of the two frames. Cognitive functions comprise what they termed, "logical process" and "cognitive strategies". Logical process includes proposing, expanding, evaluating, negating, suggesting, restating and giving evidence. Cognitive strategies are defined as constructing and raising questions, hypothesising, using evidence and recreating experience. Social functions comprise "discourse moves" and "social skills". The discourse moves include initiating, extending, eliciting and responding. They described social skills as managing conflict, giving support and controlling progress. The separation of the two frames (cognitive and social), and their descriptors, was undertaken for the purpose of coding and analysis. They acknowledged that this separation was merely for convenience. In reality they believed that social skills and cognitive strategies are inextricably linked.

> Cognitive strategies are carried out by means of social skills and social skills are identified by their contribution to cognitive strategies. Thus it may be possible to identify a particular utterance as instance of both a social skill and of a cognitive strategy. (p. 22)

A major issue related to coding and analysis is identified in this early study. By separating and coding some utterances as one type of talk for a certain purpose, the complexity and connectedness of dialogue can be over-simplified. They clarified this, when appropriate, by coding some talk as both cognitive and social. Similarly, Graves (1996) pointed out that studying social interaction and how it may relate to cognitive growth makes methodology more complex, creating challenges in coding data. And Prisk (1987) maintained that the social and cognitive acts in data are impossible to separate.

In an attempt to meet this challenge of reconciling data which include social and cognitive functions, Barfurth (1996) examined children's disagreements with their peers from two perspectives. Each of the children's utterances (while they worked with lego in a technology lesson) was coded for both social and cognitive moves. She found that most of the cognitive moves consisted of what she coded as "adding" or "seeking" information. In terms of the social moves there was a high degree of what

she coded as "opposition" but the children often sought to resolve these. She concluded that children's disagreements are a legitimate form of communication which can be helpful in collaboration and problem solving.

Simply recording and coding what children say when they work together is not always sufficient. Kieran (1996) found that transcripts from video-recording cpds working on mathematics problems, revealed that most of their discourse did not relate to what they were thinking or how they were learning. She eventually sat alongside the children while they worked and interviewed the children in order to gain insights to their thinking. Coding schedules that are based upon children's talk while problem solving may need to be supplemented with interview data to probe what children actually think and how they think.

Field notes and follow up interviews were used by Clarke and Helme (1997) to supplement their video-recordings and audio-recordings of children's talk during mathematics problem solving. Moreover, they used stimulated recall interviews based upon the video-recordings of the children working in pairs. They claimed that their methodology enabled them to minimise the amount of inference they made about what the children were thinking and base their coding and analysis on carefully scrutinised episodes of talk. Data were categorised in terms of events within episodes. Each event related to a particular form of "uncertainty" or "resolution" in the children's talk. The uncertainty or resolution pertained to both process and product. The category of uncertainty was based upon empirical evidence in their data and took a variety of forms. Similarly, they explained resolution in terms of a number of forms evident in the data. Their codes and categories provided illustrations of the "uncertainty-resolution" relationship they claimed to be central in negotiating meaning (see 4.3 below for a review of their conceptual analysis and thesis).

Further studies code children's verbal interactions with general categories which pertain to specific talk criteria. For example, Daiute (1989) studied children working with a partner to write stories collaboratively. Two of the categories which emerged during analysis were "playful" and "controlled" talk. Playful talk was defined as role playing, trying out concepts and using imagery. Controlled talk was defined as talk that occurred when planning, labelling, evaluating or controlling the actual writing process. Daiute claimed that the children's writing improved as a result of collaborating and the influence of both playful and controlled talk during dyad collaboration.

In addition, Mercer (1995) identified three qualitatively different types of talk when primary school children work together on a computer which he termed disputational, cumulative and exploratory. He argued that "disputational" talk is unproductive disagreement wherein one child initiates an idea and is challenged, either with a rejection or a counter hypothesis and the dispute has no clear resolution. "Cumulative"

talk occurs when they uncritically add to what has gone before. In contrast, "exploratory" talk refers to children actively engaging with each other's ideas. While the children may challenge each other their ideas are justified clearly and negotiated so that "progress thus emerges from the joint acceptance of suggestions" (Light & Littleton, 1994, p. 99).

The coding of children's talk in peer interaction studies has developed considerably from an earlier focus on classification frameworks and the counting of types of speech. Greater attention is now given to the intent or the purpose of the discourse and cognisance of the social context of dialogue is often acknowledged.

4.3 Talk, social constructivism and sociocultural theory

A major theoretical issue in the literature is the role and influence of children's talk in problem solving and peer collaboration. Barnes and Todd (1977) argued that, "Collaboration, however, is not enough: the talk must lead to the construction of new ways of understanding" (p. 50). There is general agreement that talk plays an important role in developing understanding. The extent, however, to which talk fosters or reveals understanding is an area in which academic opinions differ. Some researchers theorise that talk provides an explicit medium for the process of problem solving made evident through cognitive rehearsal (e.g., Chang & Wells, 1987; Palincsar 1986; Vedder, 1985). Ericsson and Simon (1985) argued that verbal reports "can claim to being the closest reflection of the cognitive processes" (p. 16). Primarily, they posited that "talk aloud" and "think aloud" are examples of the direct verbalisations of thinking. Children (and adults), however, can be restricted by their command of language in making explicit their thinking. They may be more elaborate with drawing or writing about their thinking (see also Pramling, 1995). Furthermore, they may not see the need to make their thinking explicit.

Further to the contribution of Piaget in understanding children's learning, there is increasing interest in the work of Vygotsky which results in research which focuses on how children understand and upon their constructions of their world (McLeod, 1995). Children's talk about their thinking and their activities is examined in this tradition to gain an insight into their beliefs and perceptions. These are regarded as sociocultural perceptions as children's thinking is seen as interwoven with their relationships with people and the world with which they interact. As a result, research influenced by the Vygotskian tradition witnesses growth in the use of child interview techniques (including classroom-based interviews) and qualitative studies aimed at uncovering the children's learning processes and perceptions.

In contrast to the Piagetian view that knowledge is constructed within the individual, knowledge from a Vygotskian perspective is considered to be

collaboratively constructed between individuals. The construction site of knowledge between individuals can then be "appropriated by individuals into their personal repertoires" (Roth, 1995, p. 183). The Vygotskian emphasis is upon joint decision making and knowledge construction rather than the alternating of different, and conflicting, individual viewpoints. Neo-Vygotskian research has adapted Vygotsky's ideas to study symmetrical peer relationships and the ways in which knowledge can be mutually constructed in a bidirectional ZPD (as explained previously under section 3.1).

The Vygotskian perspective is that talk does not constitute some "kind of transparent window on the mind" (Mercer, 1994, p. 95) and is not "think aloud" as proposed by Ericsson and Simon. Instead, talk is a "social mode of thinking" (Mercer, 1994, p. 95) wherein information is shared, ideas exchanged and alternative viewpoints considered. Talk from this point of view, does not constitute a direct reflection of one's thought but provides a channel in which to communicate with others and be influenced by others. As such, talk constitutes a powerful cultural tool (Rogoff, 1990). Talk can also be used in a seemingly unconscious fashion, directed at no one in particular, but as a spontaneous expression of one's thoughts. For example, Nuthall and Alton-Lee (1994) found that children in classrooms frequently talked aloud to themselves. They claimed that this talk enabled them to have a "window" on the children's thinking. They acknowledged, however, that "not all processing is conscious and not all conscious processing gets expressed audibly" (p. 5). This relates to Barnes's (1976) notion of "exploratory talk" which he defined as speaking without the answers "fully intact" in contrast to a "final draft". Many of the excerpts of children's talk provided by Nuthall and Alton-Lee, typify talk which appears exploratory as defined by Barnes. Mercer (1995) claimed that talking about the process of learning is more common in peer discourse and that such exploratory talk aids the child's ownership of learning. He also emphasised the social construction of knowledge in cpds.

> Of course, knowledge exists in the thought of individual people. But to think of it only as an individual mental possession does not do justice to it, or to the capabilities of human beings. Knowledge is also a joint possession, because it can very effectively be shared. (p. 1)

In interaction with others, children can transform their thinking when considering ideas that take shape through words. These words can give structure to an activity (Vygotsky, 1978). When an activity is collaborated upon with a peer, a child is encouraged to interact verbally and this "interactive language is therefore an important medium through which to study children's emerging constructions of the world" (Smith, 1995, pp. 8-9).

Social constructivism claims that dialogue aids the internalising of the social world and the subsequent construction of knowledge. Learning occurs within individuals as a result of their internalisation of social interaction. Dunne and Bennett (1990) added that children actively construct their knowledge through discussion, including testing out ideas, explaining, and arguing with peers. This discourse with peers involves children in having to "structure their knowledge and find words that will be understood by others" (p. 8). Such a process is considered central to social and cognitive growth.

While social constructivism stems from constructivist theory it is broader in emphasis in that social factors are considered to be intertwined with cognitive processes. Constructivism (from a mathematics education perspective) claims that "children construct their individual mathematical realities by reorganising their personal experiences in an attempt to resolve what they find problematic" (Cobb, 1990, p. 209).

Critics of constructivist theory counter that such a view ignores the established body of mathematics knowledge and overemphasises the learner's role in making sense of mathematics. Social constructivism emphasises that learning is both constructive and interactive (Cobb, 1990). Through interaction with others mathematical knowledge can be constructed as children negotiate conflicting viewpoints, verbalise their ideas to each other, consider alternative views and attempt to coordinate their thoughts. Mercer (1995) argued that the process of social construction has often been overlooked in studies of learning and problem solving and that as human beings "we are uniquely equipped to pool our mental resources and solve problems - to create knowledge - through joint mental effort" (p. 1).

The role of children's talk in learning is elaborated on by Vygotsky (1934/1962) in his theory on the development of inner speech. He claimed that speech during problem solving begins during social interaction such as peer collaboration. He stated that this social discourse enables children to regulate their vocabulary and develop "egocentric" language. This language develops when children direct the talk they used during interaction with another, at themselves. The egocentric language manifests itself as talk wherein children direct, control and monitor their own actions. Thus, Vygotsky claimed that with egocentric language children's talk is turned inward and takes on an intrapersonal role, as well as, an interpersonal one. From egocentric language he believed "inner speech" develops as children draw upon a repertoire of internalised language in future problem solving situations.

Speech and action are regarded as integral parts of the same complex function of problem solving. The Vygotskian perspective is that there is also an intimate relationship between talk and thinking. He noted, however, that "thought has its own structure, and the transition from it to speech is no easy matter" (1934/1962, p. 149).

He recognised that there is a subtext to social speech which includes hidden motives that may not be apparent from the words someone may utter. Externalised, audible speech does not reflect thinking "because a direct transition from thought to word is impossible" (p. 150) but nevertheless he claimed that "the relation between thought and the word is a living process; thought is born through words" (p. 153). His conclusion has relevance for children's dialogue when they engage in collaborative problem solving as it underlines the relationship between thought and language on both the social and personal levels.

The pioneering work of Barnes and Todd's (1977) qualitative analysis of peer interaction (discussed earlier) contributed considerably to the social construction of knowledge literature. This literature argued that meaning is gradually negotiated through interaction. Cohen (1994) claimed that Barnes and Todd's transcripts provided some of the best examples of socially constructed knowledge in the research literature. Their study was a precursor of research that was to follow in social constructivism. According to Cohen, the social constructivists "cautioned researchers that meaning may not be explicit even to the speaker in an ongoing discussion, because criteria for relevance are negotiated moment by moment" (1994, p. 5). This has significance for any study which endeavours to analyse data comprising of talk between peers and attempts to make sense of this talk through coding and categorising speech. Barnes and Todd (1977) argued that attempts to analyse data based upon conversations are bound to be uncertain and indefinite. They claimed that the meaning of an utterance does not necessarily match what is said. Meanings are dynamic and likely to change as the discourse proceeds. This has significant implications for the researcher who

> ...is compelled to reconstruct strings of cumulative reinterpretations in the knowledge that even at the moment that the words were spoken they may have had no determinate meaning to those who spoke them. (Barnes & Todd, 1977, p. 101)

This social constructivist view of the nature of language presents considerable challenge for research when attempting to use talk as data. Barnes and Todd made a salient point about the less than explicit nature of speech. Their point also reminds the researcher to attend to other forms of communication between children, such as their body language and drawing, in order to supplement and clarify what children might say.

A number of cpd studies reflect the neo-Vygotskian view of socially mediated knowledge construction where an obvious "expert" is absent. Forman (1981), for example, found that cpds solve more problems when the pair assumes complementary roles, give each other support, correction and guidance. Also, Markell and Asher

(1984) claimed that unpopular children are less argumentative and more agreeable in cpds than usual. They surmised that it is the collaborative nature of the shared task that contributes to this. In addition, Roth's (1995) ethnographic study of science classrooms found that collaborative knowledge construction was the predominant mode of interaction when children worked in pairs and threes.

Language and human interaction are central concerns for research in collaborative learning. The ways in which meaning is constructed and understanding is developed during peer collaboration, requires an examination of social processes. For example, Clarke and Helme (1997) argued that uncertainty during problem solving in mathematics classrooms is a key trigger for peer negotiation and resolution. They posited that children's negotiations are mediated through talk and the process of negotiation requires the exploration and subjectivity of meaning. While they conceded that disagreement can also provide a catalyst for negotiation, they chose to focus on the "resolution of uncertainty" as their key concept. Their research data provided episodes of the children's talk which were analysed in terms of uncertainty and resolution relationships and features. Their analysis provided detailed examples of nuance and shades of meaning regarding the concept of negotiation of meaning, when children collaborated on problems.

The discourse of a cpd while learning algebra was the focus of a recent study wherein a pair's discussion was regarded as a mechanism for conceptual change (Graves & Zack, 1996). One partner in a dyad recognised an anomaly and the other child had a rule but could not fathom how it applied to the anomaly. Together they collaboratively reasoned a new approach and an answer. The social construction of knowledge is evident as the basis for theorising about this process of collaboration. Furthermore, the finding highlights the negotiation of meaning mentioned earlier (Schwartz, Black & Strange, 1991). The algebra problem the dyad worked on, however, was closed (one right answer). This contrasts with other findings (e.g., Cohen, 1994) which suggest that ill-defined problems, not closed problems, are required for the calibre of collaboration claimed by Graves and Zack. The quality of discourse in a cpd seems to be dependent upon the context, including the type of task engaged in by a pair of children. McCarthey and McMahon (1995) pointed out that

> Although collaborative learning may provide more opportunities for students to engage in discourse, the quality will depend on the specific context and is not necessarily a function of the type of group interaction. (p. 32)

Any study of cpds which aims to investigate the nature of collaboration should consider the context in which cpds interact, including the type of problems they pursue.

The benefits of such research includes the validation of children's ideas and constructs as important and vital clues to their thinking and learning. Nuthall and Alton-Lee (1994) also studied children's learning and recorded their talk during classroom activities. They transcribed many hours of audio-recordings and video-recordings, interviewed the children, and gave more than one test on the content of the unit the children had studied. These data revealed that the children's learning was very active, and frequently, a social process. They claimed that the processes of learning include making connections with existing knowledge, elaborating and extending ideas, evaluating content, and dealing with inconsistencies. These processes were all evident in the children's talk, whether the children were talking to themselves, or to their peers. They concluded that children's thinking reflects how they have learnt to interact with others and with their world. Classroom research of this nature provides an important counterpoint to critics of learning through talk and peer interaction. For example, Stables (1995) argued that the current emphasis on group work and children's talk overlooked time for private reflection. He stated that

> Theories of collaborative learning, or 'social constructivism', have often been inappropriately applied in terms of classroom methodology, resulting in a recommended over-emphasis on groupwork and peergroup talk while insufficient attention has been paid to reflection and inner dialogue. (p. 61)

What Nuthall and Alton-Lee found, however, was that some evidence of inner dialogue and individual reflection occurred concurrently during many group discussions, peer interactions and whole class discussions. The extent to which this may occur in cpds is not known.

The sociocultural focus takes a broader view again and enables researchers to examine children's interactions with others (peers, parents, teachers) and with their environment. John-Steiner and Mahn (1996) stated that sociocultural theory provides for a greater variety of ways in which knowledge is transformed, co-constructed and created. They claimed that through interaction with their peers, children can inform each other, transforming both the task at hand and their learning. This ability to think in partnership with others acknowledges human interdependence and culture.

The influence of culture on learning is receiving increasing attention in the literature on educational theory and practice. Bruner (1996) identified two ways in which human beings make sense of and organise their world: logical-scientific thinking and narrative thinking. Although he recognised that different cultures would have varied ways of expressing these two types of thinking, he nonetheless considered the logical-scientific and the narrative to be universal to all cultures. Furthermore, he proposed that narrative thinking is likely to be the "most natural and the earliest way in which we

organize our experience and our knowledge" (p. 121). He emphasised the role of interaction through talk as the main medium in which people learn from each other.

In contrast to Piaget, Bruner proposed that narrative is an innate aspect of human intelligence. Bruner added, however, that narrative thinking can and should be taught. The human propensity for narrative thinking should not preclude deliberate teaching of narrative ways of organising and communicating understanding. He described narrative as a sequence of events. These events are often told about something puzzling and the point of a narrative is to resolve or redress the doubt, mystery or problem. Narrative understanding is also described as creating stories in order to make events, actions, thoughts and feelings meaningful. In creating stories, it is argued that people can make sense of their experience, impose structure on their thoughts, explain ideas and concepts, and communicate to others. He suggested that the widespread use of narrative indicates that we are preadapted to narrative ways of understanding ideas, concepts and feelings.

The issue of narrative and its full contribution to educational research is beyond the scope of this review. Narrative is mentioned in this section, however, as it contributes to the debate on current theoretical and analytical issues in classroom research. Lyle (1997), for example, employed narrative as methodology, conceptual analysis and as a pedagogical tool in her study of collaborative talk in the primary school. Context, task structure and collaborative talk were all made explicit in her study of children's discussions during social studies. Over a number of years she recorded, transcribed and analysed children's (aged nine to 11 years) discussions in social studies. She used the "community of inquiry" approach (e.g., see Splitter, 1997) to introduce the tasks. She found that this approach provided a useful and necessary structure for the children. If the tasks were too open-ended the children tended to engage in off-task talk. Lyle argued, however, that some ambiguity is important as this encourages children to negotiate meaning with each other. Her tasks included reading, writing and talking about the social studies issues and she found that pairs, fours and whole class interaction were most productive in terms of on-task discussion and negotiation of meaning, compared with other groupings.

Lyle proposed that children negotiate meaning with peers though narrative. She explained that by using stories and discussing the events in these stories, children are able to clarify their thinking, contest ideas and develop empathy. It is the cultural knowledge of the children's own environment that enables them to make interpretations and explanations of the new and unknown. She argued that using a narrative approach also assists children to consider many ways of viewing the world and a range of possible interpretations.

4.4 The role of conflict in peer collaboration

The cognitive benefits from the conflict of ideas during peer interaction, form the theoretical basis of some influential writing and research in education (Bredekamp, 1993; Edwards, Gandini & Forman, 1993; Festinger, 1957; Johnson & Johnson, 1994; Malaguzzi, 1993; Perret-Clermont, 1980; Piaget, 1970). Confusion arises, however, as to the nature and definition of conflict in peer collaboration theories and studies. There is little consistent use of the terms cognitive dissonance, disequilibrium, argumentation and conflict in much of the literature, raising further questions about the clarity and robust nature of such terms (Light & Littleton, 1994). At times, dissonance and disequilibrium are used interchangeably. Dissonance refers to an imbalance between two or more events which can occur in relation to motivation, personality, or cognitive development (A. McGougan, personal communication, October 23, 1996). In addition, Festinger (1957) claimed that cognitive dissonance occurs when one feels psychological discomfort. This discomfort can arise when there are inconsistencies in thinking and experiences. These inconsistencies can create dissonance and the motivation to reduce this dissonance. He also conceded that the term "disequilibrium" could be substituted for "dissonance". According to Piaget (1970), a state of disequilibrium literally means "out-of-balance". This occurs when the learner applies his or her existing schema (basic building block of thinking) to an event or situation and there is a mismatch which causes cognitive discomfort. This discomfort can motivate the learner to search for a new solution through either assimilation (fitting the new learning with what is already known) or accommodation (modifying and adapting schemata).

Occasionally, there is neither assimilation nor accommodation in response to disequilibrium. If learners experience something which is too vague or inaccessible they may not respond to it at all (Woolfolk, 1993). Therefore, it cannot be claimed that conflict through disequilibrium is always a catalyst for cognitive development. Disequilibrium, however, can provide the spur for learners to restore balance and resolve conflict between two or more incongruous events. This can foster the process of what Piaget termed "equilibration", which is the search for balance and which, in turn, can create actual changes in thinking.

Piaget identified three main influences on cognitive development which are maturation, activity, and social transmission. The interaction with others that he refers to in social transmission can be a context for disequilibrium and subsequent equilibration. While the tendency in reviews of Piaget's work is to emphasise his theories of individuals' cognitive development, he did acknowledge the important role of learning from others. Disequilibrium can occur within the learner when experiencing a new and puzzling event or incident. It can also occur within the learner

as a result of interaction with other people. Piaget did not discount the social context and its influence on cognitive development. Moreover, he argued that social factors are instrumental and intertwined with the development of logic (DeVries, 1997). Social interaction, however, was not the main focus of his empirical research. The Piagetian view is that disequilibrium can occur in a collaborative situation when learners' thinking conflicts. The resolution of such conflict comes about through a process of reciprocal consideration of alternative views. Such a process is claimed to further an individual's development when cognitive equilibration is re-established. Roth (1995) distinguished between shared knowledge which is constructed collaboratively and shared knowledge which is constructed in an adversarial manner. He claimed that agreement did not have to be shared in order for a group to progress with a task but he conceded that too much conflict can impede direction and motivation.

The neo-Piagetian position is that conflict, based upon differences in perspective, can lead to cognitive development (Tudge, 1990). Although this notion of conflict is proposed as the main source of cpd effectiveness by some (e.g., Doise & Mugny, 1984; Howe, Tolmie & Anderson, 1991; Perret-Clermont, 1980; Piaget, 1970), conflict may not be crucial to the effectiveness of cpds. Lindow, Wilkinson and Peterson (1985), for example, found that verbal disagreements were only marginally related to achievement in mathematics. Individual children who had cognitive conflict with their peers only performed marginally better on achievement tests than those who had less disagreements. Furthermore, inter-group results were not statistically significant in that groups with the most conflict did not perform better than any other group (Webb, 1991). The influence of conflict on performance, however, could be a matter of degree. Bearison, Magzamen and Filardo (1986) studied children's performance on a spatial task and related this to the children's frequency of verbal disagreements. They found that children's performance was best when there was a moderate amount of disagreement. Children did not perform as well when there was little or large frequencies of disagreement. Evaluating children's performance in terms of achievement tests is limiting in that it provides only one measure of children's learning. In the absence of any other gauge of children's cognitive development, however, the use of an achievement test indicates (rather than proves) that some learning has occurred.

While Barnes and Todd (1977) acknowledged that conflict of ideas (wherein a child is confronted with ideas different from his or her own) is beneficial for learning, they also found that the level of conflict in some groups made these groups ineffective and unproductive. Such groups were typified by verbal attacks, sarcastic put-downs and attempts to surpass each other with boasting. They concluded that both social and cognitive skills are necessary for effective peer collaboration. Their study did not

include the teaching of social skills but rather the examination of the social skills children developed themselves when left to their own devices in groups. Of primary importance to them was the assertion that children can learn from each other and that peer discourse can provide valuable learning opportunities that otherwise may not occur if teachers continually control and direct the discourse in classrooms.

That children benefit cognitively from conflict of views in dyads is an area of contention. Doise and Mugny (1984) claimed that "if social interaction is of particular importance in cognitive development, it is to the degree that sociocognitive conflict arises" (p. 101).

The crucial role of conflict is reiterated by them throughout a series of studies which compared the performance of individuals and pairs on a number of Piagetian inspired tasks. They argued that dyads perform better than children alone if the dyads engage in frequent and strong conflicts and if the range of ability in the dyad is not too diverse. They used the term "sociocognitive" because they posited that the social and cognitive factors are inseparable and that both factors create disequilibrium. Differing points of view between children can cause cognitive conflict and, concurrently, disagreement is a social problem as individuals may attempt to relate or explain their differences to each other. Doise and Mugny argued that a dyad is not only concerned with solving a problem but also with interrelating with a partner. Conflict, therefore, occurs on two levels and is crucial, they believed, for cognitive development through peer interaction. Cobb (1990) added that sociocognitive is a more inclusive and precise term when considering how children learn mathematics. He stated that it is insufficient to focus on children's thinking alone as their cognition is linked to their social constructs of obligations, beliefs and expectations. He claimed that mathematical learning is not purely cognitive but that there is an iterative process between the cognitive and the social in classrooms.

A contrasting study to Doise and Mugny is less definite about the benefits of dyad interaction. Tudge (1990) claimed that children when paired with a partner who holds differing views (which would provide a site for conflict), do not necessarily benefit from such interaction. According to Tudge, children may exhibit regression in their thinking if one child (especially a more able child) is not confident of their conflicting view. His study compared individuals and symmetrical and asymmetrical dyads on Inhelder and Piaget's (1958) balance beam exercise. His findings showed that there was "a surprising amount of regression for all children except low partners" (1990, p. 162). This would suggest that cpds are only beneficial when the dyad is asymmetrical and only for the novice (the low partner) in the dyad. His study, however, was a large scale quantitative study undertaken outside the classroom. The children's level of ability was based upon their understanding of certain rules to explain how a beam balances. As such, his study relied upon predetermined knowledge levels related to

one specific task. His results may have altered over a range of different tasks with the same dyads. The children in his sample may have had little prior experience with balance activities which would affect their understanding and preparedness to alter their thinking. The pre-test, post-test nature of the study may have influenced the dyads' performance. For example, they may have been less likely to tolerate difference and explore more difficult concepts when in a test situation with a researcher away from their regular classroom environment. A study of symmetrical dyads in the classroom, exploring a range of problems would provide a more realistic context in which to investigate the nature of dyad collaboration.

A year long study of two dyads in a classroom working on mathematics problems provides an example of a more "realistic" context in which to study the notion of conflict in cpds (Swaminathan, Clements & Nastasi, 1996). This study combined qualitative and quantitative methods and coded data in three ways. First, they coded data as cognitive dissonance (uncertainties, curiosities, puzzles) within, and between, children. Second, they coded data as collaborative (building on each other's knowledge in a reciprocal fashion) and non-collaborative. Third, they coded data as cognitive conflicts which were defined as active conflicts in thinking. Their results focused upon the generation of cognitive dissonances which they claimed are significant in the efficacy of dyad problem solving. The impact of cognitive dissonance on the children's cognition was believed to improve their use of strategies rather than to improve their acquisition of knowledge. During cognitive dissonance, they claimed that the children monitored their own and their partner's thinking. Their study differs from many of the others in that it deliberately separates conflict from cognitive dissonance which appears to be a helpful distinction given that dissonance, in their terms, seems to invite more dialogue and negotiation than active conflict of ideas. What is not clear in this study (and in many others) is the nature of the problems the dyads undertook and how this affected their interaction. As other reviewers have noted (Cohen, 1994; Thomas, 1994), the type of problem can have a significant impact on the interaction and learning of dyads and this is seldom given attention in the research on collaboration. The topic of problem type will be discussed later in this review (see section 4.6).

4.5 Problem solving

As this study is concerned with collaboration during problem solving, a brief review of the problem solving literature is also required. While there are many interpretations of what constitutes problem solving, Polya's (1957) early explanation is still referred to by many mathematics educators. He argued that problems may be modest but if they elicit one's curiosity and desire to know, they are worth pursuing. By solving

such problems children can experience tension, satisfaction and enjoyment. He added that problems should be "not too difficult and not too easy" (p. 6).

Problems which engage children in problem solving are defined by Neyland (1996) as, "Unfamiliar, non-routine questions that require higher-level thinking skills, or put more simply, questions where the students do not know the path to the solution at the outset" (p. 4). Such a definition is still broad enough to encompass a range of problem types. Neyland, however, qualified this statement by stating that many such problems have more than one right answer and more than one solution path. He also found that teacher education students often confused problem solving with written word problems. Many word problems emphasise specific, "right" answers using a prescribed heuristic. In addition, Holton et al. (1996) suggested that problem solving is more suitable for groups than word problems but this still seems to depend upon the difficulty level of the task.

Simply obtaining facts is not sufficient for problem solving as defined above. Dewey (1933) argued that forming ideas is also insufficient. Rather, he proposed that a combination of facts and ideas are required to test out strategies and speculations. Initial ideas can guide action in problem solving and facts assist when evaluating the ideas. For Dewey, the iterative relationship between facts and ideas are essential in problem solving situations. It is the ideas, however, that he stated are the "most important catalyst in learning" (Prawat, 1997, p. 20). Problems which encourage children to do more than recall facts but develop ideas and theories can provide a greater motivation for learning.

Recent developments in mathematics education, both in New Zealand and overseas, have emphasised the importance of problem solving including the application of mathematics to the "real world". According to Hiebert, Carpenter, Fennema, Fuson, Human, Murray, Olivier and Wearne (1996), this emphasis can lead to the separation of the acquisition of knowledge, from the application of knowledge. Some approaches to problem solving encourage the acquisition of problem solving skills which are then applied to realistic problems. Hiebert et al. argued that such a separation is arbitrary and unnecessary. Instead, they proposed that the processes of acquiring and applying knowledge should be regarded as unified rather than dichotomised.

An alternative view of problem solving is presented by Dewey (1933) who argued that the acquisition and application of knowledge are not separated in his model of "reflective inquiry" which has three salient features: identifying problems, searching for resolutions and reaching conclusions. During these processes he stated that children are active searchers of understanding and need to tolerate a certain amount of uncertainty and doubt. The benefits of reflective inquiry hinge upon the new understanding that is developed, not on a particular solution to a particular problem.

The traditional approach in mathematics is the solo pursuit of problem solving. An individual wrestles with a problem through a process which may include experimentation, conjecture, counter-example, proof and generalisation (Holton, 1994). This process is often undertaken alone and sharing one's work can be interpreted as "cheating" in the traditional context. In writing about the university setting, Holton argued that collaboration is important in mathematics as many mathematicians do not work alone. In fact, it would be inefficient to always work in isolation. He stated that, "Students can learn a lot by working together-research mathematicians certainly do. Perhaps we should set up more situations where it is okay to collaborate" (p. 126). He urged teachers of mathematics to encourage more collaborative problem solving so that students remain interested and regard mathematics as a human endeavour "rather than imply that our trade is only fit for hermits" (p. 119).

When children work together on a problem a focus on both the problem, and one's partner, is required. Pryor (1993, 1995) stated that a focus only on one's partner can lose direction and momentum for the activity at hand. Conversely, a focus on the problem alone can negate any collaboration and result in separate, parallel work. Furthermore, he argued that the different emphasis on problem or partner is not of equal concern. He stated that it is more likely for partner-focused children to take some notice of the task, than for task-focused children to take notice of a partner. The implication for teachers is that they have the opportunity to modify problems to improve task-focus. This may be more readily achieved than the ongoing development of improving collaborative skills.

A focus on cognition alone does not entirely capture the nature of collaborative problem solving and most studies that investigate the effectiveness of such groups pay scant attention to emotional variables (Light & Littleton, 1994). While children's affective responses are not the main focus of this study, cognisance should be taken of children's attitudes and preferences for various problems as this tends to affect their engagement. It seems important to acknowledge how children feel about working together if we are to understand more about cpds. Holton, Anderson and Thomas (1997) noted that problem solving with peers can be a motivating and emotionally supportive encounter.

> A group can give support to its members and hence help to increase each student's confidence. Students are also more willing to make a mathematical comment in a small group rather than to the whole class. (p. 48)

Children's confidence in and understanding of a subject are influenced by their experiences with that subject. This experience in turn can influence their future

activities (Hiebert et al., 1996). With collaborative problem solving children's confidence and understanding may also be influenced by their peers. The ways in which peers may influence children's confidence and understanding bears further examination.

4.6 Problem types

A number of research studies have stressed the importance of matching the difficulty of the problem with the children (Bennett & Desforges, 1988; Holton et al., 1996; Thomas, 1994). Thomas (1994) found in mathematics with young children that "when the task was either too difficult or too easy the children seemed to engage in non-task related talk" (p. 123). It seems logical that the problem needs to be challenging enough to warrant discussion by the solvers, of a cognitive nature (Holton et al., 1996). These studies suggest that if the problem is too easy then talk in groups will be diminished considerably as there is little purpose in discussing something which appears straightforward. On the other hand, problems which are too difficult may cause discussion to falter as a way to proceed is unclear. In addition, Lyle (1996) argued that the clarity of a task is important for sustaining children's engagement. She stated that children need to have a clear understanding of a task's purpose and know what is expected of each other in collaborative work. Bruner (1960), however, stressed somewhat different factors. He encouraged teachers to pose problems which develop children's intuitive thinking. He proposed that intuitive thinking is fostered when problems require researching to prove, or disprove, children's predictions. He claimed that such problems engage children's guess work and can motivate them to investigate further, as long as the teacher resists premature judgements of right and wrong.

The type of problems which are suitable for small groups to undertake requires further examination by researchers and educators. For example, Dunne and Bennett (1990) stated that there is scant information on the types of tasks which are appropriate for small groups. Cohen (1994) claimed that a number of tasks given to groups are not suitable and would be more relevant for individuals. She attempted to clarify the types of problems that are appropriate for groups. She stated that clear-cut problems with "right answers" are more useful for individuals to undertake whereas ill-defined problems which require structuring are more engaging and relevant for groups. She claimed that ill-defined problems generate more interaction of reciprocal benefit to group members. This interaction with ill-defined problems "should be more of a mutual exchange process in which ideas, hypotheses, strategies and speculations are shared" (p. 4). A similar point was made by Forman and Cazden (1985) who argued that tasks which peers undertake together should emphasise "abstract" interactions

rather than "procedural" interactions, in order to maximise learning benefits. Cobb (1990), however, was less absolute in his recommendation. He stated that abstract and procedural interactions are interdependent and mutually contribute to effective problem solving amongst peers.

Whilst responses to different problem types have been investigated by Maker (1993), she focused on individuals (not dyads) using a structured experimental approach outside the classroom and compared gifted and "average" populations. She found that gifted children and adults preferred ill-defined or fuzzy problems which required them to redefine or reconstruct the problems. She also found that such problems appeared to encourage a wider range of strategies. Prisk (1987), however, studied six and seven year old (non-gifted) children in groups and found that they had difficulties with starting and structuring fuzzy problems and would often appeal to a teacher for help in getting underway. Conversely, when a problem was closed, she found that the children solved the problems as quickly as possible with minimum discussion. In addition, Lyle (1996) argued that problems need to have a clear structure to engage children and minimise any distractions.

Teachers can make inaccurate assumptions about which problems children find engaging, stimulating and challenging. Furthermore, if teachers dominate the discourse and problem solving strategies, children's ideas may be ignored. Smith (1997) argued that teachers need to carefully discern what children feel is a problem in mathematics, and respond appropriately. There is no guarantee, he added, that what the teacher or curriculum determines as a problem will match with a child's sense of a problem. Hiebert et al. (1996) added that the type of problem is less important than the notion of taking a "problematising" approach to teaching and learning. They argued that children should have the opportunity to problematise the curriculum so that they "define problems that elicit their curiosities and sense-making skills" (p. 12). Even basic computations can provide a context for active problem solving when children do not perceive a task as routine. Their own study of a junior classroom found that the children became totally engaged in what appeared to be a very routine problem because they were encouraged and motivated to explore and discuss alternative methods. Hiebert at al. concluded that problems which engage children and enhance their understanding do not have to be "real-life" applications. It can also be inferred from their study that seemingly closed and routine computations can be fertile ground for Dewey's notion of reflective inquiry. In contrast to a number of other researchers, they claimed that the type of task is less important than the way the task is approached and processed by children. They argued that, "Tasks are inherently neither problematic nor routine. Whether they become problematic depends on how teachers and learners treat them" (p. 16). The goal of problem solving is to improve children's understanding, ownership and structural knowledge of mathematics.

Structural knowledge is defined by Hiebert et al. as those insights and understanding children take with them beyond the classroom.

4.7 Research needs

Sociocognitive conflict, social constructivism and sociocultural theory contribute to our understanding of children's collaboration during problem solving. There are debates about the benefits of collaborative problem solving which often reflect particular theoretical perspectives. These perspectives attempt to explain how collaboration can contribute to children's growth in understanding.

Little is known about the specific ways in which children influence or affect each other during collaboration. There is some indication that the nature of the collaboration varies with the type of task. Cohen (1994) believed that researchers and practitioners would benefit from scrutiny of how both problem type and peer interaction contribute to the efficacy of small groups. For cpds this seems to be a central concern. Recent developments in coding schedules reveal consideration of social and cognitive interaction in children's discourse when working together on school tasks. The role of dialogue in cpds is contested in the literature, as is the relative importance of conflict and the social construction of meaning. Finally, investigating dyads' responses to a range of problems is necessary for a fuller picture of what contributes to dyad interaction.

5. Chapter Summary and Conclusion

Collaborative problem solving in dyads can be distinguished from the corpus of literature which pertains to cooperative group work. There are aspects from peer interaction and group work research, however, that have significance for cpds. These studies highlight, for instance, the quality and focus of the talk that occurs between children, the problem solving approaches children adopt, and the nature of children's interactions with each other. It seems that children may work in groups but not as a group, and this can also be true for dyads. Furthermore, the nature of their interactions may not be educationally or socially beneficial depending on the ways in which the children relate to each other. Conversely, there are a number of claims regarding the benefits of group work, such as the support and opportunities to share ideas that are afforded by peer collaboration. In addition, there is an international emphasis on children working in groups and discussing their ideas with their peers which is evidenced in numerous curriculum documents including those published in New Zealand.

A number of peer collaboration studies have focused upon cognitive gains which have been measured with positivist pre-test, post-test designs. The focus of such research often reflected Piagetian theories on cognitive development. Indeed, many of the studies on cpds were experimental designs using Piagetian tasks within laboratory or school settings. The performance of individuals was compared with cpds on the same tasks (e.g., Doise & Mugny, 1984; Schwartz, Black & Strange, 1991). Depending upon the composition of the dyad and the nature of their interactions, these studies argued that cpds were found to generally perform better than those children who worked alone. That this is always the case is not conclusive. In contrast, some research argues that children do not benefit from working in symmetrical dyads and, in fact, may regress (Stacey, 1992; Tudge, 1990). Cobb (1990) argued that it is insufficient to focus on cognition alone as children's thinking is linked to their social beliefs and constructs. Cobb identified an iterative process between the social and the cognitive. The nature of this iterative process requires further examination to build on the seminal work of Barnes and Todd (1977) and more recent research on classroom interaction (e.g., Alton-Lee & Nuthall, 1993; Holton et al., 1997; Thomas, 1994).

Cpd research indicates that pairing children for problem solving is relatively non-threatening and provides opportunities for children to discuss ideas during interaction. There is also the implication that dyads are more "efficient" as there is less social demand on a pair in comparison to a larger group where more negotiation of turns is required (Thomas, 1994). Some teachers indicate a preference for cpds when children undertake problem solving and they deliberately group children in this manner (Holton et al., 1996). The appropriateness of symmetrical dyads for problem solving is also supported by an overview of group work research (Kutnick, 1994). The communication that can occur in dyads is claimed to develop and clarify children's thinking. Stacey (1992) argued, however, that children's thinking and persistence is often curtailed in dyads as they tend not to sustain their investigations but opt for quick solutions.

There are analytical issues regarding the coding and categorising of children's talk which warrant consideration. Talk alone does not capture all aspects of interaction. The complexity of talk also makes it difficult to separate the cognitive from the social in discourse. Recent analytical tools take cognisance of the inter-related nature of talk and emphasise social purposes and context, alongside cognitive factors.

Debate remains about what contributes to dyad collaboration and problem solving. Explanations of sociocognitive conflict, social constructivism and sociocultural theory form the three major areas of theoretical analysis. Vygotskian theory is frequently contrasted with Piagetian theory, with Piaget (1970) focusing on the cognitive development of individuals and Vygotsky (1978) focusing on sociocultural factors in learning. Piaget did make numerous references to collaboration and social interaction,

particularly with his theory of sociocognitive conflict, but factors such as culture and peer communication featured little in his empirical research. Vygotsky, however, focused closely upon the role of language and social interaction in developing thinking. Research which has been influenced by Vygotsky's theories has further explored the role of talk in learning. Some of this recent literature regards "talk as a medium for sharing knowledge and potentially, transforming understanding" (Mercer, 1994, p. 95). The ways in which talk may provide a medium as Mercer suggests, requires further investigation.

While some researchers argue for the central role of sociocognitive conflict in cpds (e.g., Doise & Mugny, 1984; Howe, Tolmie & Anderson, 1992; Perret-Clermont, 1980; Piaget, 1950; Swaminathan, Clements & Nastasi, 1996), there is some evidence that social constructivism and sociocultural factors may be equally, or more, significant (e.g., Barnes & Todd, 1977; Bruner, 1996; Forman, 1981; Forman & Cazden, 1985; Graves & Zack, 1996; Light, Foot, Colbourn & McClelland, 1987; Mercer, 1994, 1995, Vygotsky, 1978). Holton et al. (1997) argued that the interactions of dyads during mathematics problem solving are complex and dynamic. It seems useful, therefore, to examine this complexity further to consider the implications of such dynamic processes for both collaboration and problem solving.

Vygotsky's theory of the mediation and development of cognition through a ZPD is used to underpin many peer tutoring programmes. The notion of a ZPD is adapted by neo-Vygotskian literature which argues that children's development in symmetrical dyads is bidirectional (e.g., Forman, 1986; Lyle, 1996; McCarthey & McMahon, 1995; Pryor, 1995). The ZPD provides the opportunity for both children in a dyad to contribute to each other's thinking through the reciprocal development of knowledge.

The types of problems cpds engage with can also have a bearing on the ways children collaborate. Cohen (1994) claimed that ill-defined problems are more appropriate for groups and that closed ("one-right-answer" problems) are more appropriate for individuals. Her claim bears closer examination. It may be that the difficulty level of the problem is more crucial than the type of problem. Thomas (1994) found that the difficulty or cognitive demand of problems influenced children's motivation and engagement. An understanding of how different problems may affect cpds has pedagogical significance for teachers making decisions on content and groupings for mathematics. Moreover, Hiebert et al. (1996) argued that the type of problem is less crucial than the approach that children may take to a problem and the way they process it. There is also a need for balance between a focus on one's partner and a focus on the problem at hand in cpds (Pryor, 1993, 1995). Children's affective responses to problems and collaboration can also have a bearing on their interaction, but little is known about how children's emotions and attitudes influence their engagement with one another and their engagement with a particular problem.

This review of the literature raises a number of questions related to the characteristics of a cpd. If cpds are deemed useful settings for children's learning and understanding during problem solving, what occurs in cpds to warrant this supposition? Conversely, what appears to detract from peer collaboration and what are the possible implications? The processes of cpds need to be examined to identify how children make sense of problems and how they might influence each other. There is also a need to investigate what effect different problems might have on the ways children respond and interact. A qualitative study which seeks to understand the essence of both cpds and problem solving appears to be timely. Such a micro-analysis responds to Tudge's (1990) exhortation to "pay more attention to the processes of interaction themselves" (p. 169). The central research question that draws together the issues in the literature is, what are the processes of collaborative problem solving when children work in pairs on a range of mathematics tasks? This main question is broken down into three contributing research questions in the methodology chapter to follow.

Chapter Three

Methodology and Method

1. Introduction

This chapter outlines the methodological considerations underlying the study and makes explicit the actual method employed. First, the research questions are outlined with a brief summary of their pertinence to the study. Second, an overview and critique of grounded theory methodology is provided to establish a summary of key methodological principles and concerns and the implications of these for the method employed. Finally, a description of the method used is provided, including the pilot study, subsequent alterations and the main phase of data collection. Issues and explanation of coding, categorising and analysing data to build the theoretical framework are dealt with in Chapter four.

2. Initial Research Questions

As a result of the previous review of the literature and a number of classroom observations, a series of research questions emerged which comprise direction for the study. This year-long study of cpds focuses on the ways in which children collaborate and problem solve in response to a range of problems in mathematics. The research questions act as signposts for the structure of the methodology and subsequent analysis. As is typical of qualitative research though (and particularly of grounded theory), these questions contribute starting points for the "journey", rather than precisely map the terrain that will be covered. According to grounded theory (Strauss & Corbin, 1990), the research questions should provide enough flexibility "to explore a phenomenon in depth" (p. 37). Strauss and Corbin stated that the research questions should be broad enough to allow exploration but should also be focused so as to identify the specific phenomenon of concern. In addition, they claimed that with grounded theory, the questions are likely to reflect process and action. Discussion of grounded theory will be included later in this chapter (see section 3.1).

2.1 What characterises a collaborative peer dyad (cpd)? What is educative about a cpd?

While various claims have been made about the nature and effectiveness of cpds, little is known about the factors that contribute to their efficacy during problem solving.

Furthermore, it seems expedient to know more about what seems to contribute to dyad collaboration and what seems to detract from it.

2.2 How do cpds construct and make sense of problems?

The neo-Vygotskian perspective emphasises the process of communication and language instead of placing a primary focus on the product or outcome of collaboration. As such, research of this nature has emphasised the ways in which children socially interact and communicate during activities and discussion. As this study seeks to investigate children's interaction during problem solving, the neo-Vygotskian perspective has an influence on the methodology.

The experimental paradigm of Piaget resulted in laboratory methods and detached, "objective" researcher roles, although there has been considerable adaptations of his approach in recent years towards more interactive and informal methodologies (e.g., Osborne & Freyberg, 1985). Vygotsky's work has also encouraged a shift towards more naturalistic methodologies and "the investigation of cognitive development and learning in context" (Mercer, 1994, p. 95). This study seeks to understand ways in which children may affect each other when working collaboratively.

2.3 Does the type of problem affect the way children collaborate and think?

Of import in this study is the apparent influence of the problem type on children's thinking and collaboration.

3. Methodology

As this study endeavours to examine both the processes of collaboration and the processes of problem solving in dyads, substantially qualitative approaches are required. It is concerned with the content and nature of the meaning-perspectives of children in dyads as intrinsic to their collaborative work. The purpose of the classroom field work is not to answer, "Which types of problems are most effective in enhancing peer collaboration?" or, "How does problem solving occur in cpds?", but rather, to subject to critical scrutiny assumptions about the meanings children hold about different problems and assumptions about interaction in cpds (Erickson, 1986). This study also seeks to understand the ways in which children in their interactions mutually influence their thinking and their environment. Strauss and Corbin (1990) attested that the purpose of qualitative research is

> To uncover and understand what lies behind any phenomenon about which little is yet known. It can be used to gain novel and fresh slants on things about which quite a bit is already known. Also qualitative methods can give the intricate details of phenomena that are difficult to convey with quantitative methods. (p. 19)

In keeping with the spirit of qualitative enquiry this study aims to:

- provide novel and fresh slants on cpds;
- understand what lies behind children's problem solving in cpds (about which little is known); and
- provide details of the phenomenon of collaboration, problem solving and the effects of the problem type on these.

Thus, the aim is not to prove causality between effective problem solving and cpds, or between collaboration and cpds (Erickson, 1986). Qualitative approaches are appropriate for this study as the setting is holistic and greater attention can be given to nuance, idiosyncrasies, serendipity, interdependencies and complexities (Patton, 1990). Furthermore, the principles of qualitative research are evident in the concerns of this study. For example, Smith, Harre and Van Langenhove (1995) stated that qualitative research principles include a focus on people (rather than statistics), interaction (rather than static incidences) and language and discourse (rather than only observable behaviour). They claimed that many qualitative methodologies recognise the importance of language and "dynamic interactions between people" (p. 3). The analysis of conversations in qualitative methodologies tends to regard talk as active and social rather than as a static product to be counted and tabulated. Cognisance is given to the reciprocal and complementary nature of social discourse rather than treating participants as separate and autonomous entities in the roles of speaking and listening (Drew, 1995). Methodologies of this kind rely upon observation and the transcribing of natural speech interactions.

A focus on language and interaction is pivotal to this study which scrutinises children's interactions with each other and with mathematics problems in dyads. The complexity of talk and interaction makes for detailed data which have shades of meaning and nuance that need to be considered in context. Furthermore, it is easy to misconstrue or misinterpret what is said or intended. This issue will be discussed further on in this chapter.

3.1 Grounded theory

> The grounded theory approach is a qualitative research *method* that uses a *systematic* set of *procedures* to *develop* an inductively derived grounded *theory* about a *phenomenon.* [emphasis in the original] (Strauss & Corbin, 1990, p. 24)

This definition describes what is meant by grounded theory. A key difference from some other methodologies is that in grounded theory, the researcher does not start with a theory and then go into the field to "test" the theory, but rather the theory emerges from the data which are systematically collected and analysed (Strauss & Corbin, 1990). The researcher begins with an issue or concerns in an area but is alert to what emerges from the study itself. Theoretical analysis derives from what is discovered in the actual data. Although grounded theory originated in sociology, it can be used in a range of disciplines. Charmaz (1995), for example, stated that grounded theory methods are particularly suitable for studying cooperation and conflict in interpersonal relations, in addition to studies of individual and large social processes. It seems appropriate, therefore, to utilise grounded theory to examine the processes of collaboration and problem solving in dyads.

According to Strauss and Corbin (1990) and Glaser and Strauss (1967), there are sound reasons for grounding a theory in the way they advocate. They claimed that the process of constructing a well grounded theory enables it to be soundly applicable to the phenomenon studied. Their criteria for evaluating a grounded theory includes, "fit, understanding, generality and control" (Strauss & Corbin, 1990, p. 23). In their view, "fit" pertains to the way in which the theory should be faithful to the reality of the area under study. As a result of fit, the theory should also make sense to those being studied and to those who work in the area. They should be able to understand and recognise what it states.

When the data are comprehensive enough, the theory should also be applicable to a range of related contexts. This requires that the conceptual interpretations are sufficiently broad to ensure such generality. In contrast, though, the theory should also provide some control in that actions are identified which pertain specifically to the phenomenon under study. Any conditions derived from the theory apply "specifically to a given situation" (p. 23). Herein lies an apparent paradox. While grounded theory should be sufficiently broad to warrant some generalising to similar contexts, any conditions and actions pertaining to the theory are specific to the context studied. The extent to which a theory can have both generalisability and specificity, is problematic. It seems that the emphasis on relevance to a given situation is more feasible than the emphasis on generality. Furthermore, the concept of generalising from research is usually a characteristic of studies with large samples. As Charmaz (1995) pointed out,

grounded theory procedures can be used for handling both quantitative and qualitative data. This helps to clarify the breadth of claims made by Strauss and Corbin. The ability of grounded theory techniques to serve such a wide set of purposes is both its strength and its limitation.

Grounded theory provides a challenge to criticisms of qualitative methodology as being intuitive, impressionistic and idiosyncratic. Through employing rigorous and systematic procedures, grounded theory enables intuitive hunches and emerging propositions to be checked, refined and conceptualised through data. This process adds credibility and plausibility to the research but it is claiming too much to state categorically that a theory from this process can be generalised with certainty. Rather, it seems that, as Charmaz (1995) clarified, the rich conceptual analyses of grounded theory have potential for generalisability when study is undertaken at a number of different sites. In addition, she stated that grounded theory synthesises and clarifies processes in the areas under study rather than creates substantive theory. The theory that emerges is a conceptually dense analysis of lived experience. Grounded theory methodology does not create "tightly framed theories that generate hypotheses and make explicit predictions" (p. 48).

As mentioned earlier, the literature review and research questions which arise provide direction for the study but do not determine its precise focus. The literature review in grounded theory can be a stimulus for research, pointing to areas that require further study or highlighting issues that bear closer scrutiny. As such, the literature review and subsequent research questions play a similar role in most approaches to research. In grounded theory, however, the analysis is not determined by previous theoretical issues and concepts. Nor is the literature review completed before the study proceeds. In fact, Strauss and Corbin (1990) stated that it is important to have familiarity with literature in the field of study but it is unnecessary to review it all first. With grounded theory, researchers are unaware of all that will need to be reviewed until after some analysis is completed. Only then will new categories have emerged that require researchers to return to the literature to see what (if anything) has been written about that topic and what other research may have found. Thus, the literature review of this study was not completed in advance of the study but was returned to on a number of occasions subsequent to ongoing analysis of early data.

The discovery nature of the grounded theory process determines this iterative movement from literature to analysis and back again. Strauss and Corbin argued that there should be a constant interplay between analysis and reading related literature so that the two activities inform each other and assist with the forward momentum of the study. The challenge inherent in this is the temptation to rely too much on the literature when analysing, especially when categories emerge which already exist in the literature. While Strauss and Corbin allow the use of existing literature in analysis,

they caution that researchers should strive to remain open to the unexpected. As Charmaz (1995), also, stated

> The inductive nature of these methods assumes an openness and flexibility of approach. Thus, you follow the leads gained from your view of the data, not from the careful and exhaustive literature review of the traditional research design. (p. 47)

In order to maintain what Strauss and Corbin (1990) termed, "theoretical sensitivity", the literature can alert researchers to concepts and relationships pertinent to the study. Frameworks developed in other studies may have similarities with a current grounded theory study and Strauss and Corbin suggested that these similarities should be acknowledged and drawn upon. They cautioned, however, that any existing theory or concept from the literature should always be verified by researchers against data in their own studies.

Theoretical sensitivity can also be enhanced by researchers' professional and personal experience. Professional experience can enrich researchers' understanding of certain processes and phenomena as well as stimulate pertinent questions for further investigation. Familiarity with a professional field enables researchers to understand it more quickly than a neophyte would. Strauss and Corbin acknowledged, however, that professional knowledge can also obstruct a clear view of the area of study, as many aspects may be accepted unequivocally.

Personal experience can also contribute to researchers' theoretical sensitivity when their own experience with the phenomenon to be studied highlights areas to pursue or provides contrast to the data collected. My own experience in teaching children and adults alerted me to issues in collaboration and problem solving which I was eager to investigate further. Using pair work in classrooms on occasion highlighted for me the potential of such a grouping for learning (see Chapter 1, section 2). Personal experience can be useful if it does not determine and constrict what to attend to and how to analyse data.

Charmaz added that concepts and research interests derive from a range of sources such as the related literature, professional, and personal experience. She suggested that the concepts that researchers bring to a grounded theory study from these various sources, are useful "points of departure" (1995, p. 32). She acknowledged that researchers do not begin any study with total impartiality but rather they are influenced by concepts, theoretical perspectives and research interests they deem important. She clarified that researchers' prior interests and perspectives should contribute to the development of ideas, rather than determine and constrict ideas.

The emphasis in grounded theory methods is upon analysing processes which entails a focus upon what people do. This focus can result in a range of meanings to

explain people's actions. While original approaches to grounded theory claim that meaning is discovered in the research setting, Charmaz claimed that the "interaction between the researcher and the researched *produces* the data, and therefore the meanings that the researcher observes and defines" (p. 35). Her interpretation underpins the social construction of meaning that can occur with grounded theory. Meaning is not identified and isolated in the data by the researcher, but rather, it is constructed by the researcher in interaction with the participants and the data generated. This approach acknowledges that researchers are not detached from the process but affect, and are affected by, what occurs. It is acknowledged also that the children as participants are likely to be affected by what occurs. Furthermore, in order to remain sensitive to what emerges from the process, Charmaz stated that researchers need to collect and analyse the data (rather than employ assistants) so that they stay close to the data and alert to nuances and subtleties.

3.2 Vygotskian influence

While grounded theory forms the basis of the subsequent coding, categorisation and analysis, Vygotskian theory also has some influence. The Vygotskian and neo-Vygotskian literature does not comprise the theoretical framework of this study but research from this perspective is acknowledged as pertinent (see section 4.3 in the literature review).

Research which has been influenced by Vygotsky's theories has the benefit of studying children's interactions in everyday contexts. The limits, however, of qualitative neo-Vygotskian research is that it tends to generate a plethora of data which are difficult to code, categorise and use to draw inferences from. The wealth of the naturalistic settings focused on can obscure some data through sheer volume so that the "trees" become blended into a generic "wood". Immersion in a classroom setting can make it difficult to maintain a focus on the research questions and to identify significant events and data (McLeod, 1995). Therefore, employing grounded theory is a way to create some structure and order from a wealth of data. Coding, categorising and analysing the data using grounded theory methods forms the content of the next chapter.

4. Method: Pilot Phase

Informal observations of children working in a number of classrooms were undertaken in a range of different schools for three months. Of particular interest in the observations was the ways in which children referred to a partner when working and the discourse between children when they worked in pairs. Over this time I also

discussed with the classroom teachers when and why they used pair work with children.

On the invitation of one of the classroom teachers, one classroom was subsequently focused on for the pilot study. Her invitation suggested to me that she was comfortable with my presence in her room. This was important in terms of relationships with schools and teachers when undertaking research. Researchers can approach teachers for study purposes but to be invited and welcomed, as I was, indicated the willingness and ownership of the teacher in the decision.

This class had children with a range of ability and an experienced teacher who was familiar with recent curriculum changes including mathematics problem solving and the emphasis on group work. Classroom observation over a further two months revealed that dyad collaboration was used occasionally in that particular room. The most common purposes for dyad grouping used in the classroom appeared to be for testing and checking (spelling words and practice of basic mathematics facts), for exploratory activities such as measurement in mathematics, for ball skills in physical education, and for peer editing of children's stories. This was quite "typical" of the uses of pair work observed in the other classrooms. For the purposes of the pilot study the children needed to have some familiarity with problem solving in mathematics. The study did not include the teaching of problem solving skills. Therefore, it was necessary to focus on children who had undertaken some problem solving, which was not difficult given the emphasis on problem solving in the *Mathematics in the New Zealand Curriculum* document (Ministry of Education, 1992) and the class teacher's awareness of this. The pilot study was also undertaken a few months into the school year so that children had had opportunities to do some problem solving and to become familiar with each other.

4.1 Ethical considerations

As this study involved the collection of data from human subjects, general principles for research involving human participants were followed (School of Education, 1994/1995). These principles included clear goals for the research, informing and inviting all participants to take part, outlining any potential risks, avoiding any covert purposes or procedures, sensitivity to social and cultural values, avoidance of exploitation, respect for property rights and avoiding any conflict of interest. After initial consultation with the school principal, letters requesting consent (and feedback on the letter's content) were sent first to the Board of Trustees, the principal and the classroom teacher (see Appendix A). Once the letter was approved, copies were sent to the parents (or caregivers) of all the children in the class.

As video-recording and audio-recording were used, it was important to seek everyone's consent in the class to cover any occasions when a child who was not in a dyad inadvertently appeared on a recording. The busy life of classrooms makes it likely that children will move and interact with each other throughout the day and so it was probable that recording may pick up more than was intended for the purposes of the study. The letter clarified that no data would be used for any purposes other than the study of the problem solving and collaborative processes of the chosen dyads in the classroom.

The letter also explained how data would be collected and how they would be used, if consent was granted. Participants and their parents had the right to withdraw at any stage and could access and keep copies of data which pertained to them on request. All data were stored in a safe place under lock and key. In addition to the letter, the children themselves were asked if they wished to take part and permission was sought from them to record their talk and interactions. There was a 100% affirmative response to the letters requesting consent.

4.2 Dyad selection and composition

Four dyads were chosen by the classroom teacher for the pilot study. The selection of children was based upon teacher assessment and nomination, Progressive Achievement Test (PAT) results for mathematics (PATs are a New Zealand devised series of standardised tests), Primary Progress Records (a cumulative card system with teachers' comments on individual children's progress), anecdotal records, and observations of the children and their work. In selecting the children, cognisance was also taken of their ability to cooperate with each other. While they were not selected on the basis of compatibility, care was taken to avoid pairing children who were judged to be antagonistic towards each other. The children were asked about their views on collaboration and what made collaboration "work". They identified aspects such as working together, negotiating decisions together, as far as possible resolving disagreements, and listening to each other. Of interest during the pilot study was the extent to which the problems and the opportunity to work together may contribute to (or detract from) the dyads' collaboration. The children were not specifically instructed on how to collaborate.

One dyad was deemed, from the range of sources listed above, to be above average for their chronological ages in mathematics. The other three dyads were operating at their age-related levels. It is acknowledged that these evaluations are generalised. It is not uncommon for a child to be particularly able in an aspect of mathematics (say geometry) but have difficulty with another area (such as decimals). There also exists a value judgement inherent in terms such as "average" and "above

average". PATs, however, are norm-referenced and provide some evidence for such judgements. The range of sources for assessing the children endeavoured to validate decisions about their ability and, therefore, who they could be matched with to form a dyad of similar ability.

The classroom teacher matched all but one dyad for gender. Her rationale for this was to maximise compatibility as the dyads were children she believed worked well together. She did not assume that gender matching is a prerequisite for compatibility but she did note that at age eight to 10 years, these children tended to choose the company of their own gender. This is supported by the literature on children's friendships and social development (Townsend, 1992). The dyads comprised girl-girl, boy-boy, boy-boy, and girl-boy. One boy-boy dyad was a Chinese New Zealander and a Maaori (indigenous New Zealander) boy. The girl-girl dyad was a Chinese New Zealander and a Paakehaa (white New Zealander) girl. It is not the purpose of this study to examine gender issues in dyads (for studies of gender and group work see Borg, 1996; & Pryor, 1995). The remaining two dyads were Paakehaa. The majority of children in the school, and in the class, were Paakehaa. So as to retain some feeling of "normality" for the children, the sessions took place in the children's classroom during mathematics time with the rest of the class present. This was intended to minimise disruption to the children's programme and to maintain familiarity of surroundings so that the children would act as closely as possible to their "normal" behaviours.

The children were all from the same classroom and knew each other well. Their ages ranged from 8.1 years to 10.11 years. This age range was selected because at this age children usually have sufficiently elaborate language and literacy to engage in prolonged discourse when working with a partner. They also have usually developed strong peer group affiliations and are becoming increasingly independent (Townsend, 1992). At this age range children are also expected to have developed some problem solving strategies in accordance with levels two and three of the Mathematics curriculum (Ministry of Education, 1992). The school draws upon an urban community which has high levels of employment in professional and skilled work and is at decile 10 of the statistical annex (Ministry of Education, 1995). This socio-economic indicator is based upon census data related to parents' or caregivers' employment, income, qualifications, ethnicity, housing and income support payments.

4.3 Recording

A continuous narrative recording of each dyad interaction was undertaken with a particular focus on the children's talk. Each dyad was audio-taped (and some were video-taped) while I continued with a narrative recording. The narrative recordings

were an attempt to capture the complexity and embedded nature of the processes being observed. The video-recordings and narrative recordings had the advantage of capturing body language, movement, use of materials and aspects of the physical environment which would not be apparent in the transcripts from the audio-recording. The observational data provided some corroboration (or otherwise) with the audio-tape transcript. The observations, various recordings and the tape transcript provided a variety of data with which to make an analysis of meaning in context. Recordings and interviews took place over a four week period during mathematics time in the classroom. This time duration was required to focus on each dyad with each set of problems as described below.

4.4 Problem types

To investigate the third research question, a focus on specific problem types was undertaken. The four dyads were observed closely with a focus on how they reacted to, and made sense of, the different problem types. The tool used for determining the types of problems employed is influenced by Getzels and Csikszentmihalyi (1967), Maker (1993), and Schiever (1991). That children could well redefine problems that are presented to them was also of interest and has significance for this study. In order to check the validity and reliability of the problem types, 34 different problems ranging from closed to ill-defined (see below) were given to 11 colleagues to assess. These colleagues included people from a range of disciplines, that is, they were not all mathematics educators. They were provided with descriptions of the three problem types as I have defined them:

Type 1: Closed problem (C).

The problem is clearly defined and known to both presenter and solver. The method(s) for solving are not stipulated, and there is generally a correct answer. An example of this would be when children are asked, *The doctor says to take 5 pills, one every half hour. How long will that take?*

Type 2: More than one solution and strategy possible (M).

The problem is known to both presenter and solver. A range of methods for solving is possible, as is more than one solution. An example would be when the problem states, *Jill saw some friends with tricycles and bicycles. She saw 18 wheels. How many tricycles and bicycles might there be?*

Type 3: Fuzzy problem (F).

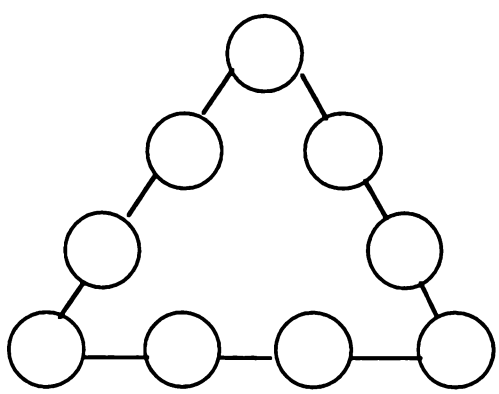
While the problem may be known to both presenter and solver, it is ill-defined and many methods may exist for solving the problem or a new method may need to be devised. An example of such a problem would be when children are asked to, *Estimate the number of vets in New Zealand.* (These are also called "Fermi" problems as they are based upon the types of problems that the physicist Enrico Fermi liked to pose to encourage estimation and problem processing.)

The problem definitions above were used as a guide by the assessors as they determined whether the 34 problems I gave them were of type one, two or three. I received ratings back from eight of the original 11 assessors and selected from their feedback only those problems which had an agreement of 75% (six out of the eight) or better. This provided the core of problems used in this study. One problem, *Make 23,* required a second round of assessment due to a low 50% of assessors rating it as M (more than one answer). The disagreement amongst the assessors on this problem seemed to arise from the appearance of the problem which, on first impression, seems to have only one possible solution. As this particular problem was enjoyed by children I had worked with in other settings I wanted to retain it if possible. With a Delphi round, the eight assessors were asked to look again at the problem and decide if they would like to retain their original judgement or change their rating. As a result of the Delphi, *Make 23* was retained with a 75% agreement from the assessors. This resulted in a final set of problems of which the following is a selection.

Problem Order: 1 (closed), 2 (more than one), 3 (fuzzy).

1. The doctor says to "Take five pills, one every half hour." How long will that take?

2. Place all the numbers from one to nine in the circles so that each side adds to 23.



3. How far do you both walk in the average week?

Problem order: 3 (fuzzy), 2 (more than one), 1 (closed).

3. How many times a day does the average New Zealander laugh?

2. 28 is the answer. What might the question be?

1. A camera and its case cost $110. If the camera costs $100 more than the case, what is the cost of the case? (Stokes, 1993, p. 11)

Problem order: 2 (more than one), 1 (closed), 3 (fuzzy).

2. Jill saw some friends on tricycles and bicycles. She saw 18 wheels altogether. How many tricycles and bicycles could there be?

1. You and your friend have $30.00 to spend at the fair. It costs you $5.00 each to get in, $2.20 each for candyfloss, $2.50 each for the roller coaster and $1.80 each for lemonade. If the ghost train costs $4.00 each do you both have enough money left to go on it?

3. Estimate the number of vets in New Zealand.

4.5 Order of problems

The children were given a number of problems to work on over time but data collection focused only on the nine problems listed above. The children were given three sets of three problems to work with over approximately three one hour sessions This resulted in nine problems per dyad. The order of the problems was varied each time so that they were not going from closed to fuzzy in each session but investigated the problems in different orders during each hour (see Table 1).

Table 1

The order of problems given to dyads

Problem Types			CPD 1	CPD 2	CPD 3
1	3	2	a	b	c
2	2	1	b	a	b
3	1	3	c	c	a
a	b	c	TRIAL 1		

4.6 The researcher

To minimise disruption to the class and the effects of my presence, I spent two months (not every day but a total of some 50 hours) in the classroom on a casual basis (prior to collecting data) observing the children and interacting with them in an informal manner. I did not assume the role of a teacher and my presence was explained to the children as an interested person who wanted to find out more about what they did in the classroom, especially when they worked with a partner. A range of lessons was observed in language, reading, art, and mathematics, and I spent some time discussing the children's work with them, focusing on their ideas.

As a result of this preliminary contact it was hoped that when the data collection stage commenced, the children would be comfortable with me and in no way threatened or anxious. It was also stressed at the beginning of each session with a dyad that this was not a test and that I was not concerned with whether their ideas might be right or wrong. Technology for collecting data was introduced gradually so as to minimise distraction. The children were invited to look through the camera lens and play back the tapes so that they became familiar with the apparatus and its purpose. Further comment on the use of technology is made later in this chapter.

4.7 Interviews

At the end of each series of three problems, an open-ended interview followed with each dyad. The purpose of each interview was to more precisely validate possible meanings that the children had, and developed, during their interaction (Strauss & Corbin, 1990). An interview can help to clarify and explore some single words and phrases that the children used.

The interviews were intended to probe the children's intentions, the reasons for their actions, questions they posed, ways they might redefine problems, equipment they used, changes they decided to make, reactions to each other's ideas, how they felt about the problems and so forth. The interviews aimed to clarify the children's meaning-perspectives, corroborating (or otherwise) what was observed and providing further illumination. Responses from an open-ended interview can enable a researcher to understand the lesson as seen by the children and in doing so, the meaning-perspectives of the children are captured without predetermining their points of view (Patton, 1990).

The open-ended interview also provided a necessary counterbalance to the rather impersonal non-participant observation (while the children were working on the problems) which did not probe the understanding and intentions of the participants. Together with the narrative recording and the tape transcript, the interviews provided necessary triangulation. All of the tapes were transcribed. Although the intent of the interviews was to be sensitive to the particular and unique interactions of each dyad with each problem, there were some guiding questions commonly asked. For example:

- When I say the word "problem" what goes on in your head?
- If you could work on _____ again, what would you change?
- Why do you think that you did _____ first?
- What made you change your mind and agree with _____?
- What made you change the way you looked at the problem to _____?
- When do you have problems like this?
- Where do you prefer to do problems like this?
- Which of these did you like the best?
- Why was _____ your favourite?
- Which was the hardest? What made it hard? How do you feel about hard ones?
- Which was the easiest? What made it easy? How do you feel about easy ones?
- Why are some problems more interesting than others? What makes an interesting problem?
- What helps to work out the problem?
- What kept you going when the problem got tricky?
- What did you think about working together on the problems?

Some of these questions are derived from Maker's (1993) research but the questions on collaboration and change are unique to this study.

5. Limitations of the Pilot Study

As a result of the pilot study, various changes were made to the subsequent method in the main study. The intention of preserving a "natural" classroom environment, and therefore achieving some context validity, was not totally effective. One may question what is natural about a classroom in the first place. Although the first session took place in the midst of the classroom milieu, the noise from the surrounding children made it somewhat difficult to obtain clear recordings of speech. I did not have the financial resources or technology to provide personal microphones but was relying upon a small but efficient, portable recorder. This recorder was appropriate under most circumstances but was not always able to compete with 35 different voices in close proximity.

Despite the intention to reduce disruption by having the dyads work on the problems during mathematics time and in the classroom, it was still in effect, a contrived situation and the dyads were the subject of some curiosity from their peers. Although I was at pains not to present as a teacher, the children appeared somewhat puzzled about my role. It seemed acceptable to them that I was interested in their work but it was obvious that I was there for a purpose which for ethical reasons had been made explicit to them and their caregivers in obtaining consent prior to the study. As such, it was clear that I had an "agenda" despite the intention to be empathically neutral (Patton, 1990). A concern with not interacting with all the children in the class arose when some children asked, more than once, "When are you going to work with me?" As a result I did take some sessions with the whole class after the pilot had been completed and initiated some dyad work so that all children felt included in some way. The whole class work, however, was not the basis of this study.

Further sessions with the dyads moved to a mezzanine floor within the classroom which had the benefit of being within the room, but slightly apart and more private, which seemed to aid the children's concentration on the tasks. The disadvantage of moving apart from the class seemed to be that it underlined the separate and special nature of the sessions, rather than embedding them within the context of their mathematics time. Moreover, I felt that the sessions on the mezzanine floor differed little from the laboratories and caravans set up for experiments on subjects within a positivist scientific paradigm. This was certainly not the intention of this study but rather to establish a context in which children would feel relaxed (rather than scrutinised) and informally engaged (rather than "experimented with").

The other aspect which caused concern was the open-ended interview which was intended to ascertain the children's views. The literature on interviewing children, particularly from Piaget and more contemporary developments in science education (Cosgrove & Osborne, 1981; Osborne & Cosgrove, 1983; Osborne & Freyberg,

1985) have focused upon set questions followed by further probing of the children's responses to those questions to clarify their meaning and ideas. In a sincere attempt to find out what children really thought (rather than what they thought adults wished them to disclose), these approaches did convey to children that their ideas were of interest and concern. What was not clear, though, was whether such interviews probed what children knew or what they were starting to know, that is, whether such interviews tended to focus on the ideas children hold rather than the ideas they are still formulating (Schaverien & Cosgrove, 1993). It may be that interviews of this nature do not reveal all that a child knows (about a certain subject) and certainly not all that they are beginning to know.

As the open-ended interview employed during the pilot was undertaken at the end of each session, it was positioned as a formal reflection on what had taken place, rather than as a conversation. Conversations rarely only take place at the end of a series of activities but are more likely to occur between and during activities, such as the conversations partners have when changing sides in a tennis game. As this study intended to investigate the ways in which children affect each other's thinking, it seemed more relevant to employ a method that sheds some light upon the process of interaction as close to the action as possible. In doing so, the conversations that take place may enable children to talk about their emerging understandings and thoughts rather than just respond to interview questions. The intention was to uncover the children's interaction and thoughts in process, including ill-formed and emerging thoughts. To extend the tennis analogy, I hoped to examine those contentious balls that land near or on the line not just the ones that land squarely in or out of the court.

6. Method: The Main Study

Various aspects of the main study are similar to the pilot phase such as the focus on dyads, children's collaboration and a range of problem types for problem solving. As is the purpose of a pilot study, it provided valuable insights into the constraints that a particular method can have on the data collected. The theoretical and philosophical implications of employing grounded theory also contributed to the shift in method. As Charmaz (1995) argued, "The grounded theorist builds the research as it ensues rather than having it completely planned before beginning the data collection" (p. 48). The questions and suppositions that emerged from the data as the study proceeded uncovered gaps and anomalies that led to future directions and areas that required revisiting or focusing upon anew.

Continual iteration (the moving back and forth between the data collection and analysis which affects both the method and the future analysis) determines that grounded theory research is not undertaken in a sequential lock-step manner (Spiggle,

1994) and neither does the method remain constant and unchanged. The analysis of data from the pilot phase proceeded from inferences based upon iteration and the forming of subsequent hypotheses and suppositions. As Charmaz (1995) suggested, I undertook all the data collection and analysis in the pilot and main study in order to stay sensitive to "nuances of meaning" (p. 35).

The early analysis of the pilot data also raised questions about the flexibility of the chosen methodology and whether its frame was in fact too heavy, too constraining and too overbearing. The framing of a picture can make all the difference to how that picture appears. Ordinary calendar prints can be transformed by elegant frames that set the picture off in such a way that capitalises upon the best features of the picture. Conversely, admirable original art works can appear dull and uninspiring when the frame is too heavy, too ornate or not striking enough. In short, the most effective frames are those that complement the picture and enhance its best features. This can also be the case with methodology. Well-selected methodology should complement and enhance the features focused upon rather than detract from or obscure them. Methodology, however, should not be so well-framed that it carries the picture completely, masking discrepancies and problematic features.

6.1 Selection of the school

Serendipitously during the research, I was asked to work with a group of young children who had interest and ability in mathematics, at a different school from the pilot study. Again, as mentioned in the pilot study, it felt less intrusive to undertake research in a school I had been invited to rather than approach a school myself. Even when appropriate ethical considerations are adhered to researchers can still initiate all the contacts, own the agenda of the research and wield most of the decision making power when undertaking school-based research. To be invited by a school went some way towards achieving a more equitable relationship and giving something back to the school, the children and the community. According to the Ministry of Education (1995), the school is at decile one of the statistical annex. The schools closest to decile one draw from the lowest socio-economic groups. The composition of the school roll includes a number of different ethnic groups which are Maaori (62%), Paakehaa (22%), Pacific Island (11%), Lao and others (5%).

I was asked to operate a withdrawal programme for a group of children drawn from four different classrooms. The withdrawal programme is not the basis of this study but it enabled me to get to know the children, their strategies, and for them to become familiar with me. This programme was part of the reciprocity I felt was important in such research. My work with the children enabled me to provide a service rather than just collect data. It was also a valuable way for the children to

become accustomed to periodically leaving their classrooms, interacting with an adult that they know, establishing a relaxed atmosphere conducive to problem solving (process, rather than product oriented) and gradually introducing audio-recording and video-recording in a relatively non-threatening way. In the withdrawal programme, the children were not encouraged or instructed to work in dyads but were free to choose whether they wanted a partner or not. Some brief instruction and practice of listening and responding to a partner was undertaken, but the teaching of collaborative skills was not a main thrust of the programme.

After operating the withdrawal programme for three months, separate sessions with four dyads were undertaken for the purpose of this study over the period of a month. The four dyads investigated over 30 problems of the types described in the pilot phase. They had not met these problems before in either their classrooms or in the withdrawal programme.

6.2 Selection of the children

The 12 children in the withdrawal programme were drawn from four different classrooms in the school and ranged in age from 6.5 years to 8.7 years. The children were selected through teacher, deputy-principal, self and peer nomination. Parents and caregivers were also invited to comment on the children's suitability for selection. The criteria for selection were based upon interest and ability in mathematics. Ability was determined through Primary Progress Records, anecdotal records, observation of the children, checkpoints, mathematics profile sheets and work samples. From these 12 children, eight children were focused upon for the dyad study and undertook further problems in addition to their work in the withdrawal programme. These eight children ranged in age from 7.0 years to 8.7 years and were selected on the basis of their willingness to talk about what they did and their preparedness to interact with a partner. A further bearing on the selection process was the age related social and cognitive development of children. There is likely to be less egocentricity and more potential for reciprocal relationships with pairs of seven and eight year olds, as opposed to pairs of younger children (Townsend, 1992).

6.3 Ethical considerations

The procedures for obtaining consent undertaken in the pilot study were employed in the main study with a few additions. The letter requesting consent (and feedback on its contents) went first to the principal and Board of Trustees (see Appendix B). A copy was then given to all of the four classroom teachers, since the children came from more than one class. Once feedback and approval was obtained, copies were sent to

the parents and caregivers of the children involved (see Appendix C). These parents were also invited to visit during the withdrawal programme if they wished and generally encouraged to question or comment on the programme.

Advice was sought from the visiting teacher who specialises in teaching English to speakers of other languages (TESOL), in obtaining consent from parents/caregivers for whom English is not their first language. This pertained to one parent of a child in the study who (as it turned out) was also fluent in English. The other parents and caregivers had at least one fluent adult speaker of English in their household. Consent was sought from all parents and caregivers of the 12 children for the reasons outlined in the pilot study. A 100% affirmative response was received from all parties. The children were also asked for their consent and conveyed considerable enthusiasm for being part of the programme.

6.4 Sources of data on individual children and the school

The main sources of data included the following documents:

- School charter (revised 1994) and policy documents
- Record of Schools Attended (E19/22A)
- Primary Progress Record: Junior School (E19/16A)
- Mathematics profile sheets

And open-ended interviews, discussions and sometimes phone calls with:

- the children
- some parents and caregivers
- the deputy principal
- the TESOL teacher
- the four classroom teachers

The other sources of data were observations of the children working in their classrooms, children's peer and self nomination, and teachers' anecdotal comments.

6.5 Limitations of initial data collected on children's ability

There were a number of limitations to the data obtained about the children's mathematics ability at the outset of the study. Information recorded on school records was not up-to-date and consisted of summative statements, rather than formative assessments which could provide more details about the processes children used when

working in mathematics. Furthermore, the records did not provide information about children's ability in a range of mathematics areas but instead, gave general statements pertaining to overall ability.

In order to obtain more recent and specific information, the children's teachers were spoken with and the children were observed working in their classrooms. As is frequently the case in schools, teachers were busy and it was not always possible to have sustained conversations, even after school hours. Observing the children was helpful in that it provided the opportunity to witness their regular behaviour and the way they worked in their own class environment. As Smith (1992) noted, however, there is bias implicit in any observation and what is observed is usually a construction, rather than a reflection, of "reality".

Parents and caregivers were consulted with by letter regarding the study and the withdrawal programme, and invited to comment on their children's ability in mathematics. While all of the parents granted consent, only two made comments about their children's interest and ability in mathematics. All of the children from the four classrooms were also consulted at the initial stages, and invited to self or peer nominate to aid the selection process, and to provide opportunities for children to evaluate themselves and others. Involving the children in this way was another valuable source of information when determining the children's abilities and interests. The children's assessments were astute and honest. For example, one girl said that she would like to be in the programme because she was good at mathematics but was worried that her reading would be a problem, as she found reading difficult. She was reassured that this was a mathematics programme and not a reading programme. Furthermore, there would be other children to read out any writing she found difficult. Incorporating peer assessment can enable a shy child who does not self-nominate to be identified. While peer and self nomination are appropriate in this context, children may perceive that peers who are fast, and can add up well, are "good" at mathematics. Speed and basic computation skills do not determine a child's understanding of mathematics and can be misleading indicators.

6.6 Dyads' composition and characteristics

The eight children focused on for the study chose their own partners with the exception of one dyad who generally preferred to work separately (two boys from the same class). It seemed logical to follow the children's natural choice of partners as these were the children with which they felt most comfortable. I was not beholden to orchestrating the pairings and felt that the major objective was that the children wanted to work together. It was hoped that the children's own selection of partners gave them more ownership and commitment to the process of collaboration. It was also hoped

that their chosen partners were children they could trust and did not feel threatened by in any way.

The dyads were matched for gender except for one boy-girl dyad. This was purely the result of their own choosing and not a direct intention of the pairing. The ethnicity of the children included Maaori, Paakehaa, Niuean, Filipino, Indian and Dutch. All of the children were fluent in English and three also spoke their home language. None of the children have both parents in paid employment and some of the children come from large families. Six of the eight children have had some early childhood education at kindergartens.

Pseudonyms were used for all of the children to maintain confidentiality, with two notable exceptions. One dyad, with particularly strong personalities in the pilot study, were difficult to rename without thinking of them as who they were. This was an unexpected phenomenon but one which had a satisfying resolution. Upon asking the two children if they would mind being named by their first names in the study they both responded eagerly that they preferred to be identified, rather than renamed. When I explained all the possible implications of this, they held firm to their insistence that they should be known by their first names. In addition, I contacted their parents who all agreed that retaining their first names would be appropriate and acceptable. Therefore, Sam and Zane who feature in this study, are the only children identified by their birth names.

6.7 Dyads' prior experiences with working in pairs

Pair or dyad work was incorporated by each of the children's regular classroom teachers in a variety of ways. The most common form was for "buddy" reading (sharing stories and reading to each other) and for peer editing of written work. There were also reports from the teachers of pairs of children writing stories together, spelling testing, dancing, mathematics problem solving and free play. Choosing a partner was usually left to the children's initiative, although occasionally the teachers paired the children for peer tutoring purposes (asymmetrical dyads) or problem solving purposes (symmetrical dyads).

Only one dyad from one class (the two boys) had been explicitly instructed by their classroom teacher as to how to work in pairs. This instruction included reminding the children that neither is the "boss", to give eye contact to the other child, to listen, to agree to disagree at times, and decide upon who would report back. The classroom teacher concerned reported that these skills took considerable practice and that the children seemed to resist pair work initially. Interestingly, it was the same two boys who did not automatically work together in this study. Their reluctance to work

together could well be the reason why their teacher focused on collaborative skills in their classroom in the first place.

Although it is not the intent of this study to investigate ways in which children can be assisted to work collaboratively (and an extensive body of literature does exist on this), it is worth noting that children are often expected to work together without having the necessary skills and guidance in doing so. When the children were asked about pair work they did not report the variety mentioned by their teachers. Instead, the children listed spelling, reading and "buzz" groups for sharing news as ways in which they had worked with a partner.

6.8 Concrete materials and equipment

The children were invited to use any concrete materials or equipment amongst a range that were made readily available. These included calculators, counters, plastic money, plastic animals, sticks, bottle-tops, atlases, and whiteboard with pens. Paper was provided and they had their own pencils and rulers. Nicky and Amit regularly used a calculator, especially when they wanted to double-check their working. They also used a ruler for the closed problem, *Doctor and the pills.* Calculators were sought by one other dyad when working on the closed problem, *Going to the fair* which involved money. Other than these instances, however, the children preferred to record computations or drawings or tally marks on paper in an incidental fashion as the need arose. This recording as they went appeared to be a guide to their emerging thinking and problem processing. Sharing one piece of paper between them seemed to encourage collaboration, even if at first there was evidence of pulling at the piece of paper to assert ownership. What was recorded on paper was often used as "evidence" when one child explained or clarified something to his or her partner.

6.9 Data collection

Some recent research methodologies have attempted to illuminate talk as data by video-recording a group of children during a lesson and using the video-recording in stimulated recall interviews with children afterwards (e.g., Clarke & Helme, 1997). By utilising this technique alongside audio-taping and recording of field notes, the researchers claimed that they have a more thorough understanding of what the children meant when they uttered certain words and phrases. The stimulated recall interview also provided the opportunity to clarify and probe areas which required further examination. A variety of data gathering techniques such as these enable researchers to scrutinise children's talk in context and revisit areas to investigate children's thoughts, actions and motivations.

The method of my study employed this range of data collection techniques (audio-recording, video-recording, field notes and interviews) but did not use the video-recordings to stimulate recall in the interviews. Clarke and Helme used advanced video software and two compact video-recorders attached to a laptop computer with a split-screen for viewing two events simultaneously. Unfortunately, such technology was beyond the limits and cost of my study.

Video and audio-recording were introduced early on in the withdrawal programme in an attempt to get children accustomed to the technology. The technology was not used every time and was sometimes left set up in the room and not switched on. The children were invited to look through the lens of the camera, turn it on and off, and play back any video or audio-tapes they wished to. Alongside the audio and video-recording, I observed and took field notes as discreetly as possible. The interviews which took place immediately after each session were also recorded and transcribed. Data were only retained about the eight dyads who were part of the study.

The withdrawal programme operated for four months and extra sessions with the chosen dyads (one pair at a time) were undertaken for the study after three months. These sessions usually lasted an hour each time and included three problems for each dyad to investigate. The problems were the same ones used in the pilot study. The dyads worked on over 30 problems in total. Their interaction and discussion (with each other and with me) was audio and video-recorded. I listened to and viewed all the tapes which amounted to some 40 hours of both types of recording (80 hours in total). Grounded theory methodology suggests that it is not necessary to transcribe all recordings but most of the recordings were transcribed in full. It was important to transcribe children's work and discussion on a range of different problem types.

Data from eight dyads or 16 children (four pairs in each of the pilot and the main study) have been used in analysis. The methods for coding and analysing data using grounded theory are outlined in the next chapter.

6.10 Limitations and reflections

The limitations of the withdrawal programme include a number of factors. Even though the withdrawal programme was organised on the request of the school, it required that children were absent from their regular class programme for an hour each week which may have created some discontinuity. Meetings were held with the children's classroom teachers in order to ascertain their programmes and attempt to develop activities that complemented what was occurring in each classroom. With four different classrooms this was not always practical. The interests of the children in the withdrawal programme also determined different directions from what their classes

may be investigating. The problems used during the study were different again, which was necessary to study how the children made sense of them without prior practice.

Another limitation is the shift in roles from being a teacher in the withdrawal programme, to being a researcher in the dyad study. The most pressing concern would be that the children might be influenced by their perceptions of a teacher as someone who monitors, checks and judges their learning. This focus on the teacher's evaluative role was the most concerning as the children may have expected some teacher-like judgement of their ideas and strategies which in turn, may have restricted their compulsion to do or say what they really thought. Even non-verbal cues an adult gives can influence how a child reacts and how they decide to respond. It was hoped that these limitations would be alleviated somewhat by the pedagogy in the withdrawal programme which was process oriented and encouraged the children to self and peer evaluate.

Furthermore, the actual dyad problem solving centred primarily on the children's interaction with each other. Interaction with the researcher was focused upon the children's thoughts and impressions rather than on their "answers" to the problems. My intention was to be an interested and curious observer (who asks questions for clarification) and occasional conversation partner, rather than an interrogator, teacher or detached non-participant observer. The children's actual perception of my role may not have resembled this ideal view as the blurred line between empathy and neutrality may be compromised somewhat, when the researcher is engaged in dual roles, albeit at different times.

There are benefits though, in establishing a relaxed and familiar rapport with the children who are accustomed to, and familiar with, the researcher. This rapport may balance the drawbacks. As discovered in the pilot study, it seemed more curious to the children that I was just an interested observer who happened to ask some questions. Barnes and Todd (1977) also commented on the advantages of the researcher knowing the children well and the children being comfortable in his or her presence. They found that the children who knew the researchers well and had developed a comfortable rapport, had more success in making sense of the problems than other groups they studied. It could also be argued that such a rapport enables the researcher to study the children's "regular" behaviour and interactions.

According to Pramling (1995), the dual roles of teacher-researcher are not as problematic as previously thought. She argued that interview methodology is strengthened when challenging questions are asked, whether their use is intended for pedagogical or phenomenographic research purposes. Furthermore she urged that, "as an educator one should learn new ways of meeting the child in dialogue and inspiring him or her to share his or her thinking with you" (1995, p. 137). It is this "meeting of the child in dialogue" which has benefits for both the educator and the researcher and

the goals of both can overlap when the emphasis is upon investigating children's thinking. Mercer (1995) explained that researchers who observe and analyse talk are also involved in their research as a language user and participant. He stated that

> The researcher's aim is to understand what the active participants understand, and to use the same means that they use - language - to do so. And in doing so, the researcher ceases to be a mere passive observer, not only because they become part of the context of the process they are observing, but because to make their analysis they inevitably have to engage in talk with the people they are observing. (p. 122)

Mercer argued that research on language and thinking inevitably requires methods which blur the distinctions between researchers and practitioners. In addition, he posited that such a blending of roles does not lose "objectivity" but rather it contributes to the transformation of more traditional research processes.

As a result of the children's responses and initiations during dialogue, it seemed unnecessarily restrictive to adhere to the interview questions employed in the pilot study. The relationship developed with the children in the main study enabled a more natural and less prescribed discourse. Furthermore, as concepts and categories emerged during early analysis it became important to pursue some areas in more depth and delete other questions which provided few, if any, insights. The aim of this study was to explore children's talk as it occurred and to record their voices, giving "priority to the meanings which children construct" (Smith, 1995, p. 4). In order to do this I needed to develop dialogues which were sensitive to the children's point of view and to also know when to withdraw and stop interfering when attempting to understand their meanings.

Collecting data with an audio-recorder and a video-recorder invariably invites the risk of making the children feel self-conscious and can affect both the quantity and quality of talk that takes place despite how subtly it is introduced. Similarly, the mere presence of an adult may influence the type of talk children use with the likelihood of more task-related verbalisations occurring when an adult is present (Brody, Stoneman & Wheatley, 1984). Nevertheless, most of the problems appeared to encourage the children to converse readily with each other. In addition, I would sometimes wander around the room and attend to something else out of a dyad's view so that the pair did not feel constantly scrutinised.

Some have argued that the presence of recording devices encourages children to stay on-task and verbalise clearly (Barnes & Todd, 1977; Prisk, 1987). The recorders may have had some effect in this regard, but transcribing the children's talk was a considerable challenge at times as their speech was not directed to the tapes and they often talked over each other as is common in natural discourse. After an initial period

of fascination with the technology, all the children quickly appeared to become indifferent to the taping and seemed unselfconscious about being recorded. Data were collected after an initial period of distraction, once the children appeared to be accustomed and oblivious to the technology. A key advantage of taping the children's discourse and interaction was that the recordings could be returned to as often as required, to examine details.

The word "video" was originally a Latin verb meaning "vision". The translation of this verb means more than the ability to see but encompasses insight and knowledge. Video-recordings can provide more than just an opportunity to see what happened. They can also help the observer to develop insight and understanding about what occurred.

As mentioned previously under section 6.7, only one dyad had received any explicit instruction on how to work together collaboratively. It can be problematic therefore to assume beneficial influences of the problem types upon the children's ability or experience in collaboration, or even to expect the children to work together. That they did so in most cases raises questions that cannot be clearly attributed to past experiences or instruction. It is a tribute to the children's tolerance and flexibility that they did participate with each other and the problems at hand as requested. This issue reminds me of how dependent such research is upon the goodwill and cooperation of the children involved. It is also a considerable imposition to ask children to work in pairs when they may not be comfortable in doing so. As the study progressed, four boys (two in the pilot and two in the main study) expressed some reservations about working with a partner, indicating that they generally preferred to work alone. Two of these boys were particularly able. This was interesting given that their teachers had suggested that they worked well together. I could understand how their teachers came to this conclusion as the four boys often worked together when requested to do so. The other children did not indicate a preference for working alone at any stage and showed no reluctance towards working with a partner. This was not a guarantee, however, that they were enthusiastic or interested in working collaboratively. I kept asking myself, to what extent was I threatening or encroaching upon the children's sense of self and independence when asking them to work together? While the affective reactions to pair work of this nature constitutes another study beyond the scope of this one, it bears consideration when questioning the intent of the methodology.

Whilst the culture of the class in the withdrawal situation was developed in such a way as to encourage debate and different points of view, the children may still have felt constrained about expressing what they really thought. When given problems to solve children may concentrate on getting the task completed rather than renegotiate, speculate and explore. This can result in a cpd accepting the first possible solution

they happen upon rather than exploring alternatives (Galton & Williamson, 1992; Stacey, 1992). There is also some evidence to suggest that children may avoid disagreements and debate in order to maintain group harmony, even at the expense of the task at hand (Prisk, 1987). Furthermore, some children (particularly girls) show a higher level of tolerance for disagreements than others (Pryor, 1993). Collecting data on children's collaboration needs to consider the possible impact of each of these factors.

7. Conclusion

The shifts in methodology outlined in this chapter came about as a result of the pilot phase which highlighted areas that required adaptation and reconsidering. As expected in grounded theory, factors emerged from the pilot trial and early analysis which needed to be investigated further or omitted. One of the factors was a persistent sense that I was blocking social discourse in the pilot phase, rather than providing the context for exploring it. The main study lacks the immersion in classroom life and the recording of private talk that Alton-Lee and Nuthall (1992, 1993) have captured in their studies. The research questions, however, required a somewhat more structured approach to investigate the affect of certain problem types and the children's influence on each other when investigating these problems. The children's familiarity with the researcher, with each other, and with conversations about their thinking and strategies, has assisted with capturing a glimpse of the children's meaning-making as it occurs and the ways in which they grapple with ideas on the edge of their understanding. Such a focus seems to be timely when considering the potential of cpds and the types of learning processes that may occur in these dyads.

The following chapter continues with a description and discussion of the methods but focuses on building the theoretical framework of this study including coding, categorising and analysis.

Chapter Four

Developing the Theoretical Analysis

1. Introduction

The previous chapter outlined the use of grounded theory as methodology, highlighting the key aspects of this research approach which influenced the way the study was planned and implemented. This chapter outlines how the theoretical base of the study has been constructed. It includes the processes of coding data, forming and refining sub-categories, abstracting general categories and heightening theoretical sensitivity. Methods of comparison and analytical coding are described, with examples from the data, to illustrate some of the processes involved in developing theoretical concepts.

While grounded theory methods have been used, this study does not purport to be a complete grounded theory. Grounded theory approaches have been used to code, categorise and analyse, but this study does not build a grounded *theory* based on a model regarding children's collaboration and problem solving. Conceptual analysis is based upon the formation of categories and the emergence of patterns and themes. The focus is predominantly on the way the categories emerged.

The following sections outline how the analysis was developed and the issues that arose during its construction. Acknowledgment is made of other theories which have relevance for this study. While grounded theory does not rely upon pre-existing concepts and theories, it does take cognisance of those ideas which overlap with the findings of a study. As discussed in the previous chapter, there are occasions when the existing literature aids in analysis, and such incidents are noted.

2. Using Grounded Theory

> The hallmark of grounded theory studies consists of the researcher deriving his or her analytic categories directly from the data, not from preconceived concepts or hypotheses. Thus, grounded theory methods force the researcher to attend closely to what happens in the empirical world he or she studies. (Charmaz, 1995, p. 32)

While this study does not claim to adhere totally to the entire structure of a grounded theory (as described in the previous chapter), there are important aspects of this approach which have been utilised. One of these is deriving the analysis of data from the bottom up. The initial coding forms the basis of the subsequent categorisation and abstraction. The coding of data in grounded theory relies upon a close attention to the

empirical world. Grounded theory is an inductive approach to analysing data and building theory. The techniques and procedures of this approach aim to assist researchers with making sense of a wealth of data, reducing bias in their analysis, and building theory which is conceptually dense and concise.

This study is concerned with children's construction of meaning when collaborating on and investigating a range of problems. The previous research in this area is often influenced by the theories of Piaget and Vygotsky, and more recently, by developments in social constructivism and sociocultural theory. Grounded theory assists researchers with clarifying or challenging existing theories. It encourages researchers to think beyond the boundaries of their professional experiences and reading. In doing so, grounded theory can provide a vehicle for resisting set ways of considering phenomena (Glaser, 1992).

The initial research questions provide some direction but should not obscure themes which emerge from the data. The coding is not based upon preconceived classifications (discussed in the literature review) but is derived from the data collected in the trial phase. This does not preclude, however, the inevitable influence of past experiences and the field of related literature. In order to derive coding and categories, a researcher needs to have some knowledge of the field being investigated. This knowledge helps to shape the way in which the data are organised and understood. Moreover, data collection, analysis, and review of the literature, proceeds in a cyclic and iterative process (as discussed in the previous chapter). Researchers bring a framework from their past experiences to any study, albeit an open and flexible one. Grounded theory methods assist with keeping this framework responsive and malleable in the light of emergent data.

Therefore, the theoretical base of this study is grounded in the data but also acknowledges the influence of existing literature and theories. No research is atheoretical and grounded theory does not comprise a complete antidote to subjectivity or an abandonment of theoretical constructs. As Edwards and Westgate (1994) pointed out

> There is a view of reality implicit in each research perspective, no research is atheoretical, in the sense of being committed to 'simply' following the 'facts' wherever they lead without preconceptions about the kinds of facts relevant to the enquiry and how they are to be collected and analysed. (p. 57)

The research questions influenced the subsequent categorisation of the coding but did not determine exactly what was focused upon and how it was labelled. Furthermore, analysis was undertaken as the data collection proceeded so that one (the research questions) affected the other (the analysis) and valuable iteration occurred enabling new propositions to emerge. This was both an inductive and deductive

process as propositions were made which could be verified (or otherwise) by the data. This concurrent immersion in both data collection and analysis enables researchers to keep the data focused around the themes and questions that emerge.

3. Coding the Data

Initially the data were scrutinised line-by-line, using open coding, unravelling the apparent intentions of the children in an attempt to proceed systematically through the entire data. As Charmaz (1995) stated, this approach is useful because, "Through line-by-line coding, you begin to build your analysis, from the ground up without taking off on theoretical flights of fancy" (p. 37). This process aids in the uncovering of any possible leads, surprises, or propositions, as is appropriate in qualitative research (Patton, 1990; Spiggle, 1994). The form and function of language was considered in coding the data in the early stages. The form of language, however, was considered much less relevant than the function of language in the transcripts. Language forms differ from language functions in that what appears in a certain form (such as a question) can have a number of functions (Edwards & Westgate, 1994). The following extracts provide examples of this distinction:

Text:	"That's four days ay?"
Form:	Question
Function:	Seeking verification

Text:	"So you think we walk four hours in a week?"
Form:	Question
Function:	Clarifying partner's idea/Challenging

The language forms did not reveal what actually occurred in the children's collaboration, but rather, yielded a series of discrete codes related to each individual. What actually occurred during interaction was still obscured. No attempt was made to generate categories from the language forms as they did not reveal much, if anything, about the way in which meaning was constructed or negotiated between the children. Analysis of the frequency of certain language forms used by each child across cases would be limited in its interpretation of the children's construction of meaning and interaction. A focus on each separate speech form reduces the actual interchanges between children to units which appear to bear little relation to each other.

In order to go beyond what was said to encompass the context of why, where, how and to whom talk was directed, a subsequent focus on language functions and interaction was necessary. This takes some account of the "prospective and

retrospective elements of action" (Walker & Adelman, 1986, p. 6). Observation of the surface features of their language forms revealed little of the social context and the dynamic nature of their interaction between each other and the problem at hand.

In order to capture the function of the children's discourse, the coding of data changed to a focus on the *act* (the smallest unit of analysis in discourse analysis), rather than the line of transcript. This assisted with staying analytical (rather than descriptive) and distinguishing phenomena. After a number of open coding trials, the data were coded act-by-act in order to retain the context and purpose of the children's discourse. It also assisted in highlighting the major idea or intent of a child's statement. There were instances where more than one act occurred in a turn which was important to note (see section 4.4 for an example). This act-by-act coding was derived from the children's talk during problem solving and also from observations and the interview data. The coding which emerged, therefore, was not just the result of interpreting the transcript but came from a range of sources relevant to the interaction itself.

Attention to speech alone does not capture enough of the meaning implicit in any interaction. Cognisance of intonation, context and body language is also required (see also Kieran, 1996). Even then, it is difficult to claim with certainty that what was recorded is an accurate picture of what occurred, and what was meant, by the participants. A focus on the words that the children used, however, alongside their actions, provides insights and comprises much of the raw data. Recordings of speech from video-recordings and audio-recordings provided the basis of subsequent categorisation and analysis. The words reveal some of the intentions of the children and some indication of the way in which they made sense of each problem. As Maykut and Morehouse (1994) argued

> Words are the way that most come to understand their situation. We create our world with words. We explain ourselves with words. We defend and hide ourselves with words. The task of the qualitative researcher is to find patterns within those words (and actions) and to present those patterns for others to inspect while at the same time staying as close to the construction of the world as the participants originally experienced it. (p. 18)

This poses the challenge of understanding what the children really meant even when they seemed to make their thoughts explicit through speech. What they say is not necessarily direct knowledge of the way they construct their world. Furthermore, the translation of their words through coding and forming categories is "coloured by the inner experiences and feeling of the inquirer" (Maykut & Morehouse, 1994, p. 28). As mentioned in the literature review, however, talk is not regarded here as some direct window on the mind but as the way in which children may socially convey their thoughts and ideas. As this study is concerned with social interaction, it is logical that

the coding is built upon the words the children used in each other's presence. Employing open coding ensures that researchers regard the familiar as new, as they are obliged to attend to each line or act of a transcript rather than take what is recorded for granted.

3.1 Systematic classroom observation schedules

Categories for coding the interaction of children and teachers are relatively common. Early attempts to design coding systems were focused upon the importance of the researcher having a set procedure or criteria for making sense of the wealth of interaction occurring in classrooms and early childhood centres (see earlier discussion in the literature review). By using prescribed coding schedules it was claimed that a researcher could avoid wasting time and would have a more precise and rigorous focus. Such an approach was deemed to be objective, rational and lacking in bias as it clearly delineated what to look for and maintained a detached outsider's view (Edwards & Westgate, 1994). Critics emphasise, however, that such an approach which uses prescribed coding systems and categories at the outset, can actually decrease objectivity by predetermining what to look for and focusing only on what is expected, rather than being sensitive to, and aware of, what the participants themselves do and say.

Systematic classroom observation schedules do assist with making sense of a plethora of data and provide some structure and order. As is appropriate with a qualitative, grounded theory approach, the schedule which was developed was not imported from other studies but arose from the data itself. Elements of children's talk did not always fit into prescribed categories and attempts to code them thus can obscure the apparent meaning and interaction. Furthermore, as alluded to above, it is questionable whether data obtained by coding classroom talk alone provides direct evidence of what happens and what is meant by participants. The coding schedule which has emerged is based upon phenomena that occurred again and again in the data, until such categories appeared to be well established. This was based upon the children's talk but also upon their interaction with each other, body language and discussions with me.

The coding schedule devised in this study was not an attempt to "force a fit" but, rather, it derived from the actual data collected. It could be argued that the subsequent coding using the sub-categories, is somewhat constraining. The coding, however, has the advantage of creating order, detecting patterns and uncovering the unexpected. As Charmaz (1995) suggested, codes and sub-categories were made as specific as possible, using active terminology. Incidents in the data were compared until patterns

emerged. This *constant comparative* method enables the grouping of similar incidents under a conceptual name or code.

Comparing many incidents in the data in order to generate codes is a major feature of the grounded theory approach, according to Glaser (1992). He warned that researchers should avoid just labelling an act. Instead, he advised that constant comparative coding avoids the forcing of data and allows codes and categories to emerge. He criticised Strauss and Corbin for forcing their codes and categories by interrogating their data with questions based upon their own professional interests and backgrounds. Glaser insisted that researchers go from incident to incident in the data until patterns emerge unaided. He stated that this will enable the codes to be relevant and appropriate.

Bearing the above points in mind, it was decided to code the children's talk as a combination of problem solving and social exchange discourse, rather than to try to separate these two functions. Separating social from cognitive acts seems unhelpful as speech cannot be neatly divided in this way and attempts to do so run the risk of fragmenting and blurring meaning (Barnes & Todd, 1977; Prisk, 1987). Prisk argued that "conversation is fluid and one speech act could often be described as fulfilling both functions" (1987, p. 92). While there may be instances where speech could be categorised as purely social or cognitive, there are frequent instances of overlap and linking between both the social and the cognitive within the same speech acts. Combining social and cognitive language aids in contextualising the speech and retaining its complexity.

3.2 Forming and refining sub-categories

With grounded theory, the theoretical analysis emerges from the bottom upwards. That is, codes and sub-categories are formed before broader conceptual categories. Moreover, categories are generated from the earlier sub-categories (which is discussed in section 4 to follow). The sub-categories were tested in the earlier pilot phase and found to have 78.8% reliability with an untrained rater. It was predicted that reliability would be further strengthened if raters were trained. Validity of the codes was tested in discussion with two professional colleagues with extensive experience in coding data. Consultation with these colleagues resulted in numerous rewordings, selection of relevant examples, recourse to dictionaries and thesaurus, clarifications, changes and amendments. Subsequent transcribing and coding was undertaken using the labels derived from this process. This helped to clarify the sub-categories which were derived from the data.

The process of forming the sub-categories is also relevant in refinement of the sub-categories. The sub-categories were refined by identifying the essential elements of

commonality amongst the various data. Writing rules for inclusion as a propositional statement assisted in deciding upon what should be included in a certain sub-category. These propositional statements convey the essence or meaning of a certain sub-category and the rules for including a certain piece of data in a sub-category is part of the process of understanding the phenomenon being studied.

The 15 original sub-categories were further refined and subjected to the same procedure outlined above, to check for both validity and reliability. From this procedure emerged the following list of 11 sub-categories which formed the basis of the coding. Some sub-categories were formed by combining two concept labels which were complementary and in which there was a considerable degree of overlap. For example, "counter" and "correct" were initially recorded separately but the incidence and context of these phenomena resulted in a decision to form a sub-category consisting of both. The following list outlines the sub-categories and their rules for inclusion:

Accede (A): To agree to or uncritically acquiesce, with the effect of endorsing what has preceded. This is usually represented as a short statement implying agreement.
For example, Sam suggests that they have six bicycles and three tricycles. Zane replies, *"Yeah."*
For example, Sam says that after taking out two tricycles there are 12 wheels left. Zane replies, *"I know."*

Correct or Counter (CC): To point out an inaccuracy or difference in interpretation
For example, Sam says, "I moved down here when I was two." Zane replies, *"You mean UP here."*
For example, Sam is looking for Napier on the map and Zane says, *"You're looking in entirely the wrong place."*
Or, to propose a different idea/approach in direct contrast to one already given in discussion.
For example, Zane says, "It'd probably be the same as Hamilton." Sam replies, *"No, it's less-less population."*
For example, Sam questions Zane's estimate of Hamilton's population which he thinks is too high,

	"But look, this is actually bigger than this" (comparing Wellington to Hamilton).
Deduce (Ded)	To use the information given to come to a conclusion. This is not necessarily at the end of a process or discussion but can also occur during interaction. The conclusion made is not necessarily final but is formed as a result of some prior information or realisation. For example, Sam suggests that the population of Thames is about 10,000 according to the key they are using. Zane uses that population figure to confirm what the number of vets there might be, *"So that means about two."* For example, while watching Zane work out a problem, Sam offers, *"You know it's going to be 35 again 'cause the letters are the same."*
Dialogue Filler (DF):	Comments that appear to offer nothing or little to the conversation other than to fill space and maintain the discussion or momentum. For example, *"Well..."* For example, *"Hmmm...that'd be..."*
Direct (Dr):	To tell oneself or another what to do, or to give orders related to managing a way to proceed. For example, Zane tells Sam, *"Go on to the South Island."* For example, Sam tells Zane to, *"Change that to three, make it three."*
Hypothesise (H):	To suggest an explanation for a group of facts or offer a solution to a problem, accepted either as a basis for further verification or as likely to be true. Also, to speculate, suggest, surmise, theorise or moot. For example, at the beginning of a problem Zane starts with, *"They'd be nine bicycles if it was just bicycles."* For example, *"If there's eight heads there's got to be eight spiders."* For example, *"So, we could do a three there or a one."*

Inform or Verify (IV):	To make a statement that is intended to convey facts or knowledge. This is sometimes a direct response to a question asking for information. For example, Sam asks, "Is Abel Tasman a city?" and Zane replies, *"That's a bay."* At other times it is the giving of unsolicited information. For example, when discussing Wellington with Sam, Zane offers, *"That's a major city."* And sometimes it emerges as if thinking aloud. For example, *"Three million and something. There's three point two million people in New Zealand."* For example, Megan says quietly to herself, *"I'll just do the circles first"*
Non-verification (NV):	To state that one is unsure or does not know, rather than assert that something is incorrect or impossible. For example, Zane asks Sam if Napier is a city. Sam responds, *"I don't know. I hardly know any cities in New Zealand."*
Praise or encouragement (PE):	To affirm an idea or action with a statement that conveys a positive judgement. For example, *"Good one!"* For example, *"That's it - go on."*
Seek information or verification (SIV):	To ask for confirmation of an idea or proposal or request an answer. For example, Zane asks, *"Christchurch is a bit bigger than Hamilton isn't it?"* For example, Sam asks, *"How many legs has a beetle?"*
Self-correct (SC):	To realise one's error and redress it by suggesting an alternative. For example, Sam says, *"And Wellington is the SAME as Hamilton!?* (Then he realises they are using the

wrong key for the map and gives Wellington more vets than Hamilton), *So Wellington would be six."*
For example, earlier in the discussion Zane suggested that Canterbury was a city. Later on, when Sam suggests Canterbury, Zane seems to realise his error and says, *"We'll do Dunedin. I don't think there is a Canterbury actually. Isn't it a district?"*

3.3 Forming sub-categories: Similarities with other coding schedules

The sub-categories have been inductively devised from the acts in the data. There are, however, a number of similarities with other coding schedules. Phillips (1985) labelled the talk between children as operational (such as a commentary of what was taking place), argumentative (direct statements of disagreement), hypothetical ("what if" statements) and experiential (relating to personal experience). Phillips's term "argumentative" has a similarity to the "correct/counter" sub-category derived from the data in this study. In addition, the term "hypothetical" appears to have a common meaning with "hypothesise" used in this study.

Also bearing some similarity with this study is Barnes and Todd's (1977) identification of "negates" and "puts alternative view" which parallels the counter/correct sub-category. They also identified "reflexivity" which includes a range of language functions related to metacognition. As such, the code "self-correct" derived from the data would typify what Barnes and Todd would determine as a reflective statement. Furthermore, they also identified "setting up hypotheses" under the heading of "cognitive strategies", which is akin to "hypothesise" in this study. The code counter/correct has some commonality with Mercer's (1995) "disputational" category, although his emphasis is clearly upon discourse which is counterproductive to collaboration, or at best, does not contribute significantly to any joint progress with the task at hand.

It could be construed that the classification of language as hypothesise in this study is a prediction strategy, according to Tough (1976), and as such represents more complex language use. The coding developed in this study has been collapsed into more general categories which provide the basis for analysis of the data. These categories will be discussed in more detail under section 4 to follow.

As is evidenced above, there are a number of similarities with other coding schedules and categories from a range of studies. As the coding system generated in this study is grounded in the data obtained, it is representative of the specific context studied, but its relevance for and applicability to other settings is likely to require adjustment and modification.

3.4 Issues in refining the sub-categories

Three of the issues that emerged from refining the sub-categories are discussed below. The first is the decision to combine the individual and social acts in the data. The second is the limitations and strengths of the process of identifying properties and their dimensions. The third is the influence of the researcher on the formation of the sub-categories.

3.5 Individual or social?

It could be readily argued that two sets of concept labels could have been derived for coding, one set based upon speech directed at oneself, and one set classified as intended for another person (in this case, the dyad partner). Such a form of coding, however, separates individual acts from social acts in a fashion which makes an unhelpful distinction. This study acknowledges the ways in which meaning can be jointly constructed between people and their interaction with their environment. Making discrete categories of individual and social utterances can fragment the way in which social dialogue is constructed and obscure the way in which seemingly private utterances can influence another person present. Furthermore, studies on problem solving have found that the presence of a peer can effect what individuals do and say, even when they do not interact with a peer (e.g., Joiner, Messer, Light & Littleton, 1995).

Contemporary studies in collaborative problem solving have moved away from experimental designs focused on learning outcomes to more in-depth studies of children's dialogue when collaborating (Hoyles & Forman, 1995). Most of these studies have built their analyses on the coding of speech acts and interaction. Crook (1995) warned, however, that coding speech can resort to the "static tabulations of its constituent utterances" (p. 544) which contributes little to the study of collaborative dialogue in process. Furthermore, the separation of social and cognitive acts for coding purposes can excessively dilute data (Barnes & Todd, 1977; Graves, 1996). The sub-categories of this study are intended to avoid such fragmentation. They are uttered by individuals interacting with, or in the presence of, a peer. They represent both "talk within" and "talk between". While some utterances may be considered more interactive and some more personal, the purpose of this study is not to usually separate these. In general, the sub-categories have been constructed from the social context in which the talk was generated. Each label makes sense in terms of the context in which it occurred as an attempt to study the development of collaboration.

3.6 Properties and dimensions

According to Strauss and Corbin (1990), properties make up a category and these can be dimensionalised along a continuum. This process forms the basis for making relationships between categories and sub-categories. Properties and their dimensional range were explored in generating the sub-categories, which was a useful process in considering the range of plausible and possible responses which fitted within each sub-category. An example of how properties and dimensions relate to a sub-category is shown below:

Sub-category	*Properties*	*Dimensional Range*
Hypothesise	Certainty	definite--------tentative
	Speculation	safe----------ambitious
	Specificity	clear----------vague

This consideration of the nuances and possible range of hypothesise assisted with the classifying of the data into meaningful, rich, sub-categories which incorporate a range of possible forms. This has the benefit of being flexible and inclusive of the many types of statements that may be construed as hypothesise rather than predetermining a narrow and restrictive definition. The limitation in this approach is that properties and their dimensional ranges are somewhat subjective as what seems "tentative" for one person may appear "definite" to another. This can especially be the case in cross-cultural communication, which has been documented in the literature (e.g., Metge & Kinloch, 1987). The process of identifying properties, however, and considering their dimensional range, enhances theoretical sensitivity and the comprehensive nature of the sub-categories.

3.7 The influence of the researcher

> What you define in the data also relies in part upon the perspectives that you bring to it. Rather than seeing your perspectives as truth, try to see them as representing one view among many. (Charmaz, 1995, p. 38)

The initial coding and subsequent refinement of categories is inevitably influenced by the researcher's interests. Charmaz argued that in the early work of Glaser and Strauss (1967) they suggest that categories will "leap out" at the researcher. Charmaz disputed this, countering that the relationship between the researcher and the participants is reflected in the categories. Furthermore, background reading, research

interests, and professional knowledge, will influence what the researcher attends to and how he or she might refine categories. As mentioned earlier, while the researcher avoids relying upon established theories and research, he or she uses these to sensitise the data. This is especially so when refining categories. The processes of refinement such as exploring properties and dimensions, enables the researcher to remain critical of the data. My background in teaching children and my professional reading about educational issues inevitably influenced the ways in which I interpreted events.

4. Abstraction

The 11 labels that emerged from coding the data were collapsed into more conceptual groupings which incorporated the sub-categories into fewer, more general constructs. These broader constructs encompass a collection of sub-categories which appeared to share coherent common features and provide a more analytical description of the data. The formation of these broader categories resulted from an iterative process which was used to generate codes. Using the constant comparative method, I kept returning to the data to compare occurrences of the same sub-category in different situations and considered the links between the sub-categories and their properties. This process also assisted with the re-examination of propositions in the light of further evidence.

The challenge in forming categories is to make them conceptual but retain consistency with the original data (Charmaz, 1995). These broad groupings are not intended to be "descriptive categories into which all observed speech can be neatly and separately coded" (Mercer, 1995, p. 104). The three types of talk are analytic categories, and as such, provide a summary of different speech acts which appear to have a common purpose. A number of attempts were made to group the sub-categories into sets that held a common feature or key characteristic which connected each concept. Further groupings were constructed with the various sub-categories until the following categories were formed. The broad categories listed here (see Table 2) are comprised of the sub-categories discussed earlier.

Table 2

The relationship of the sub-categories to the three categories

SENSE-BUILDING (SB)	• Seek information/verification • Inform/verify • Deduce • Hypothesise
CONTROLLING (C)	• Counter or Correct • Self-correct • Direct
COMPLYING (CY)	• Accede • Non-verify • Dialogue fill • Praise/encouragement

The categories are mutually exclusive in that the sub-categories relate to one specific category and not to the others. While each category is distinct, any one episode from the transcripts frequently had elements from all three (see Appendix D for coding examples which show how sub-categories relate to categories). As such, the various categories were often complementary but with sense-building emerging as the most common pattern across many episodes.

4.1 Sense-building

This category includes *seek information or verification, inform, deduce, hypothesise* and *verify*. All of these activities relate to the gaining, giving or generation of information and ideas. These concepts also centre around making sense, or the clarification of ideas. While sense-building was sometimes an individual activity, it was also mutual and collaborative. This category has some similarity with Mercer's (1995) concept of "exploratory talk" which he defined as talk which reflects a constructive engagement with another's ideas. Mercer, however, included *correct* and *counter* comments in his exploratory talk category with a focus on constructive criticism as the category's core element. In contrast, this study has grouped *counter* and *correct* talk under the category of controlling.

It was interesting that the most frequent comments appeared to be those that related to sense-building. This pattern lends some credence to the notion of the social construction of meaning as a significant cpd phenomenon. This supposition is

determined by the way in which the categories were constructed. The very act of selecting text, and the way it is represented as categories and constructs, is a process of selection. How the researcher chooses to write about others has profound implications, not only for coherence but for how participants are understood (Sparkes, 1995).

A number of researchers (e.g., Damon & Phelps, 1989; Forman, 1989; McCarthey & McMahon, 1995) have argued that knowledge in cpds is often bidirectional. This means that knowledge is exchanged between both dyad partners during communication. According to this theory, the transmission of knowledge occurs in both directions in Vygotsky's definition of a ZPD, when there is sufficient equality and mutuality in the dyad. Rather than a distinct exchange or transmission of knowledge, this category of sense-building implies that the children in cpds often construct and augment each other's, and their own thinking, in collaboration. There were frequent instances in the data where the children added to each other's sentences, filled in gaps for each other and often provided a synchronous aspect to the discourse. This appears akin to a notion of piecing together a jigsaw or making stepping stones. This is somewhat distinct from knowledge transmission or exchange.

There were, however, instances of knowledge giving and receiving in both directions on occasion and this is typified by the *inform, verify, seek information/verification* sub-categories. The sub-categories of *deduce* and *hypothesise* were often more speculative statements which were negotiated and tested out as the problem solving proceeded. Such statements were usually followed up by both children if the problem was sufficiently engaging. As such, an initial hypothesis can be pursued by a dyad partner as vigorously as the originator of the speculation. The sense-building that occurred when a dyad collaborated in this manner is more akin to knowledge-building than an exchange of knowledge. Therefore, sense-building emerged as a major category. Even when the children appeared to be working in parallel or "co-acting", rather than collaborating, their talk often provided some commentary on what they were doing (but not necessarily on how they were doing it). Such ongoing monologue may not be coherent to an onlooker but appeared as a child's stream-of-consciousness. The sense they constructed through talk was intrapersonal in this instance. In contrast, the social discourse of collaboration is regarded as interpersonal. Of interest, however, is the way in which intrapersonal and interpersonal talk can be difficult to separate entirely, as what is uttered on a intrapersonal level can affect what is then discussed on the interpersonal level. Examples of this will be given in the following chapter.

4.2 Controlling

This category includes *correct, counter, self-correct and direct.* It was decided to place *direct* here rather than in the sense-building category because although *direct* did sometimes emerge in response to seeking information, it also occurred separately. This was frequent enough to warrant a closer examination and revealed that the action of directing often had the effect of giving a command or of monitoring what was occurring. Countering, correcting and directing relate to management and control. They imply that the one performing these actions was telling the other what to do, or what they needed to know. This was not necessarily in response to a request for information, but could have been an unsolicited command from one child to the other.

The preference in this study is for the term *controlling* which denotes that the main purpose of children's disagreements and giving of directions was to exert some control of the discourse and direction of the problem solving. An a priori approach to abstraction might focus upon those functions which appear to represent notions of conflict and the role this plays in collaborative problem solving. A focus on conflict, however, is not sufficiently dense or inclusive. Countering comments were pivotal in providing a catalyst but cannot be neatly isolated from the subsequent and previous sense-building language which surrounded it. Countering comments, therefore, led to, and often from, explanations, verifications, information seeking, hypotheses and discoveries. These comments also resulted subsequently in some compliance. The use of the category control provides a somewhat wider notion of the children's discourse than a focus on conflict. The literature on sociocognitive conflict is not discounted, however, but rather it provides a point of departure.

As mentioned earlier in the literature review, the notion of conflict is not consistently defined or substantiated in the social psychology literature. Doise and Mugny (1984) took the theoretical position that in terms of cognitive development "social interaction is only constructive if it creates a confrontation between partners' divergent solutions" (p. 77). This notion of confrontation underlines what they claim is at the nub of cognitive growth within a social context. In the Piagetian sense, the child's centration when challenged by an opposing point of view can create disequilibrium and the accommodation of a different concept. The symmetrical relationship of two children of the same age and similar ability can provide a site for different centrations which may conflict with one another. In particular, Piaget believed that such peer interaction may have significance for challenging a child's egocentrism and assist in a child's cognitive development.

The holding of different points of view by partners in a social exchange is regarded by Doise and Mugny (1984) as pivotal to cognitive progress. Furthermore, they claimed that to isolate just what sociocognitive conflict entails, it needs to be

studied in contexts where the children are of similar cognitive ability. Otherwise, they claimed that conflict can lead to imitation by the less able child of the more able and persuasive peer. They acceded that sociocognitive conflict will not necessarily lead to cognitive development or occur naturally. Therefore, they used laboratory experiments with Piagetian tasks (outlined in the literature review), to construct the opportunity for sociocognitive conflict. They also had adults partnered with the children at times, deliberately presenting opposing and contradictory points of view. The experimenters used quite directed questions such as "How can that be?" and "Can you both try to agree?" to encourage the negotiation of shared meaning. As such their studies tended to be highly controlled and technical. This study contrasts with Doise and Mugny in that it seeks to understand how children construct meaning in dyads without direction by an adult. Such an approach aims to discover something of the children's perspectives and thinking. Probing for further meaning and clarification took place during the interviews/conversations, again with the purpose of making explicit the meanings and perspectives of the children.

4.3 Complying

Subsumed under this category is *accede, non-verify, dialogue fill, praise and encourage*. These sub-categories all have the effect of uncritical comment or agreement which does not challenge the content of the discourse. Mercer (1995) termed such talk as "cumulative" in that it is generally positive and uncritical. Such comments can, however, affect the direction of the discourse as the consequence of compliance was usually to continue the current line of inquiry. What is interesting in this category is that compliance was not necessarily submissive but could occur after periods of control and sense-building by the same child. Compliance could result from agreement in the light of a persuasive argument and not just from acquiescence at the outset, to a more dominant partner. As such, it was important to consider the antecedents of compliance, as well as the ongoing affects of compliance discourse. It was also interesting to note the frequency of compliance and whether it was a role that was exchanged during collaboration.

4.4 Acts and turns

As mentioned earlier under section 3, within a single turn of the discourse there could be more than one act and these acts were sometimes categorised differently. The extract below is from Megan (M) and Linda's (L) talk during the problem *Make 23.* During Linda's turn there are two acts which are indicated in italics. In the first act she countered and corrected Megan's previous comment and in the second she

hypothesised. In response, Megan acceded and then informed which also comprises two acts within a turn:

L: Noooo, we got 23 for that, for that side (pointing to first attempt) there and then we ended up with 14 there *counter/correct.* If we put the...(starts to draw another triangle) if we put the 9 there (top corner) *hypothesise.*
M: Yeah *accede* and then...and [the 8 there] *inform/verify.*

The sub-categories of counter and correct contribute to the category of control. The sub-category, hypothesise, is part of the category of sense-building. Thus, in Linda's (and Megan's) turn there is evidence of two categories of discourse.

5. Summary

To summarise so far, the process by which sub-categories are organised into more general categories requires a synthesis of the common element inherent in each cluster of sub-categories. The three major categories which emerged from this process are sense-building, controlling and complying. These categories include all of the smaller sub-categories used to code the data. In forming the broader umbrella categories, the sub-categories become properties of the more general constructs.

Sense-building pertains to the patterns of discourse which related to the providing and seeking of information and ideas. This appears to be qualitatively different from the exchange or transfer of information in a bidirectional manner as mooted by some social constructivists. While the literature pertaining to notions of conflict is acknowledged, this study uses a category named controlling to characterise the data which relates to the role of one child in terms of correcting, giving of commands and disagreeing. This category is somewhat broader than a focus just on disagreement or dispute, as it incorporates times in which the children direct and manage the actions of their partner. Complying pertains to the times in which the children agree with each other, or uncritically accept. These three categories enable the data to be interpreted at a more analytic level.

At times there can be more than one act in a turn of discourse and these acts may be categorised differently. Turns, therefore, do not necessarily "fit" neatly into a sub-category and can encompass more than one sub-category.

6. Heightening Theoretical Sensitivity

The making of comparisons is vital for forming codes and categories. The process of comparison also assists in heightening theoretical sensitivity (Strauss & Corbin, 1990). Similarities and differences can be explored between incidents in the data

which appear to belong to the same category (Glaser & Strauss, 1967; Spiggle, 1994). Strauss and Corbin recommended a variety of techniques to assist the comparison process. Three of these, and their relevance to this study, are outlined below.

6.1 The flip-flop technique

This technique reflects its name in that it requires the inverting of a concept to imagine its opposite. This enables researchers to consider dimensions and properties that otherwise might be overlooked. It also assists researchers with breaking free from the shackles of habit, their experience in the field of study, the technical literature and the powerful theories that others have developed. For example, researchers' positive experiences of group work and knowledge of social constructivism influences their interpretations and perceptions. They may assume too much about what occurs when children collaborate and overlook features that contrast with their beliefs. The purpose of comparison techniques like flip-flop, is to resist the persuasion of bias and preconceptions and regard the data in novel and innovative ways. This approach enables the researcher to continue to generate provisional categories, consider useful questions for interviews, and think analytically rather than just descriptively.

The sub-category "inform" can be opened up to reveal potential properties and dimensions that might apply to it. The flip-flop technique suggests that this sub-category can be compared with an opposite type of cpd activity. Children problem solving in pairs can be compared with, for example, adult rowing pairs. What is significant for rowing pairs? They need coordination to move through the water. This may be important in cpds especially when making progress. Do some problems appear to engender more coordination than others? Is this related in any way to the children's informing of each other? Coordination in rowing occurs through synchronous movement. There may be a relationship between being informed and receiving information that creates some reciprocity and flow. Revisiting the data (e.g., the fuzzy problem, *The Vets*) reveals that inform was just as likely to lead to seeking more information as it was to emerge from seeking information. This to-and-fro motion from seeking, to informing, back to seeking, is somewhat akin to rowing movements.

One might further consider who does most of the informing in rowing pairs? Is it the one at the front? What might he or she inform the partner about: How close the other boats are? How close they are to the markers? How far they have to go? In summary, does the informer monitor the pair's progress? What relevance is there in this for the dyad interaction of, for example, Sam and Zane? Zane did virtually all the informing on the fuzzy problem *The Vets*. Was he monitoring their progress in some way? How important is this role for collaboration and for problem solving?

When one rower is informing the other, how do they communicate above the noise of the water and oars? The front rower can hardly turn around in the middle of a race. Informing each other must rely upon quite subtle forms of communication. What subtle forms of communication are occurring between the words of the action inform in cpds? How does video-recording assist with exploring this?

What sources do rowers use to inform them about their sport? How do they access specialist information? Who do they perceive as knowledge brokers? In cpds, do they perceive each other as valuable sources of knowledge? What signals suggest that they do, or do not? What are the consequences?

These comparisons of children's cpds with rowing pairs generated some new properties for the sub-category inform:

- synchronisation
- coordination
- flow
- monitor
- communication
- knowledge brokerage

This process can be worked through with each sub-category to generate properties and dimensions otherwise hidden from the researcher. A further example follows with the sub-category "counter". Opposition, or countering, while engaged in rowing could well be disastrous as the counter move could upset the flow and impede progress. Countering may lead to collapse of rhythm and strategy, loss of fluidity and synchronous movement, and jerky, haphazard progress. If the countering move, however, is strong and persuasive, a new finer and more efficient rhythm may emerge if the partner decides to join in rather than resist it. Some properties of counter from this comparison exercise are:

- disaster
- collapse
- loss of fluidity
- strength
- persuasiveness
- change in pattern

To extend the rowing analogy, the boat (or problem solving) can continue to move but in a different way, using a different technique.

A technique such as this can be helpful to compare and consider data in new ways. It is important, however, not to sacrifice the data to the apparent flexibility of the technique. Glaser argued that the flip-flop technique is too contrived and forces data in a manner which is unhelpful and distracting. He preferred the quick analysis of a lot of data to the intense analysis of a little data as evidenced in this particular technique. It seems that careful researchers can benefit from both approaches if they are sufficiently open-minded and careful to retain the intent of the data.

6.2 Systematic comparison of two or more phenomena: Close-in comparison.

The literature on creativity indicates that those who are compliant and passive, are unlikely to be creative and that being creative takes courage to stand out against the tide of popular opinion (Gardner,1993; Torrance, 1977). It is tempting, therefore, to regard compliance as irrelevant to innovation. Through close-in comparison, such a concept can be examined in a fresh light. A seemingly passive child can be contrasted with one who appears assertive and full of ideas. Perhaps the "passive" child just seems more compliant because she or he talks less. Is quietness sometimes misinterpreted as compliance? How does command of English affect this? Is compliance necessarily passive? What part does compliance play in breaking norms? Rather than being an uncritical acceptance, compliance often occurred directly after sense-building by both partners, implying some reasoned decision in the light of evidence.

The technique of close-in comparison is aimed (as are the other analytical methods) at keeping the researcher focused on what the data show rather than predetermining interpretation and analysis. If researchers do not over-rely on existing literature and professional experience, Glaser contended that this technique would not be necessary. It seems inevitable that researchers will be influenced to some extent by their own prior knowledge, therefore techniques such as this can assist with the analysis of data.

6.3 Far-out comparison

The contrasting but complementary strategy to close-in comparison, is far-out comparison. This requires taking a remote context as a comparison with the one under study. The way cpds regard and react to difficulty can be explored by way of comparison with yacht crews. How do yacht crews deal with difficulty? First, they endeavour to avoid difficulty by employing state-of-the-art technology so that they have the most streamlined and efficient boat that gives them an advantage. To what extent do cpds believe that technical equipment will overcome their difficulties?

What sustains their perseverance when in difficulty? Yachting crews have unity and an imperative need to work together towards a common goal. Competition is without (against another team), rather than within. Do cpds reveal more unity when the problem is difficult? What happens when they do not? Are they competing against the problem, or each other, or other cpds? Difficulty leads to tension and excitement in yachting, when a sail rips, or a slow tack puts another boat ahead. Emotions are usually heightened in such circumstances. What evidence is there of heightened emotions when cpds work on difficult problems? What do they regard as difficult about a problem? How does this aid their problem solving?

This far-out comparison has the effect of broadening the focus of the phenomenon studied. As a result, Glaser argued that such a technique can be used towards the end of a study, rather than near the beginning. The tendency of this technique to generalise can dilute the focus of a study, creating an analysis which is too broad. It does, however, enable researchers to consider data in new ways.

7. Propositions

The propositions that emerged from the analysis of data were regarded as tentative until they were represented numerous times, achieving theoretical saturation. Examples of early propositions from coding and the making of comparisons across a number of incidents include the following:

- closed problems are least suitable for collaborative problem solving
- meaning is crucial to understanding most problems but especially the closed problems
- collaboration is likely to occur when the dyad has a problem which both challenges and interests the children
- emotions are heightened when cpds are engaged in problems they enjoy
- when working together on problems cpds engage in more interactions with more-than-one-answer and fuzzy problems
- fuzzy problems have the potential for more equitable interactions between partners
- the process of collaboration becomes more constant and synchronous over time
- in cpds each child may learn from the other's ideas and this is seldom a passive acceptance of another child's idea
- hearing a partner discuss his or her ideas can benefit the problem solving process even when those ideas are not agreed to
- a cpd provides a window on another's thinking

- a cpd provides the opportunity for a child to shift their thinking
- reluctance and anxiety can be overcome in cpds

Propositions such as these are hypotheses which are not facts to be verified but, rather, are statements of probability (Glaser, 1992). Grounded theory is not about verifying facts as the propositions that emerge are subject to modification in the light of new data and new contexts. Using these propositions, however, to constantly compare incidents in the data, can strengthen the plausibility of such hypotheses.

These early propositions are returned to in Chapter 6 where adjustments and modifications were made in the light of subsequent analysis.

8. Selective Coding

Selective coding occurs once the core category has emerged from the comparison and analysis of data. According to Glaser, this core category becomes a guide for further analysis and limits the focus, hence the importance of selective coding in the latter half of a study. To selectively code earlier would be premature as there would be insufficient data and limited patterns to determine what the core category might be. The integration of the other categories around the core category emerges as connections arise between each category and their properties. The way is which the categories are integrated is described below.

8.1 Identifying the story

The integration of categories can begin with the writing of the "story" of the study. What is this study about? What are the central problems and issues? What appears to be the essential element? Identifying the story provides a "general descriptive overview" (Strauss & Corbin, 1990, p. 119) of the study.

The main story seems to be about how children collaborate on, and make sense of, a range of problems (in mathematics). The extent of their collaboration appears to improve over time as they become accustomed to each other and accustomed to working together. Their collaboration also depends upon the level of challenge provided by the problem. This collaboration is seldom just an uncritical acceptance of what one child might say and this may be a corollary of symmetrical dyads. When working on a problem which engaged them collaboratively, the children took a range of roles and moved between these. That is, the dyads did not comprise of one child making all the decisions and the other passively following his or her lead. When working through a strategy collaboratively, they often regarded each other as sources of information.

The closed problems in this study, however, encouraged little, if any, collaboration or problem structuring by the children. With the closed problems there was little evidence to suggest that the presence of a partner affected how a child interpreted a problem. There is, however, some evidence of idea and strategy sharing when a dyad worked together with the other types of problems.

Fuzzy problems tended to polarise the dyads, with the more confident children appearing to enjoy them and the less confident children revealing little perseverance or tolerance (more confident children explored what the problem meant and sensed a way to proceed; less confident children sometimes claimed it was not possible to do this). Even within dyads this polarisation could occur. Tolerance seemed to increase somewhat for the less confident partner as a dyad experienced more fuzzy problems. The more-than-one-answer problems encouraged collaboration and were generally preferred by the dyads but they were seldom perceived as having more than one solution. More significant than the "type" of problem for the children's collaboration and problem solving, was the semantic and cognitive demand of the problems. Of greatest significance regarding the enjoyment of the problems was challenge. When the problems were sufficiently challenging the dyads showed more enjoyment and more persistence.

8.2 Core category: Sense-building

Glaser stated that "discovering the core category is automatic" (1992, p. 77) as it emerges from the process of coding and analysing data. The prominence of the core category becomes apparent from the interviews, observations, recordings and transcripts. As the data were analysed, the core category fitted many of the incidents that occurred or it was renamed to more aptly capture the central emergent phenomenon. The core category of sense-building emerged from these key repeating patterns:

- Incidents of "intelligence" gathering and giving (i.e., seek information, seek verification, verify, inform, explain, discover, hypothesise, deduce) were reflected over and over in the data.

- Statements which created correction or countering of a partner's idea were interspersed between sense-building discourse. Successful countering or correction usually required justification/explanation which contributed to sense-building.

The essential message is that in collaboration children can build a shared understanding. The interplay of their ideas and knowledge can create clarification and refinement of problem strategies for both children. The extent of the children's collaboration is determined by the nature of the task, the level of challenge, and the opportunity the children have to collaborate.

8.3 Relating other categories to the core category

In relating the categories to the core category the story is rewritten at a more analytic level. This explication of the story line moves from the previous description of the study, to conceptualising the study. As Glaser pointed out, this analysis of the story is what the researcher is doing right from the beginning as patterns of codes and categories emerge.

8.4 Telling the story analytically

When a problem was sufficiently challenging but not too ambiguous, children in pairs might collaborate with each other to construct a shared sense of a problem and a shared problem solving strategy. This shared sense-building could be constructed through semantic exploration of a problem. The children could provide and seek information from each other. They sought verification from one another and posed new suggestions usually as a result of some difference of opinion, confusion or hypothesis. The context in which this was most likely to happen was when the children had become familiar with each other and had time to become accustomed to collaborating. The children's sharing of materials further encouraged collaboration. The dyad arrangement provided a context in which the children could give information and instructions, clarify ideas, or argue a point of view. Alternatively, one child could comply with their partner by non-verifying or acceding. This did not remain consistent throughout their discourse though. That is, the child who complied was not always compliant. The role of compliance was often exchanged during the problem solving.

The confidence, persistence or determination of one child had a bearing on a dyad's problem solving. Flagging momentum and motivation could be revived when one child's persistence overcame the doubt and frustration of another. The momentum of the problem solving was often increased when ideas were transferred from one child to the other. When they collaborated, the shared sense that the children constructed remained central to the way they pursued the problem. The dyads might discuss connotations of single words (e.g., what is meant by "average") and the meaning of the problem (e.g., Jill saw "both" tricycles "and" bicycles). Being in a

cpd could encourage explanation as a child made explicit his or her reasoning. This was often necessary for the acceptance of a new strategy by the dyad, and resulted in a change of direction for the problem solving. Collaborative progress seemed to occur when there was a convincing change that led to clarification and refinement for both children (not just from the domination of one child's ideas over another's).

Praising or encouraging each other was very rare and did not appear to have a bearing on the collaborative problem solving. Heightened emotions (e.g., joy, excitement, anxiety) were evident when the children had persisted for some time with a problem which was challenging, but not overwhelming.

A difference of opinion was evidenced in statements which counter or correct what a partner had said. On many occasions, these statements were responded to with further countering and correction. Some of the controlling statements were manifest as the giving of directions wherein one child instructed the other to do something. The consequences of countering or correcting were further countering or correcting, or acceptance, or further giving and seeking of information. When the children inform or verify, their statements varied in intensity along a continuum, from asserting a "fact" to proposing a suggestion.

Patterns of control were evident in the children's discourse when they countered, corrected and directed each other. Sense-building statements also typified the discourse of cpds and were exemplified by the acts which inform, verify, seek information, seek verification, hypothesise and deduce. While control statements often provided the catalyst for further controlling talk, such discourse was also present in an alternating fashion between sense-building acts. Such alternating phenomenon built a collaborative, challenging and mutual dialogue. Dyads which had less controlling statements in their discourse also tended to have less sense-building discourse. Controlling statements could contribute to, and complement, the building of sense and collaborative problem solving. Similarly, incidences of reciprocal sense-building were often necessary to build on or implement any outcomes of controlling. Self-correcting could be a consequence of both sense-building and controlling discourse, not just one or the other.

When the problem was at an optimum level of challenge the children were likely to regard each other as knowledge brokers. Having a partner could provide a sounding board as a child worked through his or her ideas. This created a reciprocal relationship at times, with one suggesting, proposing, or seeking information and the other informing, acceding and verifying and so forth. These roles were not static but were shared and exchanged between the children as their collaboration proceeded. Collaboration also provided the opportunity for one child to adopt the other's strategy, and vice versa. This transfer of ideas from one child to another built synchronicity in their collaborative exchange. The child who deduced a solution or path to follow was

not necessarily the one who first hypothesised a strategy. The shared sense that the children constructed could be crucial to the way they pursued a problem. Collaboration was not a constant feature in any cpd during problem solving. The children moved from collaboration to individual work and back again in an iterative fashion.

When a problem was too ambiguous, or perceived to be too easy, the children were unlikely to collaborate or build a shared sense of what the problem meant. In such instances, they were likely instead to work in parallel and share little of their ideas and thoughts in process. When a problem was too easy the children were likely to make brief declarative individual statements rather than engage in controlling or sense-building discourse. Sometimes if a problem was too ambiguous they were likely to talk around the topic in an attempt to make sense of the problem but this discourse seldom led to problem solving.

9. Conclusion

While the theoretical framework developed in this study is grounded in the data and has emerged from open coding and comparative methods, it is acknowledged that another researcher may construct a different analysis. Therefore, this analysis is one version, one construction, one interpretation, based upon the data and the subsequent analysis. Another researcher may persuasively tell a different story with plausibility. As far as possible in this study, actual data and processes used to analyse these data have been described for others to examine. This description and analysis does not claim to be the sole possible interpretation of events, but it does claim to be grounded thoroughly and thoughtfully in the data. The story which emerged is a reflection of this grounding. The explanation of the main categories (including the core category) provides insight to some general results of the study which are discussed in the next chapter. These results show how the categories relate to a range of emergent themes. These themes provide a context for both the discussion of results and the relevance of the categories.

Chapter Five

Results and Discussion

1. Introduction

This chapter reports on the results of the study, expanding on the analysis with extracts from the data. From a careful scrutiny of the children's talk, actions and interactions, coupled with the interview/conversation data, some themes and patterns emerged. Episodes from the transcripts are used to illustrate these themes. The ways in which the three categories of sense-building, controlling and complying pertain to these themes are also discussed. Each section of results is followed by discussion. Lastly, the initial research questions are returned to in the light of these results.

2. Themes and Categories

The results of this study are illustrated in terms of emergent themes rather than the three categories of sense-building, controlling and complying. The themes that emerged from a number of episodes across the data invariably contained sub-categories from all three categories. While the sense-building category is the core category, the other categories were inextricably linked to it in the children's discourse. Therefore, it does not assist with reporting results to illustrate the findings only in terms of categories as this would fragment the discourse and isolate utterances in a rather meaningless fashion. It is more meaningful to present the results in terms of episodes of discourse that provide examples of the flow and interchange of the children's talk including oscillation between categories.

Many episodes, however, had a predominant category which typified the discourse that occurred. A few episodes had a more equal distribution of the three categories within the discourse. Identifying the themes enables the explication of the ways in which the categories relate and also of the ways in which a category can be predominant.

3. The Core Category: Sense-Building

The core category which emerged in the study is what I have termed "sense-building". This category comprises the sub-categories of seek information/verification, inform/verify, deduce, and hypothesise, which are discussed in the previous chapter. The decision to use the term "build" was a result of the ways in which the data conveyed a sense of the children building meaning, as evidenced across many

incidents. This building was frequently a gradual and piecemeal process. It is apparent that the children sometimes built on each other's ideas but it is also apparent that they were focused on building their own understanding or interpretation, that is, this category of sense-building was not always a collaborative event.

Collaboration between both children in a dyad was not consistent throughout their problem solving and the type of problem seemed to contribute to this. There were times, however, when a child did build deliberately upon another child's idea and there is evidence of a child adopting another's strategy. These incidents were marked by an alternating discourse wherein each child contributed to a combined problem solving process.

4. The Structure of the Themes

The themes that emerged during this study are diverse and contrasting. These are as follows:

- persistence, momentum and enjoyment
- drawing upon personal experience
- collaborative, overlapping and self-talk
- reframing problems
- peer feedback: tutoring, explanations and corrections

These themes cover a range of phenomena which reflect patterns that emerged unaided, time and time again in the data. The frequency with which these themes occurred provided the saturation necessary for identifying these patterns. The two themes of "drawing upon personal experience" and "reframing problems" are distinct and have an internal consistency in that the episodes which pertain to each theme are much the same. The other three themes are more diverse in that they contain a range of issues within each set. While these issues or features of the themes could have been separated out, it was felt that this would not capture the interconnected nature of these contrasting phenomena. Persistence, momentum and enjoyment, for example, often occurred together or were interwoven throughout numerous episodes.

Deciding to connect these themes in the results and discussion is an attempt to closely reflect how they emerged in the data. This approach also embeds the themes in the context they arose from, rather than fragmenting and isolating patterns in mechanical ways (see Appendix E for an example). Therefore, this is a "both-and" approach to identifying and discussing the main themes. Two themes are singular and distinct and three themes are multi-faceted and interwoven. These themes are discussed in turn in the following sections.

5. Persistence, Momentum and Enjoyment

An emergent pattern from the discourse of the dyads was the way in which their talk often provided and generated both persistence and momentum. There were a number of instances where one of the children in a pair was ready to abandon the problem and the other child continued to hypothesise, or seek information, or some other sense-building act, with the effect of motivating the reluctant partner to continue. The action of one child in the dyad continuing to pursue a problem tended to motivate the despondent partner to persevere.

In the following episode, Sam (S) and Zane (Z) discussed the fuzzy problem, *How many times a day does the average New Zealander laugh?* On two occasions Zane appeared to want to give up:

Z: Depends on their sense of humour. If you've got a difficult kiwi sense of humour it might be different.
S: I think 100 times right now!
Z: I think up HERE (meaning where they are sitting), 100 times. Oh, impossible, it's impossible to answer.
S: You think up new jokes every day...
Z: I know an easy answer.
S: You don't really know, because you keep making up new jokes every day and you keep forgetting, so the answer keeps changing all the time, ay? ay?
Z: Maybe, once,...I've never gone a day without laughing...
S: At least once.
Z: At least 50 times!
S: There is a right answer 'cause it keeps changing each day.
Z: (reads out question again). AVERAGE- I think it means in the average day.
S: This classroom could be the average New Zealand...

When Zane stated that the problem was impossible to answer, Sam just continued on with it and so Zane did as well. The challenge of the problem appeared to be rather overwhelming to Zane and his comment indicated discouragement. Later in an interview he stated that the problem "put me off a bit". Insecurity can cause children to avoid taking risks and opt instead for "safe" easy ways out to avoid further anxiety. For example, Zane stated, "I know an easy answer", but he did not elaborate further as Sam ignored him and continued talking about jokes. Zane's easy answer may have led to premature closure and lower order thinking if Zane regarded finishing the problem as the main imperative rather than investigating what the problem meant and what solutions were possible. It is interesting to note that further on in this extract, Zane suggested a focus on what average means which was taken up by Sam and subsequently formed the basis of their strategy.

There was some evidence in the study that persistence and enjoyment were strongly linked and this was experienced by dyads even when they did not solve the

problem at hand. For example, Melanie (M) and Hannah (H) did not solve the problem, *Make 23*, and commented afterwards on it (D= Deborah: Researcher):

D: Now the next question about making 23...
M: We didn't get to do (finish) that one because we couldn't get it.
H: Yes and the little numbers always seemed to come up at the end of the answer.
D: And how did you feel about that one?
H: I felt that the little numbers were kind of getting in the way.
D: Did you feel like that too Melanie?
M: Yeah (laughs) 'cause we knew when we had just got two lines we still had all the little numbers left and we couldn't add them all up to make them equal 23.
H: You know when we used them first to work it out, we won't be able to work every single thing out.
M: So you think you've got it and then the next line you have to put the ones and twos in and you've only got four and five on the end and it doesn't equal anywhere near.
D: I really admired how you kept going on this one. What kept you going?
M: 'Cause we wanted to work it out.
H: Well...I reckon...I reckon I really like that problem. I really like it. I like solving things.
D: You really like solving things. How does that make you feel inside?
H: Kind of a bit powerful.
M: Brainy...

They reported their enjoyment of the challenge even though it was not solved. Arguably the problem was quite difficult for them but not overwhelmingly so. It provided enough challenge to sustain their interest and enjoyment despite the outcome. Challenge and difficulty level need to be balanced carefully it seems, to engender this level of stimulation. Their regard for the problem was not diminished by not solving it. Their motivation was such that they returned to this problem in their own time and excitedly shared their solving of it the following day.

Similarly, Nicky (N) and Amit (A) found *Make 23* challenging and did not solve it yet affirmed their motivation for it afterwards ([ ] = talking at the same time):

D: Which one was the trickiest one today?
(Both point to *Make 23* smiling)
A: [THAT one!] (laughs)
N: [THAT one!] (laughs)
D: Why was that?
A: Tricky numbers and stuff.
D: Before you said small numbers were an easy problem. These are small numbers but why was it not easy?
N: You had to move them around.
D: How do you feel about tricky problems?
A: Not very well! (laughs).
D: But you kept going on...why did you keep going?
N: Because we wanted to find out the answer.
D: Do you still want to find out?
A: Yeah!
D: Do you want to take it away and keep working on it? Take it home and try it?
N: No, take it to the classroom!
A: Work on it together. And then when we have nothing to do we could do it.

(end of discussion)

Such a problem as this appeared to be at the optimum level for these children as evidenced in their tenacity and perseverance. Although Amit declared that he did not feel "very well" about challenging problems like *Make 23*, his enthusiasm for pursuing the problem did not seem to wane. Furthermore, Amit and Nicky decided it would be useful to take it back to their classroom and work on it together.

The type of problem which engendered persistence, motivation and enjoyment varied across the dyads. While many of the pairs enjoyed *Make 23* and rated it as a favourite, there was less consensus about the fuzzy and closed problems. Sam and Zane, for example, conveyed a distinct preference for the fuzzy problems. In the following extract they commented on their attitude to the fuzzy problem, *How far do you walk in the average week?*:

D: So the third one, how did you feel about that?
S: That one was rather...
Z: Tricky, very, very tricky.
D: And how do you feel about tricky problems? How do they make you feel inside?
S: I LIKE it...[I like the challenge].
Z: [I like it]...I like (talking over each other)
D: Why do you like the challenge?
S: Because it's something that I've never...It's something that I always like to find to see if I can get it right and it's very new sometimes, with different questions and I like to see if I can get it right.
D: And Zane?
Z: If you make your mistakes you learn. I like the tricky ones because I like knowing what's...and trouble a bit too, 'cause I can talk people out of things by knowing things.
D: Mistakes help you learn?
S: And I HATE easy ones because I just go der, der, der, der (gestures as if marking in a sheet).
Z: And then it's all over with and you've got nothing to do.
S: Yeah, it's very stink.
Z: Apart from reading goosebump books...

Sam and Zane commented on the challenge inherent in a problem of this nature and how much they enjoyed such an investigation. Sam reflected on the novelty of such problems, "it's very new sometimes", and his concern with solving it, "and I like to see if I can get it right". Zane stated that he appreciated the learning involved in such problems, "if you make your mistakes you learn", and conveyed an enjoyment of the "trouble" and power of such learning, "I can talk people out of things by knowing things". These comments indicated their preference for problems which stretched them and their low tolerance for anything they considered easy. In particular these two boys did not report enjoyment of any of the closed problems.

At times the persistence of the dyad was influenced by interaction with me as I asked a pair of children to reflect upon what strategies they were using. I was aware of being cautious about the timing of such interventions as I did not want to thwart or direct the children's own approach to the problem solving but at the same time, I was concerned with understanding how they were making sense of the problems. In the following extract, Megan (M) and Linda (L) were doing the problem *Make 23* and Linda appeared ready to leave it for later:

M: No it can't be that. 11, 12, 13, 14. Try again.
L: Can we do this one last? (looks exasperated-laughs)
D: Are you trying a strategy? Is there a way you're approaching it that's helping you?
L: Well yes we're [doing]
M: [We're doing] a triangle for each side. Sort of like um... that triangle [we did]...

The girls went on to describe the approach they were using and in doing so appeared to renew their persistence with the problem. An attempt to interrupt the pair later on with the same problem was ignored as they were immersed in their problem solving:

L: And this one (looking at the next side) is four, and this one down here is four plus [one plus]
M: [one plus]
L: Seven, [plus two].
M: [Plus two] OK so you have four and a, four and a..I know. All right, [four]
L: [11] 12, 13, that's 14!
M: 14. So we need...
L: We need higher numbers (laughs).
D: What is it about...
M: (Excitedly) How much have we got, we got? We need, we need more...
L: We've got one, two, three, four, five, six, seven, eight, nine (counting as she goes around the shape of the triangle with her pencil)...

I started to ask the girls, "what is it about" those higher numbers, when Megan quickly interjected asking Linda to evaluate what numbers they had used and where they were up to. It appeared that Megan's agenda was more pressing than the need to listen to or respond to my query. A noticeable feature of this discourse was the way in which they picked up simultaneously on the last one or two words of each other's statement of information and built on this with further information, verification or a hypothesis. Their talk not only seemed to "build" but it overlapped, so that the point of departure was shared between the two children. This feature of overlapping discourse will be discussed in more detail in a subsequent section.

On this occasion the dyad appeared to be oblivious to my presence and intent on the problem at hand which indicates that their engagement with this problem and each

other was more powerful than my attempt at interjection. Yet it was only a short period of time between this incident and the previous one where they had responded to me. The difference appeared to be the momentum of the discourse which was related to the progress they were making. Momentum was flagging earlier and it had increased considerably in this latter episode. Timing was important in my interactions with the children; knowing when to ask a question in order to validate my interpretations of what the children meant, and when to resist interrupting so that their dialogue with each other was not impeded.

Having a partner when working on a problem can encourage persistence even when one child in a dyad appears to be overwhelmed. With the problem, *Make 23,* Ropata (R) voiced his frustration and appeared ready to give up but Hank (H) continued to persist:

R: Nine and eight is...(looks expectantly at Hank)?
H: Where's nine?
R: It's only 20! (20 is their total - they need 23). Oh, it's 19 (corrects himself).
H: (Checks Ropata's adding by counting) eight, nine, 10, 11, 12, 13, 14, 15, 16, 17.
R: 17...(twirling his pencil on the table). It's TOO HARD!
H: (Changes one of the numbers)
R: (Watching what Hank did) Yeah, change it to a seven. Rub out the seven and put a one. (Then he starts counting the new combination of numbers)...

Rather than responding to Ropata, Hank continued with the problem by changing one of the numbers. This action was observed by Ropata who quickly re-engaged with the problem and acceded to Hank's strategy. He then suggested a further idea, building on what Hank had instigated. Similarly, in the following episode Ross (R) stated twice that they were "stuck". Andrea (A), however, did not verbally agree with him but persisted with the problem which seemed to rekindle Ross's motivation:

A: Seven and one is eight. Two, three, and four...
R: We haven't got three.
A: What's six and eight?
R: That's 14.
A: Not enough. Um...I know a good idea...the seven plus eight is...
R: Is 15 (using the calculator) and four and two is...21.
A: Oh darn.
R: We are stuck (puts calculator down and looks at their paper).
A: Make that a five and a two again.
R: Unless the nine wasn't there and was over there (shifts corners).
A: But then that wouldn't equal up. Let's take two off it.
R: Unless...
A: Unless the nine comes up here (changes corner again).
R: And the eight down here (also puts it in a corner).
A: No, oh.
R: We're stuck (puts hands on knees and looks down).
A: We could just do that. Put the nine up here (changes corner again). What was that originally?

R: That was nine, that was eight (adds to 22).
A: Are we using six and two? No we're not are we? It's gone.
R: (Puts six and two in bottom line and counts) eight and six and two and seven is 23! Now what do we do?
A: Maybe take a three and four and make it 16, 17, 18, 20, 23! (They both laugh as they realise they have got it to "work")
A: [YAY!]
R: [YAY!]
(end of discussion)

This problem, *Make 23*, appeared to be a stimulus for jubilation as the children laughed and cried "yay" when they completed it. Andrea commented that it was not just the completion of the problem that she enjoyed but the challenge it provided for her. The subsequent interview illuminated further their affective response to the problem:

D: How did you feel about this problem?
A: It exercised your mind.
D: Exercised your mind? How did you feel about that?
A: Pretty good 'cause usually I use calculators or something like that and take the easy way out (laughs).
D: Did the way you feel about the problem change while you were doing it?
R: Um...I got fed up then, oh look at this, then fed up again and then finally YAY!...

This vacillation of feeling reported by Ross was also echoed in Andrea's comments in the same interview. They appeared to enjoy the challenge of the problem and acknowledged that it was both a relief and a regret to finish it:

D: Oh, right. So in terms of these three which problem would you like to meet again, you know, like a similar problem. Which one?
A: Number two! (*Make 23*)
R: Number two!
A: It was easier and then it was hard because you had to write it down instead of doing it in your mind.
R: I'm used to having exciting parts and not so exciting parts about the same thing. So it was like a normal day, like a normal feeling.
D: Can you give me an example of that? You're used to having exciting parts and not so exciting parts in the same thing?...
R: Well like I do a little bit and then it's wrong and I rub it out and then I get even better than I expected.
D: What keeps you going when something is getting "not exciting?"
A: Thinking that when I've finished I'll be really relieved (laughs).
D: How did you feel when you'd finished these two? The first one and the last one.
A: Not as relieved as number two (*Make 23*).
R: No.
D: So the relief added to how you felt about this?
A: Yeah because when we finished we went Yay! Phew! And that was just Phew!
D: Was it just relief to get away from it?
A: I was sort of sad I'd finished it...
R: Yeah.

A: Because it was quite enjoyable...

The challenge, enjoyment and relief appeared to be interconnected and interdependent. It is difficult to imagine relief without some prior challenge. It seems unlikely that a totally frustrating challenge will be enjoyable but one that stretches children can be regarded as satisfying and an accomplishment. That Andrea and Ross were challenged by it and felt positive about it seemed evident in their persistence on the problem and their subsequent exclamations and comments.

Having a problem solving partner may assist with retaining motivation for the task at hand. While it cannot be claimed that a child (such as Ross above) would have given up on the problem if they had been alone, there is evidence to suggest that a partner can keep the momentum going when one child feels they have reached an impasse. This facet of sense-building discourse occurred frequently enough, across a number of cases, to form a noticeable pattern when the problem was challenging for the children. The dyad can be a site for sustaining momentum especially when one child experienced flagging enthusiasm or appeared to have exhausted their ideas. When the other did not concede defeat but considered another opportunity, both appeared to gain motivation again.

That one child will always provide motivation in this manner is not the case. A dyad partner can also be a harsh critic or pessimistic commentator. In the following episode with the fuzzy problem, *Estimate the number of vets in New Zealand*, Ross appeared to discourage Andrea and effectively terminated their problem solving:

A: How many people in New Zealand?
R: Three million or something.
A: So how many sheep?
R: Sixty million.
A: Yeah, 60 million. It was on that programme 'Click go the shears'. But the three million, they wouldn't all be vets. About 10% of the population would be vets.
R: I have two uncles who are vets.
A: Um, how many vets in New Zealand?
R: You would have to do a survey.
A: If there was one for each island there would only be two but that's not right, that's not enough. How many people in New Zealand again?
R: Three million (sighs).
A: Say about 10% are vets...that's about 500,000 in both islands but then there wouldn't be enough work for everyone with that many.
R: You can't really do it. You'd have to do an actual study to really know.
(Silence)
A: So, about half a million.
R: About that, yeah.
(end of discussion)

While Andrea sought information from Ross and he supplied information, they were not really building a shared approach to the problem. Andrea ignored the fact

that Ross had two uncles who are vets and Ross showed no interest in estimating but repeated that they would need to do a survey. During this problem Andrea reframed the problem as posing how many sheep there are as a starting point to address the problem. She then reframed it to pose how many people there are in New Zealand and used that as a basis for estimating the number of vets as a percentage of the country's population. She self-corrected when she realised that her estimation of 500,000 would mean that there would not be enough work for all the vets. Her exploration finished there. She returned to her guess, which she knew was too large and Ross quickly agreed as if he wished to terminate the problem solving.

Such an example provided variation to the pattern regarding the presence of a dyad partner. It appears that a reluctant or pessimistic partner can be instrumental in prematurely ending both the sense-building and the problem solving. What is evident in the episode above is the lack of variety and initiative in Ross's discourse and the few attempts to build upon what Andrea says. He provided information at times such as the number of sheep in response to Andrea's query and he brought in his own experience of vets, "I have two uncles who are vets", but there were a paucity of examples where the children actually elaborated on what each other stated. Ross countered Andrea's suggestion, "you can't really do it", and finally complied with her suggestion at the end. There was a sense of resignation in his compliance in the light of his previous comments. All three categories of sense-building, complying and controlling are evident in this episode but the discourse does not convey persistence with, or enjoyment of, the problem. What appears to be missing is a sustained attempt to follow a line of thought or argument by both children.

5.1 Discussion

A theme which emerged in the results was the way in which the dyads would persist with a problem that interested them, even when one partner in a dyad was prepared to abandon it. As Runco (1994) stated, "One problem can incapacitate certain persons, but can be interpreted by others as a challenge or opportunity for creative expression" (p. 277). If the other partner persevered, the reluctant partner often rejoined the investigation. There seemed to be something about working with a partner that contributed to this. Persistence, however, cannot solely be attributed to the company of a dyad partner. The presence of a researcher was probably a factor in maintaining persistence with the task at hand, which is evident in other studies (e.g., Brody, Stoneman & Wheatley, 1984). In addition, most of the children's discourse was task-related which could well be a feature of the dyad arrangement which provides quite an intense, one-on-one focus. While Bennie, Henry and Ratcliff (1990) stated that children were less likely to be on-task during independent work compared to times that

they interacted with a teacher, there did not seem to be a problem with any of the dyads in keeping on-task.

Perhaps there is less likelihood of becoming distracted or losing interest in a dyad. It is socially difficult to cease working on a problem if your partner does not wish to. The sense that you are letting your partner down or giving up is accentuated when there are only two people involved. In a larger group you can opt out and merely observe without anyone necessarily noticing. In a dyad, there is no such opportunity to relinquish involvement without it being obvious. The obligation to take part and respond is difficult to resist when you are part of a pair. This social variable has implications for task persistence. It could be that in a dyad it is somewhat more difficult to be off-task considering the intensity of a one-on-one interaction. If one child in a pair decides to opt out of the task at hand, the collaboration ceases to exist. While there may be more onus on pairs to sustain interaction (as they only have each other) it also seems more drastic when one child in a pair goes off-task or gives up. The results of this study indicate, however, that the opting out of one child in a dyad may not be permanent for collaboration, nor always problematic for the problem solving.

The literature pertaining to the themes of persistence, momentum and enjoyment in collaborative peer dyads is scarce and somewhat ambiguous. Most dyad research has focused upon cognition rather than social perceptions and emotional variables (Light & Littleton, 1994). When the children in a dyad are of similar ability Kutnick (1994) claimed that the threat of dominance is minimised as children supposedly share status and decision making power. This claim is not based upon studies of children's social status, however, and therefore needs to be treated tentatively. Holton, Anderson and Thomas (1997), claimed that a dyad can provide support and boost confidence for the children involved. These affective elements appear to be influential and significant in dyad problem solving. The "support" factor is less evident in this study, however, than the sheer momentum generated by the presence of a persistent partner.

Forman (1981) claimed that when children in cpds take complementary roles they are able to provide each other with support and guidance. This suggests an emotional variable is significant in dyad interaction. The notion of support is further explored through the concept of "mutuality" which is highlighted by a number of researchers in the field (e.g., Damon & Phelps, 1989; Kutnick, 1994; McCarthey & McMahon, 1995). This mutuality is defined as a feeling of trust that provides the opportunity for interaction without the fear of intimidation. Such mutuality is claimed to foster a bidirectional, rather than unidirectional movement of knowledge from child to child in a pair (Forman, 1986; Lyle, 1996; McCarthey & McMahon, 1995). The concept of mutuality, however, does not seem to include how a child can encourage a partner to

persist on a problem nor does it emphasise that the momentum of problem solving may be sustained through the presence of a dyad partner.

The importance of trust in a dyad relationship is not contested in this study, but the findings suggest that persistence in problem solving is often prevalent when children work in pairs. Whether this is a result of trust is difficult to ascertain. As mentioned above, it may be the mere presence of another child and their focus on the problem that contributes to persistence for a dyad. Furthermore, Pryor (1995) noted in his study of dyads with computers that girls worked well together when they were of similar ability and one did not dominate the other. He argued that a balance of ability and assertiveness is required in dyads.

A balance of children's ability probably contributes to dyad persistence and momentum in problem solving, though this study did not compare symmetrical and asymmetrical dyads so such a conclusion is speculative. Moreover, there are other studies which examine this issue (e.g., Doise & Mugny, 1984; Light & Littleton, 1994; Tudge, 1990). Also, it is not evident that a balance of assertiveness is required as Pryor (1995) claimed. The persistence exhibited in this study seemed to be generated by one child in each dyad who, at key times of doubt and uncertainty for their partner, maintained the momentum of the problem solving. It might be assumed that they were more assertive but that is not clear from the data. What is clearer is that they were more persevering than their partner at a crucial point where the problem solving would have stalled completely if someone did not persist. It is important to note that the persistent child was not the same person during every problem. The role of persistence was transferred at times, from one child to the other.

Rather than assertiveness, it seems that persistence was a key factor in collaborative problem solving. The presence of a dyad partner and their sustained focus on the problem at hand contributed to the momentum of the problem solving. The few times when this persistence was not sustained occurred when a reluctant partner did not respond to his or her peer's suggestion, proposition or hypothesis. This is different from what Dunne and Bennett (1990) identified as "ganging up". They claimed that peers can sometimes pressure group members to prematurely agree to an idea in their haste to finish the task. There seems to be some evidence of this phenomenon with Zane in the first transcript, where he said, "I know an easy answer", to the problem. Zane, however, did not get the opportunity to elaborate on his "easy answer" as Sam continued and did not seem to respond to Zane's suggestion. Overall, there seemed to be little active persuasion of a partner with a premature idea. Rather, lack of persistence was more likely to occur when a partner consistently refused to engage with any suggestion (e.g., Andrea & Ross in the last transcript).

Sustaining the momentum of collaborative problem solving relied upon some willingness by both children to continue with a line of thought or argument. A persistent partner often provided the impetus to continue for both children. The focus or perseverance of the persistent child frequently spurred the willingness of the more reluctant or frustrated child to maintain interest in the problem at hand.

This theme of persistence is somewhat different from what Lyle (1996) argued about collaborative work in the classroom. She stated that the clarity of the task was important in assisting children with on-task behaviour. While there were instances in this study where the children seemed to have a clear understanding of the task at hand, there were also instances where they appeared to struggle with determining what was meant. At times this led to little progress or persistence (see Ross & Andrea with *The Vets*) but this was not the only response. There were episodes where a mutual confusion or lack of clarity was overcome as the children explored the meaning of the problem together (see episodes of collaborative correction in section 9 to follow).

Aligned to the theme of persistence was the enjoyment that the children reported and exhibited during some of their problem solving. Enjoyment was not obvious with all of the problem. In fact, at times, the children seemed to tolerate rather than enjoy some of the problems. The problems that engendered enjoyment were those which were challenging but were not too ambiguous or vague for the children. These problems stimulated the most sense-building and controlling talk concomitant with expressed feelings of enjoyment, challenge or satisfaction. Debate appeared to be encouraged in such problems as the children were not struggling to make sense of what a problem was asking, were not distracted or confused by semantics and could therefore more freely interact with each other's ideas.

One of the most engaging problems which sustained interaction, discussion and persistence for all of the dyads except Sam and Zane, was *Make 23*. This problem is context free in that it does not relate to a real-life, everyday problem. What appeared to be more significant than any need for context in this case was the challenge it created and the discussion it engendered. It is also a visual problem where the numbers can be easily changed and manipulated which seemed to sustain access as well as interest for both children in each dyad. Enjoyment appeared evident even when a dyad did not solve this problem. Weissglass, Mumme and Cronin (1990) claimed that peer interaction can reduce anxiety and alienation. It could be that a partner in problem solving can do more than this, given certain circumstances such as appropriate challenge and interest. A partner may help to sustain the momentum of the problem solving and share the enjoyment of the challenge. Having a partner to share both the challenge and the enjoyment can enhance the emotive reaction children have.

Even when children work alone on problems they often like to share what they have discovered, investigated or found out. Children can share both the investigation

and the satisfaction when problem solving in a dyad. In cases where a problem is not solved, a dyad can still provide a site for ongoing investigation as the challenge of pursuing it further is not the sole responsibility of one child. Furthermore, if they choose not to pursue it further they can still share their enjoyment of investigating it together. It could be argued that the problem solving process itself is what the children find enjoyable, not experiencing the process with a partner. Shuard, Walsh, Goodwin and Worcester (1990), for example, argued that the positive attitudes to mathematics are often the result of a problem solving approach. The pattern in the data, however, of the process of problem solving being maintained by one child when his or her partner wanted to give up, provides some evidence that working in a pair can influence a child's persistence, motivation and enjoyment.

This has implications for how problem solving is viewed by teachers. If teachers want children to enjoy problem solving (and it would be educationally appropriate that children enjoy their learning), they need to consider a number of factors. Actually coming to a solution is not always necessary for children to experience enjoyment and remain motivated. *Mathematics in the New Zealand Curriculum* (Ministry of Education, 1992) places an emphasis on mathematical processes, not just products, and problem solving is emphasised as a key mathematical skill. This includes the achievement objectives to "devise and use problem-solving strategies to explore situations mathematically" (p. 24) and "devise and use with justification, a mathematical model as a problem-solving strategy" (p. 24). While these objectives imply the importance of process, especially with the adjective "explore", problem *solving* is also implied as the aim. While problem solving is often useful and appropriate, problem exploration is also of import. This exploration may not lead to problem solving, however, but be part of an ongoing investigation of mathematics.

It is also important to note that ideas may not be pursued nor doubts expressed, if a partner shows indifference or seeks a quick answer. Stacey (1992) found that children in groups of two and three working on mathematics problems, often generated many ideas but did not persist or check carefully. The groups she studied were more likely to pursue easily accessible solutions and often glossed over important ideas that arose in discussion. She concluded that the children had difficulty in "selecting correct approaches" (p. 273). Dunne and Bennett (1990) also noted a range of behaviours which can occur in group interaction which mar the quality of the group's work such as pressuring a member to finish rather than persist and appearing supportive but contributing little.

There was some evidence of what Stacey, and Dunne and Bennett claimed with some pairs during some problems, but this was not a constant phenomenon. The extent to which children persisted and pursued a line of reasoning, as well as carefully checking their working, seemed to be influenced by the problem on which they

worked. For example, while Andrea and Ross had difficulty persisting and selecting ideas with *The Vets*, they persisted and double-checked their working with *Make 23* and with *Going to the fair*. Stacey's argument, therefore, is only partly supported. The literature (e.g., Kutnick & Rogers, 1994) also indicates that groups of three are less effective than groups of two for problem solving which may have had some bearing on Stacey's findings as most of the results she reported related to groups of three.

On-task behaviour could be more likely for dyads than for larger groups as there is less social demand. Thomas (1994) noted that the nature of children's on-task behaviour can be low level procedural talk if the social demand is too high. Furthermore, she found that there needs to be a balance between the social and cognitive demand of a problem or activity for children to most productively engage with a task. Cpds could be most suitable for maintaining task focus and for minimising the social demands. It is claimed that the cognitive gains for children can be diminished if teachers do not take an active role in setting up appropriate independent group tasks (Higgins, 1995). This claim is not disputed but what a dyad finds appropriate can vary considerably so the teacher's analysis of such tasks remains complex.

6. Drawing Upon Personal Experience

The ways in which the children made sense of the different problems varied considerably, even when one dyad came to the same conclusion or solution as another. A common phenomenon was the way some problems triggered children's personal experiences, especially when the problem was ill-defined or fuzzy. These personal experiences appeared to be part of the way in which the children made sense of what the problem meant. The children's experiences also provided a point of departure from the problem itself into related areas. For example, Hank and Ropata discussed the fuzzy problem, *Estimate the number of vets in New Zealand*:

R: My cat had to go to the vet.
H: What happened?
R: She got, she got bit. There's this dog next door, it gets over the fence, it hurt the cat's leg and dad had to take her...
H: That's a bad dog.
R: I got bit once, on the face.
H: Your neighbour's dog...?
R: No, there was this dog...we were visiting my uncle in Wanganui, when we were down there. It's there see? (points to cheek)
H: You can't, can't REALLY tell...

In discussing his experience with dogs, Ropata was able to share a rather traumatic event with his partner. It may be that because the fuzzy problems such as this one were more difficult for the children to process mathematically, the incidence of such talk increased with these problems. Discussion of the problem started with Ropata's experience with his cat and a vet. The topic of the vet, however, was not pursued but instead this episode quickly became a conversation about dogs that bite and the injuries they can inflict. Personal experience of this nature seemed to be foremost in their minds when considering this problem. Their experience of vets was perhaps, limited, but Ropata's experience with dogs was vivid. The discussion centred therefore, more around what dogs could do to injure. Fuzzy problems such as these required more semantic demand as they endeavoured to make sense of what was being asked. For example, Hannah and Melanie discussed the fuzzy problem, *How many times a day does the average New Zealander laugh?*:

(They both read the problem out loud)
H: Ay?
M: (laugh) Depends on if the other person who tells the joke is funny or not.
H: If someone tickles you, or tells you a joke you'll laugh more. If someone laughs then you laugh.
M: Yeah like this man at Katrina's house said we giggle all the time.
H: Does it mean laugh or go HA HA? What does it mean by laugh?
M: Just giggling really like I do. It just comes out really, it just comes out.
H: Sometimes you just laugh and it just comes out just like that.
M: 5 million laughs a day...if I got paid for every laugh I could get rich.
H: I suppose so.
M: I used to laugh BEFORE my sister tickled me!...

Such discussion appears vital to the understanding of the semantics of the problem. The girls needed to determine what a laugh was before they could endeavour to solve the problem or even consider a strategy. Defining the problem and its meaning is crucial and appears to comprise a form of intellectual "warm-up". The fuzzy problems encouraged much discussion and debate of this nature.

This extract also provides an example of sense-building which was sometimes collaborative and sometimes individual. Hannah built on Melanie's suggestion that laughing depends on whether a joke is funny or not by adding that, "if someone tickles you, or tells you a joke you'll laugh more". She included Melanie's suggestion (telling a joke) and added further information (being tickled). Furthermore, Melanie responded directly to Hannah's question about what it meant to laugh. Hannah sought information and Melanie responded by informing or verifying what she believed a laugh to be. There appeared to be a collaborative building of meaning in this instance. Melanie's aside comment about getting paid for laughing five million times a day is more individual, in effect, in that it is neither built upon nor challenged. Hannah made a non-committal comment in response, "I suppose so", which inferred agreement.

This comment is categorised as complying rather than sense-building, partly because of the function of the comment (to agree uncritically) and partly because the topic was not pursued or built upon further by Hannah or Melanie. This episode, however, is generally typified by a sense-building pattern.

For some children the context of the problem was obviously of interest as it related to their lives, preferences and experiences. For example, Ropata and Hank (seven years old) appeared to enjoy, *Jill and the wheels*, and spent time drawing all the wheels and spokes when solving it. An older dyad, however, Andrea and Ross (10 years old) found *Jill and the wheels* less attractive and conveyed their preference for the closed problem, *Going to the fair*:

D: In terms of these three problems you looked at today, is there one that you enjoyed more than the others and if so, which one did you find more interesting?
A: The fair.
D: OK going to the fair...why?
A: I don't know, 'cause it's spending money (laughs).
D: That was fun?
A: It's more interesting things than TRICYCLES and BICYCLES (rolls her eyes). It's more interesting like, going to the fair and five dollars to get in, candy floss, roller coaster, lemonade...and did we have enough money for the ghost train instead of did we have enough money for a bicycle or something like that.
R: OK you're really there and you've got the money and you spend it, and then you've got to figure out if you've got enough money to spend on the ghost train.
D: OK, so you could picture yourself there?
A: Mm, I think so.
R: If you could close your eyes and read it as well...
A: You couldn't really imagine yourself being Jill though...(in the first problem) and also it's YOU and YOUR friend and not Jill...

The age of these children may have had a considerable influence on their engagement with it. The problem related to an activity that they enjoyed doing and one which emphasised social interaction which was evidently appealing. Andrea stated that she "couldn't really imagine" herself as Jill but she reported that it was more interesting to consider going to the fair. Ross also seemed to regard the fair problem as more relevant when he stated, "OK you're really there", which indicated that he related easily to the context.

Both children intimated that the social context of the problem the fair, appealed to them. Ross felt he was "really there" and Andrea added that it involved them as it focused on "you and your friend" rather than Jill, someone they did not know. They seemed to identify with the activity and it may be more age-appropriate than a problem concerning bicycles and tricycles. Such age-appropriate material is important for sustaining children's interest, at least it was an issue for this particular dyad. It would be interesting to know if *Jill and the wheels* would have been more interesting for the

dyad if mountain bikes and three-wheeler motorbikes had been used. Greater interest seemed to engender greater satisfaction accrued from investigating the problem.

If their work had been assessed based upon their working and their solution only, it would not be apparent that they had a strong preference for one over the other. It was only in witnessing their working, and particularly in the follow up interview, that they made explicit their feelings for the problems. Children's affective responses are an area of consideration in this study. It could be argued that the relationship of cognitive to affective can be mutually reinforcing in that those activities that one enjoys can have the reciprocal effect of improving one's learning. Consequently for children like Andrea and Ross, the context of the fair had greater potential for interest and cognitive development, perhaps, than less relevant contexts.

What is surprising, however, is that the problem *Make 23* which is not embedded in a meaningful context and was not a catalyst for any discussion of the children's personal experience, proved to be the most popular problem of all. The children's responses to this problem are discussed in detail in section 5.1 above. Suffice to say in this section that personal experience and meaningful contexts are not always necessary for engaging children's interest and motivation.

6.1 Discussion

Sometimes it is not until we hear children interpreting a problem that we become aware of the semantic ambiguity inherent in some problems. The importance of listening carefully to children's interpretations is obvious. This helps to ensure pedagogical match with children's learning and can improve assessment. Children may seem not to achieve on a certain mathematics objective but that could be their misinterpretation of what the problem asks, not their ability in mathematics.

One of the main implications of this finding is what Polya (1957) stressed in his first phase of problem solving, that is, you have to understand the problem. Some problems may require prior discussion with teachers or peers in order to clarify meaning. Children's interpretations of what a problem means need to be made evident. This should not detract, however, from interpreting seemingly closed problems in inventive and appropriate ways. While some problems appear closed at the outset, they may in fact have more than one valid interpretation. In this case children need to be able to justify their interpretation of it and be aware that there may be other ways.

While the importance of meaningful contexts has been highlighted by many in the literature (Baker, Semple & Stead, 1990; Edwards, 1990; Hughes, 1986; Ministry of Education, 1992) this study produces somewhat ambiguous findings. While some problems appeared to relate strongly to children's personal lives, these did not always

lead to greater engagement or heightened motivation. While "real-life" contexts may have encouraged dialogue, such discourse was not necessarily mathematics related (see earlier comment the children made about *The Vets*). A problem like *The Vets*, however, was also a fuzzy or ill-defined problem that had rather high cognitive demand. Real-life or meaningful contexts are often assumed to be helpful for children's acquisition of mathematics knowledge. For example, *Mathematics in the New Zealand Curriculum* (1992) stated

> Students learn mathematical thinking most effectively when applying concepts and skills in interesting and realistic contexts which are personally meaningful to them. Thus, mathematics is best taught by helping students to solve problems drawn from their own experience. (p. 11)

For Andrea and Ross, the meaningful context of going to a fair proved to be motivating for their problem solving. They also made it clear that some real-life contexts (bicycles and tricycles) were not of interest to them and this discernment seemed to be age related. The research on the value of real-life contexts in enhancing children's understanding is equivocal. Taylor and Biddulph (1994) found that real-life contexts often obfuscated mathematical learning even when the contexts were thought to be highly relevant to the children's experiences. For example, a meaningful context for teaching probability using coloured clothing pegs had the following outcome:

> ...one child when asked what he had learned from an activity involving combinations of coloured pegs, said, 'Putting washing on the line' [What did you find out?] 'How to put it up.' (p. 104)

It should not be assumed that real-life contexts enhance mathematical learning. Nor should it be assumed that real-life contexts will be motivating and meaningful for all children. Factors such as age, gender, culture, ethnicity and class can all influence how children perceive and interpret various contexts. The experiences children bring to a context can influence both their interpretation and their interest in a problem. There is no guarantee that children will find a context meaningful and motivating even when a teacher or text assumes that it is (Smith, 1997). Problems which provide sufficient challenge may not be what the teacher expects. For example, it was rather surprising that the dyads enjoyed *Make 23* so much when it does not relate to real-life nor is it presented in a meaningful context. Hiebert et al. (1996), argued that context may not be crucial to children's engagement and understanding of problems. Instead they posited that problems which elicit children's curiosity are important. These problems may appear to be routine computations (such as *Make 23*) but children's explorations during problem solving can be far from routine and pedestrian.

The ways in which the children interpreted and discussed the problems can be related to the children's sociocultural experiences. Bruner (1996) and Lyle (1997) emphasised the primary role of culture in determining children's meaning making. They claimed that children (and adults) often make sense of their world through narrative. These narratives are the creation of stories to explain, explore, process and understand new information and ideas. On occasion the children drew upon their experience and understanding to discuss some of the problems. This was particularly noticeable when the problems were ill-defined. In such instances the children were likely to recall an event or experience related to the topic in order, it seemed, to clarify their ideas about the problem's meaning.

There were instances where the children discussed a sequence of events during their discourse. Bruner (1996) proposed that this sequence of events about an issue is an essential aspect of narrative thinking. Their discussion appeared to arise from the puzzling nature of the problem they considered. Again, Bruner stated that the purpose of narrative is to redress or resolve the issue at hand. The children's narratives were not universally successful in resolving the problems they discussed but did seem to play a part in exploring the relationship of the problems to their lives. There were examples, however, when the children explicitly used narrative to solve the problem at hand. This is discussed later under section 8.1.

7. Collaborative, Overlapping and Self-Talk

At times the children's talk occurred in parallel when both children in a dyad would hold separate but concurrent monologues about what each was thinking, especially near the beginning of a problem. For example, Sam and Zane discussed the problem, *How far do you walk in the average week?*:

S: So nine divided by four, I NEED a calculator, you can't get nine divided by four...(walks off to get one; returns). So I walk 300 metres, two point two five.
Z: I don't walk home. So that would be 21 kilometres in the average week...

Sam focused on how far he walked and Zane pursued his own line of enquiry and as they talked about their walking distances neither child looked at the other. They did not acknowledge each other and appeared to be intent on their own approach to the problem. This "self-talk" which did not appear to be directed at each other continued throughout the problem but was not a constant feature of their discourse. Both self-talk and collaborative talk occurred sporadically. At times they seemed to ignore each other and engaged in self-talk, but other times they asked each other direct questions and gave direct responses. Sometimes they also asked each other questions but did

not respond at all to what was asked. Even when they appeared to be engaged in quite separate work, however, they responded to each other occasionally as if they had been simultaneously following each other's working:

S: How do you write 12 kilometres? So I say two, three and a half, four and a quarter, four and three quarters, five, six point seven-five - I've got.
Z: Do you mean the average school week? What's three times five?
S: Three times five is 15.
Z: Final estimation would be 15 kilometres.
S: Six times seven is...(counts on), 28, 35...42.
Z: That far? Counting the weekend? Use a calculator, do you use a calculator or your head?
S: Do you know what six times 75 equals? Um...six times seven is 42 and six times five is 30, so that's 450...

As evidenced above, at times they ignored each other's questions and simply answered their own questions. At times like this it seemed that the children were posing questions to themselves rather than to a partner. At times, though, they did respond to a question and the questioner incorporated the partner's reply in his or her answer as Zane did with Sam's response of 15 above. Conversely Sam seemed to ignore what Zane was asking, "that far? counting the weekend?", but made it clear that it is the entire week when he multiplied by seven. So perhaps Zane's question about the length of the week did register with Sam though he made no apparent direct response but instead incorporated the idea in his working. Perhaps he always intended to employ a seven day week and felt no need to make this explicit to Zane.

A further example of this oscillation from self-talk to dialogue was evident with Nicky and Amit as they worked on the problem, *Jill and the wheels*. As shown in the previous extract, the children sometimes responded to each other and sometimes seemed to ignore each other. Collaboration was not a constant, and nor was separate monologues:

A: There's two on each so there's one, two, four, six...
N: 18 wheels...tricycles...for tricycles have three wheels don't they?
A: I don't know.
N: Mmmm...18.
A: You have to add the tricycles and bicycles together?
N: Um [three, six]...
A: [three, six], nine, 12, 15...15 yeah and then and then six, 17. There'd be seven.
N: (Entering in on the calculator) three plus three plus three, plus two, plus two... oh.
A: Because...I think there'd be seven.
N: Plus... oh, I'm counting them wrong.
A: You have to count the threes...

Their opening comments seemed quite separate until Nicky asked Amit if "tricycles have three wheels" to which he responded that he did not know. Shortly after this

Amit asked for confirmation regarding the adding of the tricycles and bicycles which Nicky seemed to ignore as she started to add sets of three together. Amit joined in with this adding and continued alone to extend the computation. When he announced there would be seven cycles altogether, Nicky appeared to ignore him. Instead, she picked up a calculator to aid in her addition of twos and threes. Perhaps she was double-checking Amit's solution. Amit repeated his answer which again, received no direct response from Nicky. She commented on her error in counting which Amit gave some advice about.

Nicky appeared to be following her own line of reasoning but it is difficult to be sure. She may have been monitoring what Amit suggested and checking for herself. Whatever the purpose of her behaviour it seemed to be what she needed and wanted to do. She seemed to want to confirm for herself rather then accept an answer with no explanation. Further on with this problem, the children drew pictures together of the wheels to depict their working. Once they had finished their drawing Nicky again picked up a calculator to double-check their answer. She looked pleased and excited when her calculations matched the drawing they had done (see Appendix F):

N: Three plus three plus three plus three plus two [plus two plus two] equals...18! (entering in on calculator then looks at Amit and smiles as she reaches 18).
A: [plus two, plus two]
A: Oh Yep! We'll write a BIG 18 (which he writes in the middle of their paper)...

It was interesting to also note Amit's excitement about what Nicky was doing even though he had already come to a solution earlier. He seemed to enjoy Nicky's discovery and even excitedly counted the last two sets of bicycles along with her. Nicky's separate "checking" confirmed what he had earlier worked out, which seemed to please him and confirm his reasoning. Their interaction was different from Sam and Zane in that they did come to a joint solution eventually.

Less talk of any kind was evident with the closed problems with all of the dyads, with the exception of *Going to the fair*. With *Going to the fair* the children talked more and used a wider range of discourse. This problem required more investigation by the children. All of the children spent time writing down their working rather than only using mental computation. With the other closed problems the children relied on their mental strategies. This did little to encourage dialogue. The following example from Andrea and Ross with the problem, *Doctor and the pills,* was typical of the total talk the pairs engaged in on this problem:

A: Hey? Take five pills every half hour, how long would that take? Shouldn't it really be how many pills in a day?
R: No, how many hours to take all five pills.

A: That'd be...
R: Two and a half hours.
(end of discussion)

While Ross played a role in clarifying what the question was asking there was no explanation of his correction nor any explanation of his answer. Andrea accepted his answer without question. An even shorter dialogue occurred between Hank and Ropata on the problem, *Camera and case*:

R: (Reads the problem out aloud, Hank reads silently with him over his shoulder)
H: TEN dollars.
R: Hmm.
H: Finished.
(end of discussion)

Ropata read the problem out and Hank instantly replied with his answer. There was no clarification of this or any justification given. Ropata's utterance after Hank's answer suggested his compliance. In the follow-up interviews with all of the dyads they reported that they felt that the answer was self-evident and did not require any discussion. The ambiguity and "trick" of the problem was not detected by any of the children. The discourse was characterised by "inform" or "deduce" statements. Such conversations were short and to the point. There was often no explanation given and an uncritical acceptance of one child's solution. Or there were explanations given but no discussion or debate about these. For example, Sam and Zane with the *Doctor and the pills* problem:

S: (Sits quietly thinking)
Z: (Starts to write on his pad)
S: (Announces) It'll take two and a half hours. I worked it out from five pills every two hours. Five is like half a number so there's five and a half...
Z: If you took one pill an hour it would be five hours. Half of five is two and a half, so that's five pills over two and a half hours.
(end of discussion)

The children made pronouncements rather than engaged with each other. While Zane appeared to clarify what Sam was trying to say, there was no further discussion between them. They appeared to be content with their solution and did not contest the reasoning. While they came up with the same answer they appeared to do so separately.

The shared use of language was another feature that arose in the data. During their collaborative work Andrea and Ross seemed to borrow each other's language which indicated joint understanding. In the extract below, Andrea introduced the phrase, "juggle those around", which Ross appeared to borrow. Ross had not used this phrase before during their interaction on the problems:

A: You can always juggle those around if they don't fit.
R: What about a three here?
A: 16, 17, 18 - No.
R: We should juggle those around. Well if we chose a nine now...

It may be significant that this shared use of language occurred during the *Make 23* problem. The nature of this task had all dyads working in concert and sharing ideas in a collaborative fashion. The dyads often used "we" when discussing and suggesting what they might do. There was also evidence of all of the children in each dyad asking each other, verifying and checking on each other's reasoning and ideas with *Make 23*. The following extract gives an example of this:

A: Yeah nine is very helpful so it has to go over here (on a corner). Now what can we use with the nine?
R: Now OK, a five.
A: Nine and five is 14 and eight is what?
R: Plus one.
A: Yeah, 23. Make that a two and that a five.
R: Then you can't use five there (pointing to the previous position of the five).
A: Oh yeah. You could make that a three and that a four.
R: What was it again? Nine, five, eight, one. Now something and seven.
A: Seven and one is eight. Two, three, and four...
R: We haven't got three.
A: What's six and eight?
R: That's 14.
A: Not enough. Um...I know a good idea...the seven plus eight is...

Andrea and Ross referred to each other to check their working and their shared progress on the problem. They monitored their decisions and reminded each other of what would and would not work. Their discourse had elements of the controlling category, for example, "then you can't use five there", peppered amongst the sense-building and complying. The controlling comments appeared to assist in the elimination of possibilities so that the children could focus their approach more precisely. As such, this problem became a catalyst for collaborative work regardless of the composition of the dyad, and this collaboration was typified by a range of discourse categories. The dyad also seemed to provide a forum for the posing of questions of a metacognitive manner from time to time, for example:

A: Are we using six and two? No we're not are we? It's gone...

Andrea did not appear to require an answer to her question but rather was talking aloud about the strategy she and Ross were using. Ross may not have been considered as she posed this question ostensibly to herself. It is still unclear as to why she decided to voice the question aloud. Perhaps there is something secure and

encouraging about the dyad arrangement that stimulates such behaviour. The dyad arrangement is not necessarily the cause of this reflective talk but rather it may be the type of problem. Or perhaps it is the combination of the problem and the dyad which made such talk a common occurrence. Whatever the case, such discussion of one's strategy does not readily occur audibly when children work individually. The presence of another person appeared to invite individuals to discuss what they were thinking when a pair was engaged with the same problem.

Another aspect of the sense-building talk which occurred was the overlapping nature of the discourse. In the following episode Megan and Linda discussed an approach to the problem, *How many times a day does the average New Zealander laugh?*:

M: Well I could, I could, um...
L: Well we could have a piece [um]
M: [of paper]
L: I, I could keep a piece of paper in my pocket and every time I hear someone laugh I could j..., um, like, like, do numbers like...(looks for something to write on)...

Megan and Linda almost seemed to speak as one person as they planned how they would monitor how often someone could laugh in a day. Megan started by tentatively stating that she "could", and while she paused, Linda picked up on the same phrase (except she replaced "I" with "we") and added, "have a piece", and before she finished her statement Megan added, "of paper". In effect, they collectively said, "We could have a piece of paper", and they both contributed to the construction of the sentence. It was as if each knew what the other meant as they added to each other's sentence, indicating a shared understanding of their strategy. Their joint hypothesis appeared to be collaboratively devised.

7.1 Discussion

The phenomenon of two people talking in parallel (rather than to each other) is not uncommon during conversation (e.g., Tannen, 1990). Such parallel talk is part of the process of social and linguistic interaction even though it does not appear to have a social function. When some children pursued their own line of discussion without reference to their partner they appeared not to consider their peer at all. It was very rare, however, for a dyad to only talk in parallel during any one problem. It was more likely for parallel talk to occur with some of the closed problems and with two dyads, Sam and Zane, and Hank and Ropata. These four seemed to be very independent children and exhibited what Pryor (1993) termed "task focus" more than "partner focus" which can be more common with boys. Sam and Zane in particular exhibited

the most parallel talk but they frequently acknowledged and responded to each other during the problems that were not closed.

While these four boys often followed their own line of reasoning, they did not always operate as a "supportive" group (Holton, Anderson and Thomas, 1997). Holton et al. defined a supportive group as one in which children work by themselves except for the occasional statement, comment or question to each other. Such talk is on-task but not necessarily aimed at a response. For example, these boys frequently appeared to monitor each other and interact to check, dispute and clarify which is characteristic of a supportive group as described above. The boys also negotiated ideas with each other from time to time, which is a characteristic of what Holton et al. defined as "joint ventures". Their interaction revealed a constant movement between engagement and separation. This supports what Holton et al. stated about the fluid and complex interactions within groups. It is difficult to make assumptions about how children are influencing each other based on extracts from their talk as close scrutiny reveals a range of interactions between each pair which do not neatly fall into types or taxonomies. The data suggests, however, that most of the closed problems in this study encouraged little in the way of joint ventures.

With all of the dyads, collaboration during problem solving was not constant. The children moved back and forth from self-talk to collaborative talk throughout most of the problems. This is not surprising given that most conversations feature this range of discourse. It is the nature of talk to range across both individual and social spheres. This indicates that cognitive functions are sometimes separate from social functions in children's problem solving. It cannot be claimed, however, that such a separation as evidenced in speech is a direct reflection of separation in actual functioning. As indicated in the results above, there were instances when a child did not seem to respond to or acknowledge his or her partner yet incorporated the partner's idea into his or her approach or strategy.

This raises questions about children's responses to their peers' explanations. While Zack (1996) claimed that children may ignore their peers' explanations this does not necessarily mean that they will not incorporate their peers' ideas or suggestions. What appears to be indifference or deliberate ignoring of a partner's explanation, may in fact be subtly registered and used by a partner in their thinking about a problem.

Furthermore, a child's lack of direct response to a partner may not be a lack of interest or appreciation of the partner's comment. A child may be checking the partner's idea for him or herself. A comment from a partner may trigger an interest or desire to verify that idea. Or, a child may be pursuing his or her own line of reasoning but be simultaneously monitoring the partner's reasoning. This could be confusing and distracting. It could also be stimulating and affirming.

A more common phenomenon generally than parallel talk, was the use of sense-building and controlling language in a collaborative fashion, especially with problems which challenged the dyads such as *Make 23*. Such problems were contexts in which the children often asked, verified and checked on each other's reasoning and ideas. Barnes and Todd (1977) suggested that such interaction occurs during collaboration as there is a constant interplay between the social and cognitive functions of language. They would categorise acts such as "suggesting" and "proposing" as cognitive functions and "responding" and "initiating" as social functions. This study does not differentiate the cognitive from the social in this manner. Barnes and Todd also conceded that separating the functions is artificial and does not reflect how the social and cognitive are linked in discourse. This connection of the social and the cognitive appears to be apparent in much of the children's collaborative talk. This finding strongly supports Prisk (1987), Cobb (1990) and Clarke and Helme (1997) who argued for the iterative and interconnected nature of the social and the cognitive in children's learning.

The children used controlling discourse when they presented a point of view which challenged their partner's idea. The functions of challenging and justifying are part of what Barnes (1976) termed exploratory talk. Barnes's definition of exploratory talk also included times when children negotiate with each other. This is evident in this study when the children's discourse revealed that they were monitoring and checking what seemed to "work" with each other. Barnes's concept of exploratory talk seems akin to talk which is collaborative rather than parallel or solo. It also contains a range of discourse types (sense-building and controlling) and not just one category. It seems that collaborative exploratory talk between children requires that they actively engage with each other's ideas. This necessitates both sense-building and controlling discourse if children are to challenge, justify and negotiate with a partner.

Another phenomenon in the results was the occurrence of metacognitive talk wherein a child would utter a comment aloud which appeared to be for his or her own benefit. For example, a child sometimes posed a question aloud and then answered it immediately. Nuthall and Alton-Lee (1994) found that it was common for children in classrooms to talk aloud to themselves. For many people such a process is helpful in clarifying thinking. For others it is an automatic response that may not be a conscious action. This is evident when people become embarrassed when someone catches them talking to themselves. Such an incident frequently results in a joke or a self-deprecating comment. The dyad context appears to provide an opportunity for talking aloud without feeling self-conscious or inappropriate, even when the talk was not directed to a partner. While Nuthall and Alton-Lee noted that talking to oneself happened frequently in classrooms, this was often a feature of the hidden or covert

curriculum of the classroom. Nuthall and Alton-Lee had the children in their study wear personal microphones to detect speech that would not be audible to a teacher or researcher. Nor would the speech be audible to many of a child's peers. The talk that occurred in the dyads was audible for both children so they were aware that what they said would probably be heard by their partner. This did not seem to diminish any self-talk but that does not preclude the chance that self-talk was somewhat inhibited by the presence of another.

The benefits of verbalisation in learning has been discussed extensively in the literature. Many learners (both adults and children) use self-talk in particular, to make sense of, or monitor, what they are doing. Vygotsky (1934/1962) stated that directing talk with another at oneself was part of the development of egocentric language. This language is used to monitor one's own actions which appears to be evident in this study. Vygotsky claimed that this process of talking to oneself in a social context conveys the intrapersonal and interpersonal role of language. This challenges Stables's criticism that children's talk in groups can result in "insufficient time for reflective thinking by individuals" (1995, p. 61). In cpds there was some evidence of children having a personal dialogue or thinking through ideas for themselves. Furthermore, Vygotsky argued that egocentric language of this nature contributes to the development of inner speech. Vygotsky explained that inner speech is "almost without words" (p. 145) in that it is concerned with semantics or the sense of a word rather than its literal meaning. It is difficult to ascertain with any certainty the extent to which the children may have developed inner speech. What Vygotsky suggested, however, is that their apparent use of egocentric language can be transformed into inner speech.

In addition, overlapping talk was a common occurrence. Even though etiquette and social expectations convey the belief that people should speak one at a time, this seldom happens in practice. Tannen (1990) found that overlapping talk is common in conversations and can be an indication of enjoyment, empathy and positive social relationships. She differentiated between overlapping which is successful and unsuccessful. Successful overlapping was defined as talk where speakers did not feel dominated but able to engage or ignore at their own pace. Energetic overlapping in such situations was tolerated and enjoyed if the speakers elaborated on a topic rather than changed it. Tannen defined unsuccessful overlapping as differences in conversational style where a fast-paced speaker interrupts and overlaps with a considerate speaker who might pause a lot. In such cases the momentum of the talk can be disjointed and communication can be difficult for both speakers in a dyad.

Energetic, fast-paced communication was particularly evident in the discourse of Megan and Linda who identified themselves as friends. The overlapping of talk which occurred did not seem to detract in any way from their collaboration on the problem

solving. As Tannen suggested, this was evident when the girls' talk elaborated on a shared point. There was less overlapping with the other dyads. This could be a result of their less familiar relationship. The other dyads choose to work with each other but were not "best" of friends.

What was different from Tannen's findings is that the dyads sometimes began to speak as one person, whether they overlapped their talk or not. This occurred when the children were in accord with their strategy for solving the problem and worked in concert rather than in parallel. This phenomenon could result from the shared pursuit of a problem so that the discourse reflects the coordination of problem solving process. Such a feature is quite different from turn taking or taking complementary roles as suggested by Forman (1981).

Two children adding to each other's sentences suggests an engagement of minds as well as language. The times that this occurred indicates a connection between the children that was not orchestrated but emerged during the process of problem solving. Clarke and Helme (1997) also found that one child would sometimes complete the sentence of their partner during collaborative problem solving in mathematics. Clarke and Helme claimed that this talking as one person is possible when the children share understanding of process and meaning. Prisk (1987) also noted incidents of young children speaking as one person where "the children did not seem to be fighting for the floor; they were creating a single story together" (p. 95). Such a phenomenon also suggests that the children build a shared language and understanding during collaboration of this nature. Clarke and Helme highlighted the intersubjective role of language as "a phenomenon of social interaction" (p. 118). The sharing of language in this manner was more likely to occur when the dyads used sense-building discourse which is not surprising.

Similarly, there were a number of instances in the data where the children borrowed each other's language. Such mutual use of certain phrases indicates a shared language and culture of problem processing. The most vivid of these episodes was the use of the metaphor of hammers and nails by Megan and Linda during their collaboration on *Make 23*. The way in which they created and shared language is discussed in detail in the next section. The sharing of certain phrases and key words by the children indicates the influence they can have on each other's vocabulary and also on the ways in which they perceive a problem. To borrow each other's phrases indicates a merging of sense-building. It indicates a strong mutual understanding between children.

The mutual sharing and borrowing of language between children during problem solving appears to be characteristic of what Holton, Anderson and Thomas (1997) termed, joint ventures. In these interactions, ideas proposed by one child were acknowledged and developed by another child. Holton et al. found that such

interactions "were often difficult to follow and sometimes the transcripts of these sessions made very little sense to anyone but the participants" (p. 52). This issue of clarity of meaning is a challenge for researching collaborative problem solving as children can devise a language of their own that may be incoherent to others. Observing and talking with children can help to clarify their meanings, alongside the collection of any drawings or work samples. In the case of Megan and Linda with their metaphor, the imagery was powerful enough to convey meaning, even to an outsider.

Children's collaborative and overlapping talk suggests some mutual understanding. Holton et al. suggested that although such talk can be rather inefficient and a circuitous path in problem solving, the strength of this use of language is that children understand each other. Such understanding may be easier and clearer than teacher explanations of the same idea or concept.

8. Reframing Problems

One of the ways that the dyads occasionally approached a problem which was challenging them, was to reframe the problem. In reframing problems a dyad might approach it in a totally new way in order to understand and pursue it. In the following episode Megan devised a metaphor to explain her thinking about the problem *Make 23:*

L: [We've got] this side and this side but now we're getting stuck on this side so we need to move some numbers...
D: Which numbers seem to help to be moved? Which ones?
L: (No hesitation) The highest ones - nine, eight and seven.
D: Why [are the]...
M: [Are you] sure?
D: Why do you think those highest ones are important?
L: Because we've only got it up to equal 14 (the last side).
M: Yeah with these ones here. And if you add those up together (the large numbers) you'll just have the little ones because the little ones are just like...(rolls her eyes upwards) well you have a hammer, you have the big stuff for the house, big hammer (pointing to big numbers) and stuff and then you have the little nails (pointing to the small numbers) to do the job for the um, house...

This metaphor of a house and the building of it with hammers (big numbers) and nails (little numbers) emerged as a way in which Megan made sense of the problem and helped them to overcome an impasse. Just prior to this Linda had suggested that they abandon the problem and return to it later. After Megan introduced the metaphor they both returned to it with enthusiasm. Their speech throughout their interaction took on the motifs of hammers and nails as a form of code for their communication. The reframing of the problem as hammers and nails for a house, rather than numbers in a triangle, seemed to enhance their understanding and motivation for the task. What

was particularly interesting was the way in which Linda quickly incorporated the metaphor (which Megan had introduced) into her own vocabulary about the problem:

L: Maybe we should try putting a hammer each on one side so it goes from highest to lowest on each side...
M: So [we've got eight]...
L: [And that leaves the little ones] which are the nails.
M: Nine...eight for the side (putting the large numbers in the middle of each side). Well there would be two hammers on this...
L: Eight, nine um seven. I know, why don't we put the eight on a different side otherwise there would be two. We'll put the eight [here].
M: [Here] The eight, the seven and the nine.
L: I'm just writing it in real light...
M: But we'll have to do kind of um...
L: Just write it in real small um...
M: So we'll try this one here (focusing on one side). The eight and six are...(looks at Linda).
L: Um...14.
M: 14, And so eight, (whispering) we'll just write it really softly in here, what would be...eight, 16...
L: A good one there would be to put a little nail.
M: A little nail but...
L: The littlest nail...

Linda's use of the language of the metaphor (hammers and nails) was borrowed from Megan and naturally incorporated into Linda's conversation with Megan. This is a further example of the mutual use of language noted in the previous section.

Most of the discourse in this episode was of a sense-building nature as the girls hypothesised, informed, verified and deduced. A little controlling discourse was evident as Linda directed, "Just write it real small", and Megan started to counter, "A little nail but...", which in turn was corrected and confirmed by Linda, "The littlest nail". And at the end of that particular problem, Linda commented on the metaphor without prompting:

L: (Small voice) We're finished. The hammers and nails really helped.
D: How did the hammers and nails help?
M: Well, well you could say um, when you're building a really big house um you need lots of hammers to do it with...
L: You need hammels, you need hammers...
M: Yeah.
L: The big ones in the corners to keep the house standing...
M: Yeah and um, we were thinking of um... we needed LOTS of hammers but we didn't need that many...
L: Actually, we only needed three for the three corners because we need...like if we were making a triangle house, we need three big planks of wood for the corners and then...
M: Yeah so that would be, we could have...
(They talk over each other- indecipherable).
M: We could have three hammers and then you go, one, two, three, four, five...(counting the circles between the corners)
L: Six.
M: Six little nails and then you could go around.

D: I'm really interested in how you both understood what each other meant straight away about hammers and nails.
L: (Laughs).
D: And yet if I suddenly started talking to someone about "Oh yeah, those are hammers and those are nails", I think they may think I was a bit strange!
L: (Laughs).
M: (Laughs).
D: How, how was it you that you knew what each other was talking about straight away?
L: Because we've been with each other [a lot] (laughs)
M: [A long time]...

That these girls knew each other well and were friends seemed to feature strongly in their perception of their mutual understanding and the way in which they reframed the problem. Being familiar and comfortable with each other seemed an important prerequisite for collaboration and the sense-building illustrated here. That such familiarity is always a necessary prerequisite is far from conclusive, though the construction of a common interpretation seemed pivotal to their problem solving.

Megan and Linda had transformed the problem with their building metaphor which appeared to assist them with making the crucial connection between the size of the numbers and their placement in the triangle. They reframed the problem in order to make sense of it, building a shared understanding based upon building materials rather than numbers. In doing so their existing ideas were both challenged and reformulated.

A countering comment or hypothesis was the form in which problem reframing occurred. Sometimes a reframing of a problem by one child required verification and explanation by the other in a dyad. This, however, was not always the case. For example, the first problem reframing by Zane in the fuzzy problem, *Estimate the number of vets in New Zealand,* was adopted uncritically by Sam as a way to proceed. Sam seemed to readily comply with Zane's hypothesis. Similarly, Linda did not question or counter Megan's initial problem reframing (discussed above) and seemed to immediately recognise and agree with what Megan was saying.

In Sam and Zane's second problem reframing during *The Vets*, Zane countered Sam's statement to state that the difference between districts and cities was important in interpreting the problem. Sam did not automatically comply but sought further information before complying with Zane. In the third reframing the boys came to a compromise about using the population size of each city as an indication of how many vets there might be. This problem reframing of using the ratio of vets to population size emerged from countering by Sam, and hypothesising and deducing by both children. Sam's countering statement appeared to be the catalyst for collaboratively reframing the problem.

Sam and Zane emerged from that interaction with a compromise on how to proceed with their new strategy, using the relative sizes of the cities as a guide.

Problem reframing also appeared to encourage one child to adopt the other child's strategy, not in an uncritical imitative sense but after the verbal exploration of the reframed nature of the problem. This adoption of the other's strategy was also evident in the discourse between Megan and Linda. After Megan reframed the problem *Make 23* as hammers and nails, Linda used this metaphor as part of her language in the problem solving.

When the children reframed a problem they did so by controlling (through countering) or sense-building (through hypothesising). Compliance was high when one adopted the other's strategy and when they compromised. Acceding, however, was not always an uncritical acceptance but was usually connected to seeking to verify the reframing. With children such as Megan and Linda, however, who understood each other well, such verification appeared to be superfluous.

In most cases problem reframing lead to an agreed strategy for a dyad, but not necessarily to an agreed solution. When Hannah and Melanie discussed *The Vets*, they also reframed the problem by using cities as a guide for the number of vets as Sam and Zane had done:

H: It depends how much countries there are...cities there are.
M: There's quite a few.
H: How many cities?
M: I know quite a few (lists some she knows - Invercargill, Dunedin, Auckland, Tauranga)
H: So big cities have quite a few.
M: But there's not all vets like SPCAs are like vets but not really. And there're some little pet shops like in Tauranga.
H: I suppose the cities might have three or something.
M: Auckland would have quite a few.
H: Yeah. Depending on the number of vets around the country...
M: But Hamilton only has SPCA and pet shops.
H: But pet shops aren't vets.
M: I think there might be 50.
H: In all of New Zealand? Depending on the number of towns and everything there might be 1000.
M: I doubt it, more like 100, 200.
H: Well Morrinsville is a town and I know a vet there.
M: But it's quite a big town. What about Paeroa?
H: That's too small. I'm not counting them, I'm counting the big towns and cities. I think there'd be about 1000.
M: I think 200...

In this episode the girls' reframing did provide a strategy but not a collaborative process of problem solving based on their strategy. Hannah focused on the cities and the possible ratio of vets to cities. Melanie seemed to follow this reframing at times, "Auckland would have quite a few", but became concerned with pet shops and the Society for Prevention of Cruelty to Animals (SPCA). She stated that Hamilton only had these and ignored Hannah when she countered that, "pet shops aren't vets." Their

subsequent discourse consisted of controlling statements as each countered the other's statement, followed by separate hypotheses with no justification of these. They appeared to make broad guesses as to the total number of vets without systematically pursuing a strategy to support their estimates. Their attempts at justifying an approach did not develop as they tended to counter each other's statements with little in the way of explanation or verification.

8.1 Discussion

For a problem reframing to be collaborative, there needs to be some joint commitment to the reframing and the incorporation of the reframing in the children's problem processing together. If they work separately on a reframing of the problem there is little need to draw upon each other's ideas or insights. A certain reciprocity is required. Westgate & Hughes (1997) argued that

> ...this notion of reciprocity emerges as a common criterion for 'good quality' talk in a range of contexts. The degree to which participants listen and build upon each other's contributions is seen as pivotal, especially in small-group talk...(p. 132)

This criteria of "good quality" talk seems to be relevant for problem reframing. The "success" of the reframing often seems to depend upon the extent to which both children embed their ideas about the problem into an accessible and illuminating narrative form. By the word "accessible" I mean that both children need to understand the metaphor, or analogy, or story, that is used to reframe the problem. By the word "illuminating" I mean that the narrative used should clarify the problem and aid its solving.

When a problem was reframed by the children they used a form of narrative. This narrative form does not have to be a story in the traditional sense but can include metaphors, analogies, a chain of events and explanations about those events (Bruner, 1996). The reframing attempts made by the children appeared to illustrate ways in which they explored some of the problems in personal ways. These reframings appeared to be a vehicle through which the children searched for meaning, structure and resolution.

The reframing of a problem may be the key to its solution. For example, the problem of losing weight can be reframed as identifying healthy food such as fruits and vegetables. The reframing from weight loss to food shifts the focus from what was problematic to what can be the solution. Reframing or redefining the question or problem has the potential of providing a solution, or new path to follow. The process

of reframing can hold within it the elements required to construct an answer to the problem at hand.

When the reframings assisted a dyad with their problem solving process there appeared to be enjoyment and persistence shown by the children. Such reframings also involved the children in reshaping problems to make them new, or at least, create ways in which the problems could be played with, teased out and possibly solved. The striking use of a metaphor by two of the girls proved a powerful way for them to visualise and clarify the problem. In doing so, the girls created an original way to restructure the problem so that it became their own interpretation. This appears to be the value of such narratives. Smith (1995) stated that

> In the process of acquiring skills and information children transform them. When children are involved in social interaction they ignore some aspects of situations and participate in others and they change what they participate in to suit their uses. They forge new connections and reformulate existing ideas. (p. 9)

Reframing problems is a palpable way in which children can transform information and make new connections. Smith argued that collaborative dialogue, such as the girls' metaphor, "is a rich context for creativity" (p. 9). The results suggest that the problem needs to be accessible, interesting and challenging to warrant the need and opportunity to reframe. Reframing the problem can assist in clarifying a problem or suggesting a way to solve it.

Sociocultural theory supports this concept of children collaboratively and actively constructing meaning through reframing or narratives. John-Steiner and Mahn (1996) argued that the sociocultural perspective acknowledges a range of ways in which knowledge can be created, constructed, and altered through interaction. They argued that children can both inform each other and transform the task at hand through interactions of this nature. The theme of reframing supports this concept as the children seemed to transform some problems with their original reframings, and these reframings often enabled the children to inform each other. Yackel, Cobb and Wood (1991) concurred that such dialogue between children can serve to develop and negotiate their thinking.

It seems particularly useful that children draw upon their own words, images, experiences and imagination to construct their narratives. In doing so they are owning the process of problem reframing and solving. It becomes more than just some numbers to work with or some puzzle to fix. The use of narratives could, in the best circumstances, provide an insightful way for children to retell and explore problems for themselves. In doing this with a partner they can learn to understand another's perspective or they can communicate their own reframing. This appears to be akin to Graves (1996) concept of children learning from each other's partial knowledge in

cpds. Graves stated that such communication can be challenging for children. Interestingly, however, some reframings did not require explanation. The communicative power of the narrative used was often sufficient to convey what was intended.

It may be that friendship contributes to the use of such narratives. Linda and Megan were good friends and this seemed to contribute to the relatively easy way in which they devised and incorporated their reframing of the problem. They appeared to understand each other and communicate well which are hallmarks of the interpersonal skills of friendship (Townsend, 1992). Furthermore, friendships can engender sociability, enjoyment and tolerance. Such cooperative skills are claimed to enhance collaborative problem solving (Bennett & Dunne, 1990). The enjoyment and tolerance of a problem reframing seemed to occur with Megan and Linda. The other reframings reported in this study were somewhat less "dramatic" and were not devised by children who identified themselves as friends. It could be that friendship enhances the use of such problem reframings where there are higher levels of support and acceptance than in non-friendship dyads. This does not rule out the possibility of effective problem reframings amongst non-friendship dyads but it suggests that such dyads may require encouragement and guidance with communication skills.

Just what makes a reframing collaborative and useful for both children in a dyad is still unclear. While it can be construed that familiarity with each other helps there is also likely to be the need for narratives that communicate key ideas well. If the narrative used is too diffuse and broad it may dwindle away as a aimless plot that is never resolved. The narratives that seemed to help the children's thinking appeared to be those that created some order out of chaos.

Problem reframing through narrative shows how children can compose an innovative, non-routine response to a problem. This process requires that children are active searchers of understanding (Dewey, 1933) which is encapsulated in the problem reframing process. Dewey stated that during problem solving children needed to tolerate a certain amount of uncertainty and doubt. While this point is not disputed, it seems that the process of reframing can act to redress this anxiety and doubt. When the children worked with a mutually acceptable reframing of a problem they appeared to be motivated by their new way of viewing a problem. In such cases, a problem became something personalised and familiar to them rather than an exercise "out there" to be sorted and solved, but not necessarily understood. As Runco (1994) stated, "But curiously, it may not be the problem that is motivating them. In fact, it may be that they are creating the problem" (p. 278). During problem reframing there is a sense of this phenomenon. What was motivating for the children may have had little to do with a problem itself. The motivating aspect could well be how the children reframe or create a problem.

The concept of problem reframing has some similarity with the concept of problem construction. Mumford, Reiter-Palmon and Redmond (1994) claimed that problems are not inherent in situations but rather, problems are constructed by individuals in particular contexts and situations. They emphasised the active human interaction which defines problems. When children work together on a problem and reframe it in their own unique and mutually acceptable way, they are socially reconstructing an existing problem. This is somewhat different from individual agency in choosing and determining what problems are. It implies that problems, through narrative, can be socially mediated. The problem itself becomes dynamic and open to change, not static and restricted.

9. Peer Feedback: Tutoring, Explanations and Corrections

It should be noted that the children were not trained as "tutors" and therefore any instances of tutoring reported here was incidental and unpremeditated. It may be more accurate to use the description, "peer explanations and corrections" but the word tutor is used for simplicity. The role of tutor, therefore, was an informal position that arose during the children's interactions, rather than a role that was defined, prepared and practised. The role and influence of trained peer tutors is discussed in detail elsewhere (e.g., see Topping, 1994). This section also reports on episodes where the children corrected each other (without explanation or clarification) and episodes where they discovered errors together.

The dyads were of similar ability and therefore the knowledge differential between the two children in a dyad was not marked. This was a deliberate aspect of the pairing of children to reduce the possibility of one child dominating the discourse. Incidences in the data of peer tutoring, however, emerged in a range of circumstances. In such circumstances it was not always the same child in a dyad who took the role of tutor. The role of tutor was occasionally exchanged during a particular problem. In the first example, Sam and Zane debated the meaning of "average" in the problem *How far do you walk in the average week?*:

S: That's four days ay?
Z: No, that's five.
S: No four is the average.
Z: I don't get that.
S: There's three on each side, one, two, three and five, six, seven. So four is the average.
Z: So you think that we walk four kilometres in each week?
S: No, that there's four days in the week.
Z: No, that's the median to work out four. No she means average - what is the average distance you walk.
S: I reckon four, see. (writes down one, two, three, four, five, six, seven and draws arrow to four).

Z: I think what she means is that some weeks you might walk eight miles and some weeks you might walk 10 miles and some weeks you might walk 15 miles...

Sam later accepted Zane's explanation and their joint understanding resulted from this initial disagreement. The discourse in this episode was typified by controlling talk with each child countering and correcting the other. While Zane was peer tutoring in this episode, this was not his role in all of their discourse or in all of the problems. While these boys were unlikely to actively seek clarification from each other they were usually able to explain their reasoning clearly if they had a contrasting point of view. The following episode shows how the role of peer tutor swapped to Sam in the problem, *Jill and the wheels*, as he clarified for Zane how many tricycles and bicycles they would need:

Z: You'd have to get nine each. No, nine bicycles.
S: Yeah but six tricycles. Nine bicycles and six tricycles.
Z: What's wrong with that?
S: No, nine bicycles is 18 and six tricycles is 18. You could go four tricycles, that's 12...

Zane proposed a hypothesis that nine bicycles were required. He thought that nine bicycles would suffice but the question asked, *Jill saw some friends on tricycles and bicycles. She saw 18 wheels. How many tricycles and bicycles did she see?* Sam acknowledged Zane and added an alternative stating that it could be six tricycles to make the total of 18. He also corrected Zane by inferring that counting bicycles or tricycles alone does not answer the question. Instead, he proposed that they start with only four tricycles. Of further interest in this episode is that once Zane understood what Sam explained, he used Sam's approach to solve the problem:

Z: One four-wheeler would help.
S: Or a unicycle (laughs).
Z: You can't have one of them. Four tricycles is 12 which is how many left...?
S: Which is six wheels left.
Z: Which is how many bicycles?
S: Which is...(appears to be pondering answer)
Z: Three bicycles.
(end of discussion)

After some playful, alternative suggestions (a four-wheeler and a unicycle) Zane suggested four tricycles. This suggestion provided a way to solve the problem as they worked out that the six wheels left over would match with three bicycles. After Zane's initial confusion, he became the instigator of a solution to the problem. Sam proved helpful in clarifying what the problem meant and providing some responses to Zane as he sought information and verification. Once Zane understood what the

problem was asking and once they had experimented with an answer, he was able to deduce an alternative strategy that did work.

Sam and Zane often asked each other direct questions during their problem solving. They seemed to be comfortable with seeking information or verification from one another and often incorporated the information their partner provided into their problem solving. The role of "informer", like the role of tutor, was not confined to one child throughout but was exchanged between the boys. The following episode from *The Vets* exemplifies this:

Z: Do you know where Plymouth is?
S: Where?
Z: It's in England.
S: Is Abel Tasman (a city)?
Z: That's a bay.
S: Fiordland? Have you got that?
Z: No I haven't. I've got Invercargill...
S: Morrinsville? Is that a main city?
Z: No way. Oh Thames is.
S: Yeah, write it down. What about Coromandel Penny-sulya?
Z: PeNINsula. I don't think so.
S: What about Kaitaia?
Z: Never heard of it.
S: It's right at the top of the North Island...

For most of this episode, Zane either gave information or corrected Sam. Sam requested information directly from Zane by asking questions. Zane also corrected Sam directly, "that's a bay", and indirectly, by not writing down Fiordland as a city but telling Sam he had Invercargill instead. For most of this exchange Sam played the role of seeking information or verification and complying, until the end of this extract where suddenly, he became the informer, by telling Zane where Kaitaia was. This exchange of roles was common in their discussions. There was no debate about the information provided which could intimate trust and respect for each other's knowledge, even when that knowledge was inaccurate (e.g., Thames as a major city).

There were instances, however, of the children checking out their partner's ideas. Also with the problem, *The Vets,* controlling statements appeared to be significant for Sam and Zane in terms of both interaction and thinking. For example, Zane countered Sam's suggestion of the Bay of Islands as a city, explaining that it is a district. Rather than passively complying immediately to this correction, Sam located an atlas to verify Zane's claim. They then come to an agreement with the aid of the atlas and a demographic symbol as to what constitutes a city. The instances when one child's hypothesis was countered by the other had differing results. The child who was challenged did one or more of the following:

- sought further information

- explained their reasoning
- discovered new relationships
- adopted a new strategy
- complied or appeared to ignore
- compromised
- counter challenged

This range of possible responses indicates that the children did not always passively accede to their partner's suggestion.

It could be assumed that controlling discourse might be prevalent in episodes of peer tutoring (remembering that the children had not been trained as tutors) as a tutor countered, corrected or directed their partner. This, however, was not always the case as illustrated during an interview with Andrea and Ross:

R: Except I don't mind if it's the nine times tables 'cause I have a special way of doing it.
D: What is your special way?
R: Well say you want six times nine, you go up to six times 10 and then take away six and you get 54 which is the answer to six times nine.
A: Oh wow! Does that work for them all?
R: You try one Andrea.
A: Um...nine times seven...that's 10 times seven which is 70 minus seven which is...63! Yeah! And another child taught me the three times tables. It was so clear when they explained it.
D: Why was that?
A: I don't know. It just clicked in my head. And it's the same with division. I understand it more when another child talks about it...

Ross made his strategy explicit for Andrea who then excitedly applied it. She went on to recall instances of peer tutoring and the effectiveness of it in terms of clarity and improved understanding for her.

Sometimes the peer feedback seemed to be just the correction of an error in computation or semantics, rather than a clear explanation by one child to another. For example, in the following episode Hannah corrected Melanie's estimate in the problem, *How far do you walk in the average week?*:

M: I think I walk about a kilometre every day. So that's about 700 kilometres a week.
H: SEVEN HUNDRED kilometres!
M: I wrote seven kilograms a week! (laugh). Kilometres are quite long you know. Andrea has to bike two kilometres a day to her house...

While Melanie did not directly acknowledge Hannah's correction of her statement she did write down seven, instead of 700, and also corrected herself about the use of kilogram instead of kilometre. It could be that the first correction by Hannah helped

Melanie to make the next correction also. Not to be outdone, Melanie informed Hannah that, "kilometres are quite long you know", and provided further information about how far Andrea bikes from home. There is a sense here that the peer tutoring is not a "one-down" relationship with the tutee being dependent on the tutor. There appeared to be a consideration of the new information provided and then movement onwards with the incorporation of this.

Another example of a minor peer correction was the feedback Ross gave Andrea during their work on, *Going to the fair:*

A: That's 10 already gone (referring to how much it cost them to get in i.e., $5 each). Put 10 and then put 20 (instructing Ross what to record on paper). Put $10 and then, you need to put it properly (meaning the decimal point and the place holders for the cents). Then 2.20 under it, then 2.20 and 2.20 is 4.60 - that's 4.60 gone.
R: 4.40.
A: Yeah, each.
R: Each...

Ross corrected Andrea's computation which she seemed to immediately recognise and accept. She complied with Ross's correction and added that the four dollars 40 cents would be what each child had left. Ross then confirmed this by repeating the word "each". This exchange indicates that they were monitoring and checking each other and that this seemed to be a helpful and affirming process. As with Hannah and Melanie above, there was also a sense that they were maintaining some momentum or at least, keeping focused. It could be argued that such minor corrections may slow the problem solving process down but this did not seem to be the case. In fact with this problem it was important that their computations were accurate.

It is not always clear that one child is tutoring another as often a minimum of explanation was required. For example, in the following episode Andrea and Ross discussed, *How far do you walk in the average week?* Andrea both corrected Ross and provided information for Ross:

R: How far is it to Westside from here?
A: It's only five minutes. It can't be very far. Not even a kilometre.
R: That's why I'm trying to think.
A: Now hang on, what's halfway for me? I think yours would be about a quarter of a kilometre.
R: Seven times...
A: Five times, you don't walk to school in the weekend.
R: What do I put for half a kilometre?
A: Point five. One point five kilometres a week (laugh). Very unfit!
R: Then add a bit more for walking around for the time at school.
A: (Laughs) That's not much!
R: No.
A: Unless it was Falmer High. Unless you went on a hiking trip but you don't do that in an AVERAGE week. That says average...

In this episode Andrea often used controlling discourse by correcting and countering Ross's statements. Her sense-building comments related to those times in which she provided information for Ross after he directly requested it. Andrea's control of the discourse was particularly apparent when Ross suggested they incorporate some of the distance they walked at school and Andrea dismissed his suggestion with a laugh. She then went on to explain why she had dismissed it, which effectively terminated that line of argument.

When one child corrected another it was not always done with diplomacy regarding the feelings of their partner. In the following episode Hank and Ropata discussed, *Jill and the wheels*, and during the observation of these boys it seemed that Hank became frustrated with Ropata's counting of their sets of wheels which they had drawn to solve the problem:

R: I'll, I'll make the wheels (Ropata draws wheels with spokes at the top of the piece of paper they share. Hank meanwhile writes a line of numerals in multiples of three to make 18. He then draws nine sets of two circles to also make 18 and circles one set. He sees what Ropata is doing on his part of the paper and leans across to join in. As Ropata draws the wheels, Hank puts some spokes in and puts circles around sets of three and sets of two. He also writes underneath their drawing the numerals 3+3+3+3+2+2)
H: Three, six, nine, 12 (counting the tricycles they've drawn), 13, 14 , 15, 16 (and the bicycles)...oh yeah. (They both realise they are short of 18 by one bicycle or a set of two wheels). Ropata draws more wheels and Hank scribes the last numeral to add to the equation he had started. It now equals 18 but he does not write the 18)
R: Now, 3, 6, 9, 12 (counting all the sets), 13, 14, 15, (becomes careless)16, 18, 19...21!
H: NO, you counted that (one of the sets) TWICE. (Points to their drawing and states) three, six, nine, 12, ...
R: 13, 14...
H: 15!
R: 15, 16, 17, [18!]
H: [LOOK!] 15, 18.
R: (Ropata looks at Hank). 12, 13, 14...(checks again counting the wheels in their drawing) 16, 18 (sounds resigned).
(end of discussion)

Hank virtually shouted at Ropata as he corrected him, counted with him, and demanded that he looked at how he was counting their sets of wheels. While Hank pointed out Ropata's error in counting, Ropata did not seem to enjoy being corrected judging by his resigned tone of voice. Interestingly, this was the one dyad that had received some instruction by the class teacher on how to work together. Ropata complied with Hank's correction but it is not clear that he understood what he had done even when he did count correctly at the end. From the audio-recording Ropata almost sounded disappointed that Hank appeared to be right.

The apparent lack of empathy for the feelings of a partner during this episode may be attributed to Pryor's (1995) thesis that boys tend to be more task focused, than partner focused, during collaborative problem solving. Even when children are well acquainted with each other and have had training in how to collaborate, there is no guarantee that their interactions will be affirming or diplomatic. What is interesting in this episode is that at least Hank did take the trouble to show Ropata where the error was and did not merely tell him the answer with no explanation. Nor did Hank dismiss or ignore Ropata. Hank's effort in demonstrating to Ropata provided enough information for Ropata to see where and how he had miscalculated. The video-recording also revealed some further information regarding their interaction. As Ropata began to draw the wheels Hank pursued his own strategy on their shared piece of paper. While they were working on the same problem they were not working with each other until the moment that Hank joined Ropata and circled his sets of wheels. Hank suddenly seemed to be interested in the way that Ropata was depicting the problem and helped Ropata to illustrate the sets of wheels. This appeared to be the crucial moment when the boys started working together collaboratively on the problem. As Ropata finished drawing wheels Hank then complemented Ropata's diagram with a matching equation (see Appendix G).

Perhaps it is not that Hank and Ropata are more task focused than any of the girl dyads, but rather, that they seemed to interact differently. Part of this difference may be attributed to the large incidence of controlling discourse during their interaction. It is not possible, however, to draw conclusions regarding gender on the basis of this small sample. There was also little dialogue between the boys compared to their actions as evidenced in the extract above.

Hank's apparent frustration with Ropata near the end, did not appear to be related to their process of problem solving but rather, appeared to be impatience with Ropata's inaccurate counting. Hank appeared to willingly join in with the diagram Ropata started. He also showed me at the end how there could be more than one way of solving the problem if you circled the wheels differently to make six bicycles and two tricycles. It seemed, therefore, that his annoyance came from Ropata's addition error. Hank seemed to like the drawing they had constructed and perhaps he felt it was so clear that he could not understand how Ropata could miscount.

There were many instances where the children appeared to collaboratively correct themselves. While the actual correction may be made by one child, the preceding comment of their partner seemed to provide a catalyst for this correction. There also appeared to be joint confusion to begin with and the subsequent correction emerged during the children's interaction. In the following episode, Hannah and Melanie discussed, *How far do you walk in the average week?* and for some reason they

interpreted the question as asking, How much time do you spend walking in an average week?:

H: Well I walk for 50 minutes.
M: In a whole week?
H: No, a whole day. So if we add seven, I mean times seven...no five.
M: It takes me five minutes to get to school but sometimes I go to the supermarket and sometimes the park...
H: I don't walk much 'cause I'm a lazy pig.
M: You're what?
H: A lazy pig! (laughs).
M: I think the average day is 12 hours a day, no, an hour a day.
H: But at lunch time you walk a whole lot and that's an hour.
M: It would be at least five hours I think.
H: Six?
M: Four and a half. I don't know. Put down five hours times seven.
H: No times by...seven. That's 42 hours a week.
M: For me it's 35 hours and a half. But we don't know for sure. (Reads question aloud again) How far do you walk in a week...
H: How FAR? Oh, that's how LONG.
M: Like a metre or something. I think I'd be walking about one kilometre, not. Oh, about 50 metres to school...

When Hannah heard Melanie read the question out she self-corrected, realising that the question asked them to consider the distance, not the length of time. When she corrected their misinterpretation Melanie responded immediately with an example to support the new interpretation, "Like a metre or something". The girls then proceeded to focus on distance for the remainder of the episode. This is distinctly different from peer tutoring as the children shared both the initial misinterpretation and the subsequent correction.

Megan and Linda also clarified their interpretation of the problem *Make 23*:

L: [Oh, one, two, three, seven, six]
M: [So that's three, six, seven]...that's 10.
L: 10...there but...(realising that they need more than 10)
M: What did we have to add up? To 23?
L: Oh (laughs). So it's kind of like moving around and stuff. So they're not in order.
M: OHHHHH (rolls her head) right.
L: OK...(they both talk over each other and it is indecipherable)...

It appeared that both girls were confused about how to approach the problem. Their first attempt at placing the numbers on one side of the triangle only added up to 10. Linda seemed to realise straight away that 10 was not enough. Megan then questioned what they were aiming for with each side and after she suggested 23, Linda realised what they needed to do with the numbers. Her comments indicated a sudden awareness and understanding of what was required, "Oh (laughs). So it's kind of like moving around and stuff. So they're not in order". In response to this

comment Megan complied as she seemed to recognise what Linda was explaining. While Linda made the correction and clarification it seemed to emerge during their dialogue, rather than be something she knew from the outset. Their initial attempt which added to 10 made them both realise that they were rather short of the needed total. There was a sense that Linda's clarification aided them both and was not one child informing the other with her prior knowledge.

Sometimes the corrections the children made seemed to occur simultaneously. In the following episode Sam and Zane realised that a hypothesis Sam made during *Jill and wheels* was not going to work:

S: OK, six bicycles, three tricycles?
Z: Yeah (writing).
S: OH! (reads it out and recognises that it won't work).
Z: That's not right.
S: That can't be right. How about...

In this episode, Sam's realisation is confirmed by Zane. They both discerned the inaccuracy of Sam's hypothesis. Zane claimed it was "not right" and Sam complied with this adding that it "can't be right". This indicates that he was not merely following Zane's judgement but had seen the error for himself. In this instance the boys seemed to be thinking through the hypothesis independently but in concert. This provided a "double-check" on Sam's guess.

9.1 Discussion

Correcting a peer is different from explaining a concept to a peer. Explanations are usually intended to provide clarification whereas corrections do not necessarily inform the receiver. The peer interaction which showed instances of children tutoring each other usually took the form of explanations but sometimes comprised corrections.

As evidenced in the writing and editing process, a peer will often pick up errors that the writer does not discern as it is difficult to see one's own work clearly. As human beings we say and write things that we do not always mean. We do not always hear or see what we have stated in error. When a peer corrects or reflects this back at us we often see the error immediately (and wonder why we did not see it before). A partner in this case, can act as a mirror, reflecting our words and ideas back at us. Such a mirror can aid in the process of self-correction as evidenced in a number of episodes with the children.

This disputes somewhat Webb's (1991) claim that being told a correct answer with no explanation is negatively related to achievement. Sometimes the children did give each other answers during the process of their problem solving. These answers, however, were not the final solutions but rather, were responses or suggestions

during the solving. It depends upon what Webb meant by "answers" and what point in the process answers are communicated. In the midst of their problem solving, the telling of answers or the correcting of each other was often a helpful spur and seemed to aid momentum. There was also a sense that the children provided a monitoring role for each other, checking, confirming or dismissing contributions to the problem solving. Correcting each other often helped in the elimination of possibilities.

It has been claimed that well timed explanations by peers which are relevant, required, and understood by a peer, are beneficial for learning (Vedder, 1985). According to Webb (1991), the strength of peer explanations lies in their immediacy and a peer's use of easily comprehended language. There were a number of episodes where a child would ask for clarification from his or her partner (e.g., see Sam & Zane) and the explanations given appeared usually to be understood. Andrea seemed to summarise the power of a peer's explanation when she stated, "I understand it more when another child talks about it." There were exceptions to this though. It is not clear whether Ropata understood Hank's correction or not as he tried to show Ropata how he had miscounted the sets of wheels. While Ropata recounted the sets of wheels, following Hank's instruction and came to the "correct" answer, he could well have been imitating Hank rather than understanding him. While Hank tried to explain to Ropata what he did wrong, and demonstrate how to count correctly, this was no guarantee of Ropata's understanding. It seemed clear, however, that Ropata understood the process they used as he had instigated the drawing of sets of wheels to depict the cycles. This strategy conveyed his understanding of the problem and how to solve it which is more significant than counting correctly.

Explanations and corrections were not always clearly articulated or helpful in terms of the problem solving. For example, Andrea dismissed Ross's suggestions with, *How far do you walk in the average week?* with a curt comment and Ross quickly relented. There was no discussion of Ross's suggestion and no elaboration on why Andrea felt it was unnecessary to pursue it, other than she thought that the time walking around at school would not amount to anything worth counting. In this instance, Andrea and Ross seemed to match what Stacey (1992) found with many of the groups in her study who did not explain their doubts in any detail and tended to pursue easy solutions. There was also an unquestioning acceptance of incorrect ideas with Sam and Zane in *The Vets,* but this was not typical of their discourse. These boys readily questioned each other and were unlikely to accept ideas at face value. Their unquestioning acceptance seemed to have more to do with maintaining the momentum of their problem solving during that particular problem. The fact that these instances occurred during two fuzzy problems suggests that the difficulty of these problems may have influenced the children's behaviour. Perhaps they are less likely to discuss, justify, question and elaborate when the problem is ill-defined. Perhaps

the semantics of the problem dominates the children's thinking and narrows their options for investigation.

The role of "expert" was often exchanged during the problem solving, occasionally within a problem and often between problems. This exchange of roles has been noted by Lyle (1996), McCarthey and McMahon (1995), and Pryor (1995) who argued that the opportunity for leadership and tutoring is fluid and dynamic within symmetrical dyads. The influence of a partner, however, can be quite subtle. The earlier discussion about persistence (section 4), and types of talk (section 7) indicates that something other than peer tutoring, is occurring beneath, or alongside, the overt behaviour of explanations and corrections. The notion of an expert and their role as tutor is one feature in dyad collaboration but not the only significant one and certainly not a constant feature. The notion of a persistent partner or a collaborative talker may be just as significant, particularly when the children in a pair are of similar ability.

Some of the children's corrections and feedback seemed to occur simultaneously. It was as if they had come to the realisation or insight that the path they were pursuing was flawed at much the same time, and their shared acknowledgment of this confirmed their decision. This feature of peer feedback could be added to the description of a joint venture which Holton et al. (1997) identified. In joint ventures children negotiate ideas and collaboratively pursue lines of inquiry. The results in this section also suggest that ideas can be collaboratively eliminated or corrected in a joint venture. Such interactions are distinct from peer tutoring in that there is not the same sense of one child informing or instructing another. There is more mutuality in the relationship and less deliberate tutoring. The "checking" role that a peer plays can provide helpful reinforcement of the line of inquiry.

10. Returning to the Research Questions

The following sections return to the initial research questions which emerged from the review of the related literature. The three questions relate to the central concern of this thesis which is the nature of the processes of collaboration in children's mathematical problem solving. The first two questions relate to collaboration and the processes involved. The responses to these, therefore, are in terms of that focus. That is, I do not discuss in depth the times that the children did not collaborate at all. The responses to the third question, however, do refer to times when the children did not collaborate or collaborated minimally. Each of the research questions is discussed in turn.

10.1 What characterises a collaborative peer dyad (cpd)? What is educative about a cpd?

The foremost characteristic of a cpd is that it is not consistently collaborative. This may sound contradictory and in some ways it is. When the children worked together in pairs they did not always collaborate but moved between individual agency and collaboration. The children's discourse indicated that they worked alone as well as together on many of the problems and that this oscillation was a normal and seemingly natural feature. Even when the children pursued ideas collaboratively and came to a joint solution there was usually evidence of each child voicing his or her own thoughts. These thoughts were sometimes connected to the children's joint problem solving but other times appeared to be their own individual musing, reflecting, hypothesising, and so forth. In other words, cpds do not always collaborate even when they work together on the same problem and seem to pursue a shared line of enquiry. This raises an issue about the notion of collaboration. Collaboration cannot be regarded as a constant phenomenon but rather, as something which is negotiated and dynamic during any one problem solving process between two children.

To consider the characteristics of a cpd it is helpful to return to what the literature in this area claimed.

> There have been few studies of the process which make collaborative dyads so effective. It is safe to speculate that there is a high level of elaboration between members with little potential of threat or dominance between pupils. (Kutnick, 1994, p. 22)

This quote (which was cited in the literature review) raises a number of issues. Much of the literature indicates that dyads can be "effective" in terms of cognitive development and task focus for the children involved. The reasons given include that peers have the opportunity to discuss, debate, explore and so forth with considerable mutuality and reciprocity. The power and status dynamics are claimed to be relatively equal, at least in symmetrical dyads. This study does not totally dispute this claim but it does add some caveats and additions. First, this study did not focus on assessing the children's cognitive development over time but rather on their problem solving approaches, their interactions, their constructions of meaning and their responses to a range of problems. "Effectiveness", therefore, depends upon what is being scrutinised and how that particular phenomenon (such as cognitive development) is evaluated. Rather than some measure of effectiveness, this study sought to examine the processes of collaboration when two children work together on a range of problems.

Second, the notion of a large degree of "elaboration" requires examination. Some of the elaborations the children made had little to do with solving the problem but were more to do with the problem's meaning. This was particularly the case with the fuzzy problems with some of the dyads. While they elaborated on the problem, drawing from their past experiences, the elaboration often became constrained by discussion of semantics rather than problem solving. In contrast, some of the closed problems had the opposite effect. In many cases, little or no elaboration occurred between the children. These results indicate that the degree of elaboration between children often depends on the nature of the problem they are working on. While it is tempting to claim that the more-than-one-answer type of problem was a catalyst for the most elaboration between children of both a cognitive and social nature, the children generally did not perceive the problems as having more than one answer. Rather, it seemed that the challenge and the engagement these problems encouraged was the key factor in the children's social and cognitive elaboration. The effect of the problem type is discussed in more detail under question three.

Third, the issue of lack of "threat or dominance" is borne out to some degree but is not absent. Dominance did occur but not as a static and predictable role between any two children. The roles of tutor and tutee, for example, were often exchanged during collaboration and the pattern of controlling discourse was not limited to one dyad partner. Both children in any one dyad used countering, correcting and directing discourse during most of their dialogues. This indicates that dominance does occur but is not the constant dominance of one child over another. Often, the role of dominance is swapped, negotiated, traded, asserted, countered or accepted. It was a fluid and dynamic phenomenon and it seemed necessary for progress in problem solving at times. It often helped to keep the children focused, or it helped to eliminate possibilities, or it helped to consider alternatives, or it simply helped to "edit" errors in their working. This indicates support for the role of sociocognitive conflict which is discussed in the literature (e.g., Doise and Mugny, 1984; Howe, Tolmie & Anderson, 1992; Perret-Clermont, 1980; Piaget, 1970; Swaminathan, Clements & Nastasi, 1996).

These three points respond to Kutnick's statement and signal some of the characteristics of a collaborative peer dyad. Cpds seem to encourage task-related talk when the problem is interesting and challenging. This task-related talk is particularly focused on the cognitive aspects of the problem when the problem is not perceived as too difficult. Dyads do not seem to collaborate at all on problems that are perceived as easy. A collaborative dyad is one where there is sufficient challenge to warrant interacting.

Elaboration does seem to be a characteristic of a cpd. The elaboration is part of the collaborative process. The times that the children did not elaborate were often the

times that they also did not collaborate. The effect of the elaborations were not always "educative" or focused on the cognitive aspects of the problems. This is not to say that some elaborations were still not helpful in clarifying children's understanding of meaning.

Dominance is a characteristic of cpds but not a static feature and nor is it the preserve of one child. The notion of dominance is akin to the category of "controlling" used in this study. The incidence of controlling in the children's discourse was often a helpful feature in their problem solving progress. The exceptions were when a dyad partner would effectively terminate discussion by not pursuing any avenues of exploration. Their dominance in these cases was influential but did not further the process of problem solving.

A key characteristic of a cpd, in the "best" circumstances, is persistence. The pattern of persistence and the related phenomenon of momentum which emerged was frequent enough to warrant a substantial theme of this study. The presence of a partner can sustain both interest and momentum during problem solving, even when one child in a pair expresses his or her desire to give up or expresses the belief that the problem cannot be solved. Partners in problem solving do not always guarantee persistence but there was evidence to suggest that they can be highly influential in this regard. The persistence of one child was often enough to encourage a more reluctant child to continue with the line of enquiry. This persistence was often quite subtle, such as continuing to talk about the problem and ignoring comments of dissatisfaction or frustration from a partner. It never consisted of a child voicing encouragement directly to his or her partner, such as, "Come on, we can do it". Such obvious encouragement to persist was absent from the dyads' discourse. Persistence, therefore, came about it seemed through the presence of a partner who persevered at a difficult point in the problem solving. Often the result of this was to encourage the more reluctant or disgruntled child to continue as well. The persistence of one partner seemed to draw in the other on many occasions.

Another characteristic of cpds at times, is enjoyment. Enjoyment is not always easy to identify and define but there were numerous incidents where the children reported feelings of enjoyment and expressions of delight. This was not a constant feature and was mostly tied to the challenge and interest of the problem a dyad was investigating. Even during problems the children reported to "enjoy", this enjoyment did not seem to be constant throughout a problem. Enjoyment seemed to be linked to the satisfaction of solving or the stimulation of being challenged, or both. There was also a sense that the children had made a breakthrough, had overcome a struggle and were pleased with what they had achieved. On a few occasions they expressed enjoyment even when they had not reached a solution but were still grappling with a problem. It cannot be claimed that cpds encourage enjoyment as the children may

have had a similar level of enjoyment working alone. I cannot discern whether this would be the case. What I did notice was the way in which the dyads often shared their expressions of enjoyment with each other. This mutual emotional sharing appeared to arise naturally during their collaboration. It seems very human to want to share joy with another and the sharing of it can increase the feelings involved.

Dyads which collaborate provide opportunities for children to draw upon their past experiences, share their knowledge, contest each other's ideas and investigate meaning. Dyads without sufficient challenge and impetus to collaborate do not guarantee this range of activity. Whether the opportunities are taken up depends upon a number of factors which may include one or more of the following: the children's willingness to persist in the face of difficulty; their consideration of each other's point of view; their preparedness to reframe problems for themselves; and their incorporation of ideas in the pursuit of solutions.

A cpd seems to build a shared sense of what the problem means and come to an agreed path or direction for solving it (the ways in which they made sense of problems is discussed under the next question). This does not mean that a path is not contested or countered along the way and possibly discarded. This discarding and elimination is an important aspect of collaboration in the process of problem solving. A cpd is an interweaving of personal views and ideas with collaboratively constructed thoughts and insights, not a constant line of agreement. Sometimes a cpd appear to talk as one person indicating a strong synchronisation of ideas. At other times, including during the same problem, children in a dyad take separate and parallel paths and appear not to collaborate at all. During such instances there is often an ongoing monitoring of each other or a checking back with each other alongside their parallel work.

The literature tends to polarise over the relative merits and influences of social constructivism and sociocognitive conflict with the tendency of researchers to claim the central role of one or the other in contributing to dyad efficacy. It seems that the type of conflict and the type of social construction that may occur in dyads, is more significant than whether one or the other is a crucial factor in cpds. Children's social construction of meaning is commented on below.

10.2 How do cpds construct and make sense of problems?

This study tends to support Hiebert et al. (1996) who claimed that the context of problems may be less important than the curiosity factor in eliciting children's engagement and response. Children's constructions of meaning are highly idiosyncratic and they bring a range of different experiences and expectations to any one problem. These experiences are culturally and socially determined. The actual context of a problem may or may not resonate with a child's experience. Even if it

does there is no guarantee that such a problem will be more appropriate for a child. That is not to say that children will not enjoy problems in which they recognise the context. Some children in this study explicitly stated that they enjoyed some problems that related to their lives. The sense that the children construct seemed to draw from their social and cultural background but they also showed evidence of drawing upon each other's insights and understanding at times. The actual context of a problem was just one factor in the children's understanding and response, and it was not always the most motivating factor. The most motivating factor appeared to be those problems that sparked curiosity and were accessible in terms of devising some solution.

The sense making strategies the children used were varied and diverse ranging from drawing on past experiences, using narratives to reframe problems, seeking information and verification from each other, drawing what they were doing, countering each other with explanations, incorporating a peer's idea to improve one's own, building on a peer's idea, pursuing a line of reasoning to check whether it "works", eliminating possibilities, and other strategies like this. The sense making was often both collaborative and individual with a distinct movement between these two.

Of particular note was the way in which a dyad would, at times, build a shared meaning of what the problem was asking and how it could be pursued. The category of sense-building provides some support for the theoretical notion of social construction of meaning discussed in the literature (e.g., Barnes & Todd, 1977; Forman, 1981; Forman & Cazden, 1985; Graves & Zack, 1996; Light, Foot, Colbourn & McClelland, 1988; Mercer, 1994, 1995, Vygotsky, 1978). This building was dynamic and sometimes disjointed, not a linear or necessarily methodical construction. One child in a pair would sometimes pursue their own line of reasoning but show evidence of monitoring their partner and adding to what they were doing. Other times, they would start separately and then join together in their problem solving approach. And yet, at other times they would seem to work together throughout but were in fact moving back and forth between their own reasoning and their joint endeavour.

There were also repeated instances of the children building upon each other's ideas in a way that built momentum and sometimes seemed to increase excitement. The sense-building sometimes consisted of the children talking as one person or overlapping their talk in a mutual manner. These features of their talk seemed to indicate a shared understanding of what they were doing and thinking during their problem solving.

10.3 Does the type of problem affect the way children collaborate and think?

It is acknowledged that the notion of a "problem type" is limiting. What appears to be a closed problem can in fact be open-ended, for example, 16-4= ? While the text book may have 12 as "the" answer, a number of other answers are possible, valid and "correct". For example, an answer could be a dozen, 6+6, 8+4, half of 24, and so forth. For the purposes of this study a taxonomy of problem types was devised but it is acknowledged that this is an imperfect tool that attempts to broadly categorise problems. Inevitably there are limits to a taxonomy of the type used in this study and in the use of most such lists which attempt to simplify complex phenomena. The difficulty with clearly defining problem types raises questions about Cohen's (1994) claim that closed problems are more relevant for individuals and ill-defined (or fuzzy) problems are more appropriate for groups. On the surface, this may appear to be the case but there are a number of caveats to such a claim. These cautions and some further suggestions are outlined below.

Some dyads were less tolerant of the fuzzy problems and found them less enjoyable (e.g., Andrea and Ross). Some individuals within a dyad found some of the fuzzy problems "impossible" which at times affected their perseverance and enthusiasm (e.g., Zane and Ross). Working with a peer, however, seemed to encourage the more reluctant partner to persevere with a fuzzy problem (e.g., Zane) but not always (e.g., Ross). The success of mutual support therefore seems to be affected by the problem type and the child's readiness or confidence. The more confident partner (e.g., Andrea and Sam at times) could often provide just the impetus needed at the right time for his or her more reluctant partner (e.g., Ross and Zane at times).

It appears from this study that most of the closed problems provided little incentive for dialogue. Most of the dyads found the closed problems easy (as a result of misconstruing meaning) and therefore assumed that there was little point in discussing them or investigating the problems further. This was characteristic of the closed problems, except for *Going to the fair*, with nearly all of the dyads. All of the dyads misinterpreted the meaning of two of the closed problems as discussed earlier under results. My occasional attempts in the follow-up interviews to challenge the children's thinking and construction of meaning was unsuccessful. For example:

D: Now, here's the last one (camera and case), tell me your feelings about this.
S: Easy.
Z: Very easy, like the five pills one. I waited till you finished it and I was going to say, 'cause I just read it very fast and I was going to say "Ten dollars" before he even finished reading it. But we ended up saying it at exactly the same time.

D: I notice that neither of you wrote anything down...
S: Not for that one.
Z: Zap, zap, it came up.
D: What if I was to say there could be another answer to that one?
S: I could believe you because it could be 1000 cents...

Sam was quick to reply that another answer to ten dollars could be 1000 cents, which is "correct" but not an accurate response to what the problem asked. As Holton et al. (1996) stated, "the actual wording of a problem can change the difficulty for the student" (p. 111). All the dyads assumed that the two closed problems, *Camera and the case* and *Doctor and the pills,* were easy and naturally enough expended little energy on solving them. Nor did they engage with each other in any sustained or interactive way but tended to work in parallel. The apparent ease of the problems necessitated that they did not require each other's input. Problems that appear clearly defined to a teacher or adult may be ambiguous for a student, an observation which has been previously documented (e.g., Hughes, 1986).

The problems of the camera and the doctor mentioned above were deliberately chosen to challenge the children but the semantics of the problems obfuscated their construction of meaning and became a barrier to cognitive challenge. Furthermore, unlike the other problems, these closed problems generated little discussion including little debate and minimal sense-building or controlling statements. This seems to concur with Prisk's (1987) finding that closed problems are solved as quickly as possible by children in groups with minimum discussion. The exception was *Going to the fair* where information and figures were elaborated more fully in the wording of the problem itself (see Chapter 3). This clarity appeared to aid the children's engagement. Lyle (1996) argued that task clarity was important for ensuring that children were not distracted. The children, however, did not seem to be distracted by the less engaging closed problems but rather, they appeared to respond quickly and automatically to what they seemed to think were mechanical tasks. Therefore, it seems that some closed problems support Prisk's argument but this depends on the way in which the problem is interpreted and the wording of the problem itself.

According to *Mathematics in the New Zealand Curriculum* closed problems, "develop only a limited range of skills" encouraging "memorisation of routine methods rather than consideration and reflection" (Ministry of Education, 1992, p. 11). This generalisation, however, is not always supported. It depends on the nature of the closed problem. The closed problems employed by Holton et al. (1996), for instance, do not match this pejorative description. In fact, in their study, some children devised useful and ingenious strategies in response to the closed problems. For children, many of their discoveries in mathematics are original and creative as they may be experiencing a certain process or approach for the first time. The closed problems in

my study, however, did produce the reaction described above by the Ministry of Education. The children seemed to do no more than apply routine computations, either in their heads or on paper, which did not seem to challenge them. While this appears to substantiate the Ministry's claim, the caveat to add is that most of the closed problems proved to be ambiguous for all of the dyads. Had they fully understood the problems they may have engaged in more discussion and may have employed a range of heuristics. Closed problems can discourage both learning and collaboration if they do not challenge children or are semantically ambiguous.

As mentioned earlier, some of the fuzzy problems also provoked little discussion of problem solving strategies due mainly, it seemed, to a concern for semantics (what does the problem mean?). The semantic focus often overwhelmed any other concern and became the central element of dialogue. The two notable dyad exceptions were Megan and Linda, and Sam and Zane, on some of the fuzzy problems. These children were particularly able and therefore may have had greater tolerance and interest in such problems (Maker, 1993). They spent somewhat less time discussing what the problem meant and were able to move on to devising a strategy for solving the problem and proceeded to employ it. For all of the dyads, however, what emerged from the coding was the greater diversity of language use with the fuzzy and more-than-one-answer problems, and the greater incidence of what Barnes (1976) termed "exploratory talk".

The children did engage in task-related talk when the problems were too hard but the nature of the talk, as mentioned above, was often about semantics and perhaps, a brief mention of possible problem solving approaches. A couple of the dyads did focus closely on the task with the fuzzy problems (which the other dyads seemed to find too hard) but they did not seem to find these problems overly difficult. In contrast, the children in this study hardly spoke at all when the task was thought to be too easy. It was as if they did not see the point in discussing something which was patently obvious. This contrasts somewhat with Thomas (1994) who found that the majority of children's interactions in independent group work were task-related but tended to centre on the social demands of the task. Perhaps if I was not present the dyads might have concentrated more on social demands as Thomas noted in her study. As mentioned previously, the presence of a researcher can influence the behaviour and reactions of those participating in a study. This can be magnified when the participants are children and the researcher is an adult. The children may have felt obliged to keep focused on the task since I was present, even though this was not communicated to the children. As mentioned previously, however, the smaller groupings of two in this study makes the social demands less pressing than they would be in larger groups of children working on a shared task.

The different dyads consistently rated *Make 23* as their most preferred problem in the first set. It is not embedded in any real-life context but it did provide the children with challenge (every dyad had to work at it). On the day that the children had the problem *Make 23* all of the dyads considered it their favourite, even when it was not solved. For example, Melanie and Hannah commented:

D: Was there a question you liked the best today or one that you really didn't like?
H: I really liked that one (*Make 23*) more 'cause solving problems is kind of like a hobby.
M: My favourite one was probably...that one took the most (*Make 23*)...Yeah but then I usually quite like that one (*Make 23*) because it took longer. It wasn't too easy 'cause not everyone knows the answers...

The structure of the task also encouraged collaboration as they worked on the triangular shape together to place the numbers. In the other sets of problems there was no pattern to the children's preferences but for every dyad, *Make 23*, appeared to be well received.

Their reasons for problem preferences varied but all seemed to gain more challenge at their level of interest from the ones they chose. For example: Andrea reported that it was more "interesting" to imagine going to the fair than to look at bicycles and tricycles; Melanie reported that it was a "challenge" to work out what worked with *Jill and the wheels*; and Sam and Zane reported that they "enjoyed" using the atlas and estimating with *The Vets*. Interestingly, Andrea and Ross also reported more concern with getting "right" answers and using set procedures to answer problems. A consequence for the cpds when they engaged in a problem that both challenged and interested them, was their heightened emotions evidenced in both the transcript during their working and reported afterwards in the interview. This was evidenced in the pattern of enjoyment which came through frequently with the problems that challenged the children. There also seemed to be greater need or motivation to collaborate on such problems.

With suitable challenge and interest in the problem at hand, the children seemed more likely to work collaboratively. It seemed that they often appreciated the need to draw upon each other's knowledge and insights and they also seemed to willingly give of their own. In effect, the challenge and interest of a problem appeared to encourage children to view each other as "knowledge brokers", sounding boards, mirrors, checkers, confirmers, hypothesis testers and so forth.

The type of problem is less important than the suitable engagement and challenge a problem encourages. With suitable challenge and interest children can take a "problematising" approach (Hiebert et al., 1996) to their learning through defining problems for themselves and negotiating meaning with a peer. Graves & Zack (1996)

claimed that this negotiation of meaning can bring about conceptual change which is not confined to engagement with a certain problem type.

The literature also debates the affect of the task on children's interactions. Forman and Cazden (1985) claimed that the problems or tasks peers undertake should emphasise abstract interactions rather than procedural interactions in order to be most beneficial for children's learning. Cobb (1990), however, emphasised the interaction between procedural and abstract interactions in children's discourse. This study seems to support Cobb's argument regarding the interdependent and mutual nature of procedural and abstract interactions. The children often shifted from procedural to abstract and back again in their discourse, although this would depend upon how Forman and Cazden, and Cobb, defined "abstract" and "procedural". Furthermore, the fuzzy problems were sometimes too abstract for some children which limited their engagement and did not seem to be beneficial for their learning. In terms of collaboration, a certain amount of procedural-type interaction seemed necessary to sustain their engagement with both the task and with each other.

11. Chapter Summary

The main focus of this study was the processes of collaboration when children work in pairs on a range of mathematics problems. The themes and categories that emerged provide evidence of the complexity of children's interactions with both each other and with a particular task. The central role of sense-building was illustrated through the themes of persistence and momentum, problem reframing, drawing on personal experience, collaborative, overlapping and self-talk. The categories of controlling and complying were also evident in these themes but to a lesser extent. Controlling discourse was largely predominant in the theme of peer feedback which also had instances of sense-building and complying. The themes which emerged provided an appropriate way to present the contextualised nature of children's interactions across episodes.

This study provides empirical data of children's collaborations and draws some inferences and insights from the grounded categories and themes. There is much debate in the literature about the merits of dyad interaction but little in the literature provides the detail of the actual processes of interaction as evidenced in this study. Much of the existing literature generalises about the affect of certain types of problems. In addition, it tends to base its analysis on either social constructivism or theories of sociocognitive conflict. This study found that both theories provide complementary insights.

Collaboration was not found to be a constant feature, despite what may appear to be happening in dyads. Children moved from working alone, to working with their

partner, in an iterative fashion. The type of problem was less significant than the interest and challenge of a problem, and persistence, momentum and enjoyment emerged as a theme when children were sufficiently challenged. The role of tutor was often exchanged in a cpd, and at other times, children jointly negotiated their strategies and eliminated possibilities. When they worked closely together the children in a dyad often appeared to speak as one person. In addition, the strategy or reframing of one child was often appropriated by their partner. Collaboration was non-existent when the problem was perceived as too easy. Task-related talk occurred with very difficult problems and often focused upon semantics and personal experiences.

These and the other findings detailed in this chapter, have implications for theory, classroom practice, curriculum and further research. These implications are discussed in the next chapter.

Chapter Six

Conclusions and Implications

1. Introduction

The nature of this study on children's collaborative problem solving, has a number of implications. Some of the implications are theoretical in that they challenge, or add to, debates in the literature regarding collaborative peer dyads and problem solving. Some of these are more practical or applied in that they relate to the learning of children, the practice of teachers and the development of curriculum. This final chapter summarises the major findings, explores the implications of this study for theory, classroom practice, curriculum and further research. It includes reflections on the limitations of the study.

2. Overview of Findings

In summary, this study has found that collaborative peer dyads (cpds) can encourage persistence and momentum when the problem on which children work is not perceived as "too easy" and when one child in a dyad persists when his or her partner appears to have given up. A child's persistence in the face of difficulty was often a key factor in recapturing his or her partner's interest and enthusiasm. The role of "persister" was not always the same child in a dyad. The willingness of the reluctant partner to rejoin the problem solving remained crucial in sustaining momentum in collaborative problem solving. In the majority of cases, the reluctant child did rejoin the problem solving, which indicates his or her willingness and the attraction of a persistent partner. Cpds seem to encourage this persistence which in turn, sustains both the collaboration and the problem solving. An earlier proposition which emerged during this study (see Chapter 4, section 7 for early propositions) stated that reluctance and anxiety could be overcome in cpds. What remained elusive at that early stage was how this could occur and what factors, feature or action appeared to be associated with this overcoming of reluctance and anxiety. The subsequent results and analysis highlighted the theme of persistence and its role in encouraging momentum and perseverance in the face of difficulty.

Enjoyment was often a corollary of the process of persistence and momentum. An earlier proposition suggested that emotions were heightened, but evidence to support such a general statement was not substantial. Instead, there was evidence to suggest that the children enjoyed a number of challenging problems and that this was related to their persistence.

In addition, collaboration was not a constant phenomenon for any dyad during any one problem. Individuals within the dyads moved back and forth from collaborative talk to private musing in an ongoing manner throughout their problem solving. Such movement from the social to the personal seemed to be a natural part of the children's interactions. Nonetheless, even when a child appeared not to listen to his or her partner there was often evidence that the child had been monitoring what his or her partner said or did. For example, a child would often incorporate what his or her partner had said into the problem solving even though the child had not acknowledged it in any way and appeared to be pursuing a separate line of enquiry. This partly supports an early proposition that listening to a partner discuss his or her ideas can benefit the problem solving or at least can influence the thinking of the dyad partner. An early proposition also stated that collaboration became more synchronous and constant over time. While it seemed, however, that children became more accustomed to working together over time their collaboration did not become more constant as continual collaboration did not exist.

There was frequent evidence of children borrowing and building on each other's ideas, strategies or interim solutions during the process of problem solving. Sometimes both children would devise a joint approach from the outset. At other times the children might commence working independently and then begin to work together as their problem solving progressed. When the problem appeared to be easy they would not consult with each other at all, suggesting that they did not see any need to work together as the solution seemed straightforward. In such instances, the children did not check on each other's thinking or reasoning.

The context of a problem and the "type" of problem appeared to be less important than the challenge and curiosity the problem elicited. This finding contrasts with the early proposition that closed problems were least suitable for problem solving. This proposition was not borne out by the subsequent analysis (and is discussed further in section 3 to follow). Problems which appeared to challenge children at an optimal level engaged children in a number of ways. This variety of engagement elaborates on the early proposition that challenging problems which children find interesting encourages them to collaborate. The children could, for example, reframe the problem in their own way, take the role of tutor or corrector, take the role of tutee, finish each other's sentences, borrow each other's language, eliminate possibilities, negotiate strategies, challenge and counter each other, and so forth. These roles, and others, were often exchanged in a cpd which seems to be a feature of symmetrical dyads. That is, when children in a cpd are of similar ability there is potential for both to take the role of "expert" and "novice" at different stages during their collaboration.

The extent to which the roles were shared in an equitable fashion was not a pattern across certain types of problems. Fuzzy problems, for example, did not necessarily

encourage a greater sharing or exchange of roles. This contrasts with an earlier proposition that indicated that fuzzy problems encouraged a greater variety of roles. It could be surmised, however, that when children are of similar ability they are likely to take a variety of roles when collaborating with each other and there is less likelihood that one child will intellectually dominate the other. It is acknowledged, however, that factors such as personality, attitude and confidence may affect the roles and relationships in such a dyad.

3. Implications for Theory

The literature on cpds suggests that collaborative pairs are non-threatening and provide opportunities to discuss ideas with a peer. The literature postulates that these discussions can contribute to cognitive growth through sociocognitive conflict or negotiating meaning and socially constructing knowledge. It does not seem helpful to argue for the predominant influence of one theoretical position over another. Both Piagetian and Vygotskian perspectives contribute understanding to the complexity of cpds, as discussed in the previous chapter.

The extent to which a cpd is non-threatening remains moot. The support, guidance and complementary roles reported by some researchers (e.g., Forman, 1981; Forman & Cazden, 1985) were not always patently evident. In fact, in the area of peer feedback, for example, there can be more peer disagreement than statements of support (although Forman also mentioned the role of peer correction in cpds). Affective responses such as enjoyment, however, seemed evident at times when both children in a dyad were engaged and challenged with a problem, regardless of the amount of disagreement.

As discussed in the previous chapter, a cpd can provide opportunity for elaboration and provide impetus to continue pursuing a challenging problem for a number of possible reasons. The first of these appears to be the persistence and momentum which can be generated in a cpd. Previous theorisation about cpds has not mentioned this factor. Persistence, and the momentum it can generate, is different from what the literature states about emotional support, the opportunity for elaboration, and provision of a non-threatening grouping with a dyad. Persistence emerged as a key pattern in sustaining engagement and motivation. Of particular import was that it often took only one child to persist in order to recapture the interest of his or her partner who had become reluctant, disgruntled or eager for an easy answer. This is not mentioned in the literature, at least not in these terms. Support, and an encouraging atmosphere are suggested but not the role of one child in a dyad at a crucial moment in their problem solving. This finding makes a unique contribution to the dyad research and generally disputes Stacey's (1992) claim that children in

dyads neither pursue nor explore problems with persistence but tend to opt for premature closure and quick solutions. As mentioned in the previous chapter, there were instances where premature closure and lack of persistence occurred but this was less prevalent than the opposite phenomenon. It also seemed to be connected to the children's confidence about the particular problem with which they were engaged.

Persistence was a subtle feature of many cpds. It did not present as an overt encouragement of one child by another, but rather, appeared to be the unintentional spin-off as a reluctant child, who had appeared to give up, listened to his or her partner's comment and watched what he or she did next. Frequently, this was enough to re-engage the reluctant or disgruntled child. The very subtle and almost covert nature of this social action provides the opportunity for the reluctant child to "save face". He or she can re-enter the problem solving process with their partner without feeling a failure or in need of special help. An analogy which parallels this phenomenon is a child leaving a game with a friend in the swimming pool when she feels too tired or overwhelmed. She coasts around the perimeter of the pool looking unsure and ready to get out. Once she sees her friend do something new or intriguing, however, she pushes off from the wall and rejoins the game, with renewed vigour and enthusiasm. No one pointed at the child and told her to get out. Nor did they urge her to rejoin the game. She was able to observe and make her own decision about returning when she was willing to return. This maintains her feeling of control and seems to heighten her engagement when she returns as it has been her decision to return, not anyone else's. This seems to capture what happened in many of the cpds and was the powerful influence of persistence.

Ashton-Warner (1963) described the relationship between teacher and child as a form of "espousal", so powerful and potentially enhancing is the bond. With cpds, there can also be an element of a marriage or partnership when children are committed to each other and to the task at hand. Such a relationship needs a certain degree of trust and willingness to persist when difficulties arise. In the best circumstances, a cpd can provide this persistence and encourage this commitment. Like an espousal, it is often the mere presence of another that encourages and sustains commitment. Many analogies such as this capture something of the persistence that a cpd can encourage. My own tramping (hiking) excursions have always been more rigorous when I have a tramping partner. There is a sense that I do not want to let my partner down by lagging behind or not carrying my share of the weight. I tend to be more adventurous with a partner and definitely persist at times when I would have probably given up, or at least, taken a rest. With disbelief I have found myself at the top of rock faces and across the most perilous of swing bridges wondering how I possibly had the courage to achieve these feats. Then I looked at my partner who had persisted with the task and led the way. After a brief pause I followed because, if my partner could do it, so

could I. Conversely, there have also been instances where I have taken the lead and provided the impetus for a partner. In order to maintain the relationship, or save face, or because my partner felt motivated, or for some other reason, my partner would follow me (sometimes reluctantly) across challenging, or up steep, terrain. Invariably, he or she would comment afterwards that it was difficult but there was a sense of satisfaction and achievement in completing or conquering the physical and psychological task. There is a sense, then, that a cpd can make many difficult things appear possible and attainable. There is also a sense that a more reluctant or anxious partner can discover achievements which he or she did not consider within his or her capabilities. Such an outcome can be both exciting and motivating. There was evidence of this occurring with the children in this study. The presence of a dyad partner who persisted during a difficult period was often instrumental in maintaining the interest of a reluctant or disillusioned partner. This occurred frequently enough to warrant a distinct theme in the findings. The instances where persistence was thwarted appeared to be linked to the times when the reluctant partner repeatedly refused to re-enter the problem solving process.

Theories of mutuality, reciprocity and the bidirectional development of knowledge in cpds are generally supported by this study. Mutuality refers to the development of trust in cpds which enables children to interact freely with each other without feeling dominated or intimidated. This mutuality can build reciprocity in interactions between children and concomitant bidirectional knowledge sharing rather than a one-way "delivery" of knowledge by one child to another. The concept of mutuality may contribute to the overlapping nature of children's talk and has relevance for the notion of collaborative correction discussed in the previous chapter. The fluid and dynamic bidirectional nature of both tutoring and leadership in cpds is evident in this study, but so is individual agency and self-talk. A cpd is not consistently collaborative. The iterative movement of children from self-talk to collaborative and overlapping talk indicates their movement from individual thinking to social engagement. Theories on cpds seldom mention this variety or the implications of it. Such oscillation from the private musings of the individual to the more public sharing with a peer appears to be a necessary and natural process during dyad interaction. While it appears as public in transcripts, what a child shares with a partner, however, may feel intimate and can be private in intent. Nonetheless, there appears to be ongoing movement from talk with a peer to talk with oneself. This supports what Vygotsky (1934/1962) mentioned about the role of egocentric language, discussed earlier (see 7.1 in the previous chapter). Vygotsky claimed that social discourse can develop a child's egocentric language in that a child's talk with another can develop the talk with oneself. According to Vygotsky, this egocentric self-talk assists a child with monitoring his or her own ideas.

Nuthall and Alton-Lee (1994) also noted that children would frequently talk to themselves during class time. The children in their study seemed to use self-talk to make connections with existing knowledge, elaborate the content and develop metacognitive awareness. The role of self-talk in monitoring one's own thinking, alongside the making of connections, often seemed apparent in this study. This provides further support for the role of self-talk in learning and raises questions as to the opportunities children have to talk through ideas to themselves in classrooms. While Nuthall and Alton-Lee noted that children covertly talk to themselves during class time, it may be more appropriate that self-talk is both acknowledged and encouraged, when appropriate. This has been developed somewhat in the practice of "cognitive self-instruction" where children are encouraged to "talk themselves through" tasks (Woolfolk, 1993, p. 47). This approach, however, suggests that children need to talk aloud "when they are confused, having difficulties, or making mistakes" (p. 47). It seems that children have more use for self-talk than suggested by Woolfolk and that their uses of it can be exploratory and self-regulating, rather than just as an aid in times of difficulty.

There was also evidence of children monitoring each other's ideas, even when one child in a dyad appeared to be ignoring another. This apparent "eavesdropping" sometimes encouraged one child to adopt the strategies of the other. At other times, this appropriation of each other's strategies was more deliberate and part of their collaborative process. It did not appear, however, that one child had a "window" on another's thinking, as suggested in an early proposition. Such a claim does not acknowledge the complexity of thinking. What a child says or does is not necessarily a direct reflection of his or her thinking. As Vygotsky (1934/1962) noted, thought does not translate directly into speech even though the relationship between thought and word is an intimate one.

This study has shown that collaboration is not a constant state and that the roles that children assume in any collaboration can vary considerably during a problem and between problems (see also Holton et al., 1997). What this study contributes is an in-depth discussion of various interactions children have during problem solving and the implications of these for children's persistence, learning strategies, attitudes and collaboration. A child in a dyad can take the role of tutor one moment and then tutee the next. A child may spend most of his or her time during one problem seeking verification from his or her partner, but during another problem take a very different role. This variety of roles within a symmetrical cpd appears to be related to the similar ability of the children and therefore the opportunity for both children to take different roles at different times. It seems appropriate for collaboration that the individuals involved learn to take more than one role. For example, they should learn to listen as well as lead, and they should learn to counter a statement as well as justify their

position. By matching children for similar ability (and with a challenging enough problem), this range of roles, taken by both children, appears to arise unforced.

Furthermore, collaborative problem solving may change the way problems are viewed in the first place. For example, the episodes of problem reframing by some dyads indicated that children could transform some problems in order to access and understand them. While individuals may also reframe problems, there is something affirming and motivating about having someone else understand what one means. It is like language itself. Speaking fluent Italian is a wonderful achievement but of less enjoyment if you do not have anyone to converse with who understands it.

A further question emerges regarding the types of problems that encourage children's thinking and collaboration. For example, *Mathematics in the New Zealand Curriculum* (Ministry of Education, 1992) strongly promotes problems that have a meaningful context and which relate to children's lives. Some writers argue that ill-defined problems are more likely to encourage problem solving and collaboration (e.g., Cohen, 1994) whereas others are less concerned about the type of problem and place more emphasis on the approach learners take to problems (e.g., Hiebert et al., 1996; Lyle, 1997). This study finds more agreement with the latter view. Some problems engendered a surprising amount of engagement (such as *Make 23* mentioned in the results), whereas others were met with relative indifference. With the exception of *Make 23*, the children's preferences for various problems differed from dyad to dyad so it is not possible to make conclusions regarding problem types based on their preferences. The children's preferences were strongly linked to the challenge they experienced. The children's preferences did not necessarily relate to problems with meaningful contexts or a consistent type of problem (closed, more-than-one-answer or ill-defined). While it would be tempting from the results to assume that the closed problems were less suitable for collaborative problem solving, this is misleading. The closed problems engendered the least collaboration (and apparently, the least thinking) but this appeared to be due to the ambiguity of the problems and the children's judgements of the problems as being very simple.

In retrospect, the use of problem types in this study was rather limiting and restrictive. I do not believe my analysis benefited from delineating problems according to a taxonomy of types. As mentioned previously, the whole notion of a problem type is a rather speculative, situated construct which may mean something to the people who decide on the "types" but may mean little to learners (see Chapter 5, section 10.3).

The potential of dyads for collaboration and problem solving is indicated by the actions of some researchers themselves. Perhaps it is no coincidence that many of the writers and researchers in this area have themselves formed cpds (e.g., Barnes & Todd, 1977; Bennett & Dunne, 1990; Clarke & Helme, 1997; Doise & Mugny, 1984;

Dunne & Bennett, 1990; Forman & Cazden, 1985; Galton & Williamson, 1992; Garton & Renshaw, 1988; Glachan & Light, 1982; Graves & Zack, 1996; Kutnick & Rogers, 1994; Light & Littleton, 1994; Light & Perret-Clermont, 1989; McCarthey & McMahon, 1995; Palincsar & Brown, 1986). It seems that a cpd can be useful in the realms of academic research, just as it may provide a site for learning in the classroom. This study has provided some insights into why cpds can provide opportunities for learning and how these opportunities may arise.

4. Implications for Classroom Practice and Curriculum

There are a number of implications for classroom practice and curriculum arising from this study. Teachers could consider that it can be helpful for children to work in pairs when investigating problems that children find challenging. Having a partner may assist children with persevering, maintaining interest and enjoying problem exploration in mathematics and other curriculum areas. Doubt, reluctance and frustration may be overcome by the mere presence of a partner or the persistence of a partner. Such persistence in problem solving is a useful quality and its absence can result in cursory or superficial efforts. For example, Holton (1994) identified that

> In fact, research has shown that if students in the United States can't do a problem in two minutes, then they think it cannot be done. The time limit for Japanese and Chinese students seems to be in excess of 10 minutes. It would be nice to foster the view that, if it *can* be done in two minutes, then it's not worth doing. [emphasis in the original] (p. 124)

Having a partner to collaborate with may help children to persist with problems and to consider that they can be solved. A social context such as a dyad can make it harder for a child to give up and easier for a child to persist. Furthermore, enjoyment and enthusiasm can be shared as children meet the challenges together. A more confident child could be paired with a less confident one with the aim of helping the latter to persist. The confidence that the more anxious child could accrue through joint problem solving may assist with both attitude and motivation. This implication does not overlook the possibility that a partner can also be a discouragement if he or she does not wish to pursue a line of inquiry and makes no attempt to do so. The readiness of a reluctant child to listen to and respond to their partner's suggestion seems crucial in sustaining a collaborative problem solving process.

Children can be encouraged and guided with staying open-minded, persisting in the face of difficulty and resisting premature closure. These traits are common with gifted children. They can also be encouraged in all children. As Dewey (1910) stated, teachers have a tendency to hastily push for answers from children rather than

encouraging them to suspend certainty while they search for possible solutions. He claimed that it was important that children became willing "to endure a condition of mental unrest and disturbance" (p. 13). Cpds can have a role in developing this endurance and tolerance.

Furthermore, cpds can enable children to develop independent decision-making and judgement skills. For the most part, the children in this study came to their own conclusions and realised their own solutions. They were not dependent on a teacher to assess whether they were "right" or "wrong", and they did not seek affirmation of their ideas and solutions from an adult. It seemed that their collaborative engagement provided the feedback they required and enabled them to assess for themselves when they had reached an appropriate solution or not. This independence in judgement and decision-making is a valuable skill for not only mathematics but for life-long learning. A corollary of this independence, however, is that children may resist attempts to challenge and develop their thinking when they have misinterpreted a problem or come to an erroneous solution (as the dyads did with two of the closed problems). The teacher's role is, therefore, important in assisting children with recognising their errors and with pursuing alternative and more appropriate approaches.

This study cannot be considered an empirical basis for establishing that cpds are preferable to any other grouping, whole class, or individual work. A number of other studies, however, do suggest that cpds are a preferable arrangement for problem solving including Kutnick and Roger's (1994) international analysis of a range of dyad studies. Even so, these studies and others agree that cpds are but one option in any classroom which should incorporate a variety of approaches to teaching and learning. This variety could include teacher-led discussions, teacher demonstrations, child or children's demonstrations, larger cooperative group work, independent work, children-led discussions with larger groups and the whole class, peer tutoring and so forth. In addition, it is often useful to change from one approach or setting to another, and another, in any one lesson. Conversely, it may be most logical and educationally appropriate to stay with one approach for the duration of the lesson. Such decisions would depend upon the learners' needs, their prior knowledge and the curriculum. It would also depend upon the essential skills, the attitudes and values, and the essential learning areas (Ministry of Education, 1993) that a teacher intends to develop with children as a result of ascertaining children's needs and strengths. By choosing pairs or asking children to form cpds for problem solving, the teacher is conveying an expectation, either explicitly or implicitly, that she or he wants children to work together. The teacher is also communicating that she or he values the learning the children may gain from each other or experience together. It should also follow that the focus of the lesson is suited to cpds and not more suitable for independent study, whole class discussion, or some other alternative.

In this study it appeared that some children were learning to persist in problem solving, some were learning to collaborate with another and some were learning to do both. Furthermore, what each child was learning seemed to vary from problem to problem and over time. The skills of problem solving can be learnt individually but the skills of collaboration cannot (except theoretically). Collaborative problem solving, therefore, requires that children combine and develop two sets of skills simultaneously. At first glance this may seem a very large task, yet on reflection it is more meaningful and relevant to collaborate about something (a problem or issue) than to collaborate because the teacher, or curriculum or state requires it. The integration of problem solving and collaboration, therefore, enables children to develop two sets of skills more or less concurrently. Such integration of skill development enables teachers to realise the links across essential learning areas (such as mathematics) and essential skills (such as problem solving and cooperative skills). The development of these links can enable teachers to integrate curriculum in their planning for children's learning.

While I use the word "skills" here I acknowledge Irwin's (1996) critique of this word in the *New Zealand Curriculum Framework* (1993) and concur with his analysis that it is a misleading and rather inadequate word when one considers the breadth of understanding required in each of the "essential skills" areas (see Chapter 1, section 4). I use the term for convenience and clarity as this is the term used in *The New Zealand Curriculum Framework.*

The focus of this study is mathematics problem solving but the principles of cpds may also be relevant for other curriculum areas. This is not to deny that mathematics possesses unique features and issues, but to acknowledge that some factors such as problem solving and collaboration are familiar issues in other subjects (Hiebert et al., 1996).

Arising from my study, cpds seem to provide opportunities to learn when:

- the nature of the problem encourages talk about cognitive aspects, that is, when the problem is sufficiently challenging to warrant discussion;
- the problem is relatively unambiguous or the children are able to establish a shared understanding of what the problem means;
- the nature of the problem encourages children to explain their thinking to each other and justify their ideas;
- the children have time to become accustomed to working collaboratively; and
- at least one child has the willingness to persist in the face of difficulty and his or her partner is willing to rejoin the pursuit of a solution.

These points can be considered in any subject (or essential learning area) of the curriculum.

This study also has implications for our understanding of how children learn mathematics. Bruner (1996) suggested that scientific and mathematical thought should take form through narratives so that knowledge is created by learners through their personal meaning-making, rather than being an exclusive concern for discovering facts and answers in the external world. It seems that there is potential for exploring children's use of narratives as a problem solving heuristic and for teaching narrative ways of approaching problems in mathematics. This study suggests that narrative forms of problem solving are used by some children when they find a problem challenging. Furthermore, these narratives can be collaboratively constructed or they can be devised by one child and actively used by his or her partner.

Taking a narrative approach to mathematics challenges the conservative and prescriptive views of mathematics. It is an epistemological issue when story, metaphor and analogy are proposed as ways to understand the language of mathematics. A number of teachers use such metaphors and analogies in their teaching of mathematics. For example, a successful teacher of algebra with less able children described the equals sign in an equation as a "fence". He explained to his class that the numbers on one side of the fence needed to add up to the same as the numbers on the other side of the fence. The totals of each side had to balance. Such a narrative was effective in enhancing the children's understanding (Pirie, 1997). It seems useful to also encourage children's own generation of narratives if it aids their understanding of mathematics.

Transcripts of children's talk and video-recordings can be used as tools in the professional development of teachers (also suggested by Westgate & Hughes, 1997). Teachers can be involved in analysing what they see and hear with cpds in their own classrooms. This can enable teachers to explore how children make sense of problems, what strategies they use and how they influence and affect each other. Such information can indicate the extent to which children own a problem as opposed to mechanically doing what is required with minimal engagement. Discovering how children learn and exploring the ways in which children make sense of problems is essential if teachers are to make pertinent links between curriculum and children's thinking. The scaffolding of new learning within a child's zone of proximal development should be more effective and efficient if a teacher understands how a child is making sense of a concept, idea or problem.

Without necessarily looking for definitive problem types, teachers could discern which problems (and which approaches to problems) seem to encourage collaborative problem solving and which do not. Recordings could also help teachers to identify the trait of persistence, its influence on a partner, and the unique reframings that children

may devise. Such information should be helpful in devising a programme to meet children's needs and selecting appropriate problems which encourage children to wrestle with ideas and develop their understanding. It can also help to discern what occurs when children work together, independent of the teacher which happens in classrooms whether intentionally or not (see also Thomas, 1994; Higgins, 1995). As Prisk (1987) noted, it is inevitable that children will sometimes "jump to the wrong conclusions but this does not constitute a valid reason for rejecting unsupervised group learning" (p. 90). Unsupervised group learning (including cpds) occurs in schools, communities, businesses, prisons, service organisations, political parties and sports' groups (to name a few common settings) the world over. This prevalent but often incidental phenomenon makes it both a worthwhile topic to investigate as well as a challenging context to describe, hence the organisation of cpds which was undertaken for this study. I could not afford to wait until children might decide to work with a partner but requested that they did so. I also wanted to study dyads of similar ability and that was a further constraint or condition on the cpds. The times that children choose to work with another child without coercion or request by a teacher would also merit study. Such research would probably require an ethnographic and longitudinal methodology.

As mentioned earlier, using cpds in the classroom is not advocated as an alternative to present practice or as the only approach to use. Nor are cpds excuses for teachers to withhold information or abdicate their responsibility in challenging children's thinking. Just because children tend to be "more available to each other than the teacher is to any of them" (Cazden, 1985, p. 448), this is not a reason, or an excuse, to leave children to their own devices. Children "would make very slow progress if they were asked to rediscover all the information available to the teacher" (Hiebert et al., 1996, p. 16). A patent example from this study was that many of the dyads did not seem to realise that there was more than one answer for some of the problems. Teachers can and should intervene, at times, to develop children's understanding and this includes helping children to explore more than the first and most obvious solution to a problem. The studies on teacher-child interactions in classrooms need to continue so that we can discover more about how to facilitate children's thinking in effective, meaningful and lasting ways.

Cpds do not guarantee that children will explain and justify their ideas to each other. The teacher has a key role in providing the climate and guidelines for ensuring that children learn to justify their reasoning. This is vital for examining and improving children's strategies, be they using narratives, drawing, role playing, making a simpler case, working backwards, guessing and checking, or some other heuristic. The sharing and justifying of children's methods also helps them to clarify their thinking in explaining what they mean and sharing "the responsibility for developing a

community of learners" (Hiebert et al., 1996, p. 16). This also requires that children learn to learn from each other, to critique each other's ideas and to compare and contrast their justifications. They should learn to listen with intent so that "listening serves both a social and intellectual function" (p. 17). There is evidence in this study that cpds can encourage this social and intellectual function of listening which contributes to the development of social and cooperative skills. There is no guarantee, however, that, left to their own devices, children will develop listening, justification and other collaborative skills. Cpds can provide a starting point for practising these skills, with input from a teacher at the outset. Justifying one's methods to a partner can be much less threatening than providing explanations to a large group or whole class. Listening to a partner can be less distracting and more focused than following a whole class discussion that may meander at times or be dominated by the ideas of a few. For these reasons, listening and justifying in a cpd can be a foundation for developing these skills in more public contexts.

Teachers need to identify and understand the skills of collaboration and problem solving themselves. While these skills are part of the current curriculum, not all teachers necessarily know the components which comprise collaborative skills and problem solving skills. In order to facilitate these skills with children, teachers need to know what they are and be practised in these themselves. They could use professional texts to guide them in the teaching of collaborative skills (e.g., Bennett & Dunne, 1990; Dalton, 1985; Dunne & Bennett, 1990; Hill & Hill, 1990). These texts provide suggestions on how to facilitate children's skills of collaboration starting with the foundation skills of listening, questioning, challenging, helping and providing explanations to others. Teachers could also watch and analyse video-recordings of children interacting to ascertain the skills they already possess and to build upon these.

While official curriculum documents provide outlines for teachers of what to teach, there is scant reference in such documents for how to teach. This underlines the teacher's role as the key curriculum decision-maker (McGee, 1997). Teachers make decisions about unit topics, planning, resources, assessment and lesson sequences based upon both the children's learning needs and the requirements of the curriculum. Teachers' informed decisions about curriculum includes how it will be communicated to children and the types of learning experiences appropriate for children's needs and abilities. McGee argued that teachers are not passive "conduits" for the transmission of curriculum blueprints. Instead, their professional decision-making influences and determines to a large extent how curriculum is implemented.

Teachers also need to be involved in collaborative problem solving situations themselves to fully experience the dynamics, variations, challenges and possible benefits of such interactions. Teachers are often involved on a daily basis with collaborative problem solving as they liaise with a social worker about a child's poor

health and attendance, or consult with a speech therapist about a child's clarity of verbal expression, or plan a unit on pubertal change with a teaching colleague. Many teachers have excellent collaborative problem solving skills but they do not always recognise it. Nor do they always know what contributes to the knowledge and ability they have accumulated over time and the skill that appears, to them, to occur "naturally". For many children (and adults), collaboration does not occur naturally and the skills need to be learnt. Many studies have found that children need time and practice to develop the skills of collaboration and that the teaching of collaborative skills can improve children's ability to collaborate (Kutnick & Rogers, 1994). Furthermore, teachers need to consider why they are teaching collaborative problem solving and what the purpose of such skills are for children. Otherwise, the teaching of these skills will revert to a series of mechanical tasks to be accomplished rather than being a meaningful, engaging and dynamic phenomenon.

A collaborative culture amongst teachers should not be a synonym for conformity, however, and nor should collaborative problem solving suppress individuality, debate and healthy disagreement. It is important to avoid the situation "where teachers feel pressured to conform against their better professional judgement, just for the sake of reaching agreement" (McGee, 1997, p. 242). As the results of this study indicate, collaboration in problem solving is not about continual compliance and complete accord between people. Ideas were contested and issues explored during many of the children's collaborations. Children, like adults, should not be coerced to conform for the sake of solving a problem but instead they should feel that in a cpd they have the right to express and argue their point of view. A cpd also provides the opportunity for children to change their idea or view in a relatively unthreatening setting, when (and if), they are persuaded by an alternative view a partner provides.

Finally, there are implications from this study for children's attitudes and values. They may be likely to persist in a cpd when faced with difficulty and they may have the courage to continue if they are not alone in their problem solving. The enjoyment and satisfaction of making a breakthrough can be shared with another who understands what was undertaken to reach the point of solving a problem. Someone who shares the journey, who contributes to creating the path of that journey, can be a valued companion. For some children, a partner in problem solving may boost their confidence and persistence. For other children, a partner may be a rather irritating distraction. What is interesting from this study is that even the most independent children showed instances of learning from their partner, negotiating ideas and seeking feedback.

5. Implications for Further Research

One of the greatest challenges for research on collaboration which includes talk as data is the development of analytical procedures which have relevance to other contexts. This is emphasised by Westgate and Hughes (1997) who stated that, "It hardly needs repeating that language is too complex for any analytical procedures to have simple predictive power or easy transferability from context to context" (p. 137). They also suggested, however, that researchers needed to develop more reliable observations and conceptualisations of children's talk. They called for firmer and more specific analysis of talk with categories that can "enlighten practice" (p. 137). In addition, they urged "unpicking categories into their possible components" and examining the "relationships between categories as well as within them" (p. 135). The present study makes some contribution to the analysis of children's talk by specifying the components of each category and suggesting a range of properties and dimensions for each component (see Chapter 4, sections 3 and 4). Furthermore, it provides a way of examining relationships between categories as well as within them by developing themes which emerged from the contextualised nature of the children's discourse across a range of episodes. The themes enabled the study to avoid the restriction of analytical categories related solely to individual moves. The themes also provide a vehicle for presenting the connections in discourse and the ways in which text can be jointly constructed.

It is acknowledged, however, that further development of coding and analysis is required in the complex area of collaborative problem solving. In addition, Westgate and Hughes called for greater attention to cognitive coding and categorisation, and the creation of hierarchies within categories. This may aid in our understanding of how children's talk with their peers relates to the development of their thinking. The moment a hierarchy is formed, however, it constrains and determines what is deemed most valuable or influential. The subtle persistence factor discovered in this study may be overlooked by a hierarchal coding system that may, for example, place a "hypothesising" statement above an "informing" statement. The themes of this study, such as persistence and reframing, enabled the identification of episodes where the influential utterance (or action) was "not necessarily the immediately preceding one, but one which occurred at a slight distance in time" (p. 135). This is one response to a research need identified by Westgate and Hughes. The further challenge is to develop finer tools of analysis relevant to a range of contexts. Grounded theory methods may assist with developing these tools.

In terms of data collection, video-recordings appear to be especially illuminating as they can show the context, actions, body language, use of materials and response of children to each other. Transcripts alone can be misleading and do not show all that

occurs. A limitation of my reporting of results is the reliance upon transcripts of episodes of children's talk with little explicit description of intonation, body language and so forth. Non-verbal features are mentioned on occasion when they seemed significant to the interaction. The decision about significance was mine, however, and may be open to other interpretations. With care taken for ethical considerations, other people viewing and listening to the video-recordings for themselves would be a way to possibly redress this.

In transcribing the children's talk I brought my experience of being there and observing their interactions a number of times through both the camera lens and replaying the video-recordings. This aided my coding and analysis as I was alert to what went on behind and between the children's words. I could, however, have made this more explicit for a reader by annotating my transcriptions more thoroughly to ensure that the interpretations made are supported by evidence accessible to an outsider. In addition, I cannot claim that my analysis provides a full understanding of what the children thought or their motives for saying or doing certain things. As Vygotsky stated, "every sentence that we say in real life has some kind of subtext, a hidden thought behind it" (1934/1962, p. 149). These "hidden thoughts" are the continual challenge for the researcher who uses talk in his or her data collection process. The researcher can (as I did) follow-up with interviews, play back video-recordings, probe children's understandings through incidental discussions, collect work samples and compare transcripts across time and incidents to get closer to what the children's words seemed to mean. An "exact" understanding, however, will always remain elusive as the words, like the research process, are interpretations devised by humans for the purpose of conveying meaning. They are not, necessarily, the meaning itself. Vygotsky (1934/1962) clarified this point when he claimed

> A thought may be compared to a cloud shedding a shower of words. Precisely because thought does not have its automatic counterpart in words, the transition from thought to word leads through meaning. In our speech there is always the hidden thought, the subtext. (p. 150)

It is these subtexts that provide the challenge for researchers. These include the sense, connotations, functions and motives behind and between language.

Further research needs include a closer focus on what children appear to learn in cpds, alongside how they appear to learn. The strategies that children devise in cpds can provide insights to their thinking. It would be useful to know more about what learning for individuals is "new" as a result of peer interaction and it would be illuminating to discover what children retain over time. It would be intriguing to know if strategies devised in a cpd are used by individuals at a later date. Could cpds maximise the use of time in a classroom? If so, when and under what circumstances?

Could they enable children to engage more with the content of a lesson and persist when it becomes difficult? We also need to know more about the children's attitudes, feelings and emotional responses to various problems and why they may, or may not, enjoy working with a partner.

We need to know what pairs are most suitable for collaborative problem solving and how stable these should remain over time. Ability and gender are discussed in the literature but the areas of attitude, confidence and persistence of individuals in cpds are only just starting to be considered. We also need to know more about the status differences of children and the ways these may influence their collaboration. The question of who gets to participate and how in cpds requires a closer focus on class, culture, ethnicity and disability. Problems that engage children with the task and with each other are required to extend and enrich the options in classroom practice. A corollary of further research in this area would be to further elucidate the relationship between inner speech and social interaction, between individual cognition and the social construction of knowledge.

In terms of problem solving this study raises more questions than it provides answers. Can cpds enhance children's problem solving ability? Although this study suggests that cpds can encourage children's persistence and momentum, it makes no categorical claims about the effect on children's ability to problem solve. While there was evidence of children borrowing, negotiating, monitoring and sharing each other's strategies, little attempt was made to evaluate the effectiveness of these strategies. This limitation suggests an area of further research. Could cpds increase children's enjoyment of problem solving? While the results indicate this is possible for a number of dyads, there were four boys who expressed a preference for working alone. Is this a concern, and if so, how might it be addressed? It would not be appropriate to insist that children constantly work together, just as it would not be to insist that they always work alone.

It is also acknowledged that problem solving is not the sole skill that can be developed in cpds, or in mathematics or any other curriculum area. Problem solving implies that a problem can and should be solved. Many important issues in life and learning are not just problems we fix, with or without the help of a partner. It would be misleading to think that problem solving is the basis of mathematics or of learning in school. It is one set of skills that children need to develop. Cpds, however, can be utilised in pursuing more than just problem solving. Building on the work of Lyle (1997) and Splitter (1997), it would be interesting to study the role of cpds in exploring moral issues, attitudes and values. Many of the concerns and issues in life do not have easy answers. They may have many possible solutions from which we need to make ethical and moral choices. Or they may seem to not have any solution at all because of the limits of our current knowledge, or because we are asking the wrong

questions, or because the issues are complex and multi-faceted. The role of cpds in forming questions, posing problems and identifying issues would therefore be worth investigating.

6. Conclusion

This thesis is about children's collaboration in pairs during problem solving. It provides some insights into the interactions that occur between children. It also provides some suggestions about the value and purpose of a collaborative peer dyad under certain circumstances which adds to the literature on classroom research, collaborative peer dyads, children's talk and problem solving.

The skills of dyad collaboration and problem solving are of benefit to children's learning but there is no suggestion that they should be constantly employed in the classroom. There are implications for teachers and curriculum design, however, as cpds are a potential site for the development of these skills which are generally valued in the home, community, work place and global arena.

The study examined the interactions of children in eight dyads as they investigated a range of mathematics problems. It found that collaboration is not a constant feature of cpds, that children can exchange a variety of roles during problem solving and that cpds can play an important role in developing persistence when children find problems challenging. These findings add to an understanding of collaboration and how children problem solve, enabling a close analysis of the intersection of these two factors. Partners in problem solving can encourage perseverance, share enjoyment and sustain momentum with the task at hand.

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Appendices

Appendix A

Tuesday 13 June, 1995

Dear (name of principal)

Here is a draft of a letter I wish to send out to parents/caregivers of children in (name of teacher) class. It outlines my intentions for the research as I mentioned on the phone to you. Please let me know if you have any suggestions to make regarding this letter. I welcome your feedback. Thank you for permitting me to proceed with this endeavour.

Deborah Fraser

Dear parents/caregivers

I am currently undertaking research into children's problem solving when working in pairs. In particular I am interested in understanding more about the way children influence each other's thinking when working collaboratively and what relevance this may have for cognitive and social development. In addition I am focusing on the extent to which children in dyads (or pairs) clarify or alter the way in which they approach and interpret a problem. This is a micro-analysis of children's interaction and construction of meaning.

I seek your permission to undertake some of this study in (teacher's name) room with children in her class. This will not entail any disruption to the classroom programme and as far as possible will be arranged to blend in with the ongoing class events. Specifically I intend to give pairs of children, some maths problems to work on together so I can record what they do and say. The problems range from closed to open-ended and are appropriate for the class level and the curriculum. It will be emphasised to the children that it is not a test of any kind and that I am not concerned with 'right' or 'wrong' answers but rather with their ideas and feelings about the problems.

I seek your permission to videotape some interactions and any child in the class may appear on the video if they happen to be walking by at the time. Similarly, I would like to audiotape some discussions and various voices may be picked up in the recording during the activities. This taping will be arranged so it does not unduly distract the children. I have already worked in (teacher's name) classroom a number of times so I am known to the children.

I would like to make explicit that all recordings (audiotape or videotape) remain confidential and that no child will be identified. Where names are used they will be pseudonyms or first names only. Similarly, the class and school will not be named. You and the children are welcome to view transcripts and other materials. All consent forms, written notes, tapes, transcripts and computer disks will be locked securely in my office to ensure privacy and safety. You may also choose to withdraw your child at any time. I will be in the classroom for four weeks and will work with the children for two to four hours each week.

I hope that the work that I undertake will contribute to teachers' understanding of children's learning and the effects different problems and collaborative groupings can have on that learning.

As some of the data collected may be useful for publishing, teaching and/or conference purposes I would like to reiterate that participants will not be identified. Again you have the right to view any materials that may be collected and used. If you would like to have your child named and acknowledged then you have that express right also. The final form of some of the data collected is as an unpublished D.Phil thesis with the University of Waikato.

I hope that I have made these ethical considerations clear. If there is any aspect of this that you wish to discuss please do not hesitate to contact me at:

School of Education
University of Waikato
Private Bag 3105
Hamilton

Ph. (07) 838 4500 (work) or (07) 8490824 (home)
Fax (07) 838 4555
E.mail deborah@waikato.ac.nz

If you are in agreement I would appreciate it if you would sign the consent form below so that I have an official record of your permission as required by the protocol of research procedures at the School of Education, University of Waikato. Thank you for considering this.

Yours faithfully

Deborah F.G. Fraser

.....

I do consent to having my child participate in Deborah Fraser's study on collaboration and problem solving.

Signed:----------

Appendix B

To: The Principal
From: Deborah Fraser
Re: Ethical considerations and consent
Date: 3/8/95

Kia ora (principal's name)

Please cast your eyes over this and let me know if you require any changes. Is the language appropriate? It may be too technical but I don't know the parents involved. Are there any parents/caregivers who are new learners of English? Are there enough details? Do you want me to include more about the purpose of the withdrawal programme for extending the children? I've mentioned that I've visited the children's rooms already as by the time they get this, that will be the case. Please fax or write in reply any responses that you have. Thank you.

Dear parents/caregivers

I am currently undertaking research into children's problem solving when working in pairs. In particular I am interested in understanding more about the way children influence each other's thinking when working collaboratively and what relevance this may have for cognitive and social development. In addition I am focusing on the extent to which children in dyads (or pairs) clarify or alter the way in which they approach and interpret a problem. This is a micro-analysis of children's interaction and construction of meaning.

I seek your permission to undertake some of this study at (name of school) with your child. This will entail a withdrawal programme for an hour once a week. Specifically I intend to give pairs of children, some maths problems to work on together so I can record what they do and say. The problems range from closed to open-ended and are appropriate for providing extension for your child. It will be emphasised to the children that it is not a test of any kind and that I am not concerned with 'right' or 'wrong' answers but rather with their ideas and feelings about the problems. There will also be opportunities in the programme for the children to work alone.

I seek your permission to videotape some interactions and audiotape some discussions. This taping will be arranged so it does not unduly distract the children. I have already visited their classrooms so they are familiar with me. I would like to make explicit that all recordings (audiotape or videotape) remain confidential and that no child will be identified. Where names are used they will be pseudonyms or first names only. Similarly, the class and school similarly will not be named. You and the children are welcome to view transcripts and other materials. All consent forms, written notes, tapes, transcripts and computer disks will be locked securely in my office to ensure privacy and safety. You may also choose to withdraw your child at any time. I hope that the work that I undertake will contribute to teachers' understanding of children's learning and the effects different problems and collaborative groupings can have on that learning.

As some of the data collected may be useful for publishing, teaching and/or conference purposes I would like to reiterate that participants will not be identified. Again you have the right to view any materials that may be collected and used. If you would like to have your child named and acknowledged then you have that express right also. The final form of some of the data collected is as an unpublished D.Phil thesis with the University of Waikato.

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If you are in agreement I would appreciate it if you would sign the consent form below so that I have an official record of your permission as required by the protocol of research procedures at the School of Education, University of Waikato. Thank you for considering this.

Yours faithfully

Deborah F.G. Fraser

.....

I consent to having my child participate in Deborah Fraser's study on collaboration and problem solving.

Signed:----------

Appendix C

20/11/95

Dear parents/caregivers

I am currently undertaking research into children's problem solving when working in pairs. In particular I am interested in understanding more about the way children influence each other's thinking when working collaboratively and what relevance this may have for cognitive and social development. In addition I am focusing on the extent to which children in dyads (or pairs) clarify or alter the way in which they approach and interpret a problem. This is a micro-analysis of children's interaction and construction of meaning.

I seek your permission to undertake some of this study at (name of school) with your child. This will entail a withdrawal programme for an hour once a week. Specifically I intend to give pairs of children, some maths problems to work on together so I can record what they do and say. The problems range from closed to open-ended and are appropriate for providing extension for your child. It will be emphasised to the children that it is not a test of any kind and that I am not concerned with 'right' or 'wrong' answers but rather with their ideas and feelings about the problems. There will also be opportunities in the programme for the children to work alone. You are welcome to visit the programme at any time and I would appreciate your comments.

I seek your permission to videotape some interactions and audiotape some discussions. This taping will be arranged so it does not unduly distract the children. I have already visited their classrooms so they are familiar with me. I would like to make explicit that all recordings (audiotape or videotape) remain confidential and that no child will be identified. Where names are used they will be pseudonyms or first names only. Similarly, the class and school similarly will not be named. You and the children are welcome to view transcripts and other materials. All consent forms, written notes, tapes, transcripts and computer disks will be locked securely in my office to ensure privacy and safety. You may also choose to withdraw your child at any time. I hope that the work that I undertake will contribute to teachers' understanding of children's learning and the effects different problems and collaborative groupings can have on that learning.

As some of the data collected may be useful for publishing, teaching and/or conference purposes I would like to reiterate that participants will not be identified. Again you have the right to view any materials that may be collected and used. If you would like to have your child named and acknowledged then you have that express right also. The final form of some of the data collected is as an unpublished D.Phil thesis with the University of Waikato.

I hope that I have made these ethical considerations clear. If there is any aspect of this that you wish to discuss please do not hesitate to contact me at:

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If you are in agreement I would appreciate it if you would sign the consent form below so that I have an official record of your permission as required by the protocol of research procedures at the School of Education, University of Waikato. Thank you for considering this.

Yours faithfully

Deborah F.G. Fraser

.....

I consent to having my child participate in Deborah Fraser's study on collaboration and problem solving.

Signed:----------

Appendix D

CY [A M: Yeah with these ones here. [And if you add those up together (the large numbers) you'll just have the little ones because the little ones are just like...(rolls her eyes upwards) well you have a hammer, you have the big stuff for the house, big hammer (pointing to big numbers) and stuff and then you have the little nails (pointing to the small numbers) to do the job for the um,

SB [H house.

L: (Big breath) So the hammers should go...

M: Well the first ones...

L: The first ones, like OK...

M: By the um... [We'll draw it again, do a HUGE triangle. We'll do a GREAT big

C [Dr one (draws new triangle on new sheet of paper). We'll do this side here first.

SB [H So we could put an eight as a hammer...And then...

L: A one as a nail.

CY [A M: Right...nine (adding eight and one). [Eight, nine, is 17, [then you could do a

SB [IV

C [Dr three here and then...

SB [Del L: We need six more...

M: And that would be a four.

C [CC L: (In a quiet voice to Megan) Yeah but that wouldn't equal 23 that would equal 24.

SB [H M: We could do a three there or a one and then a two.

C [CC L: Yeah but then that's one, two, three, four, five (pointing emphatically to the series of five numbers on one side of their triangle, tapping on the diagram), there's only supposed to be four!

CY [A M: Yeah I know (sees the error and scribbles out number two and moves it down to the corner).

L: OH you mean that, down here (the two should be on the corner).

C [SC M: So that's a two, so that's... oh (laughs)

L: Too many numbers! (laughs).

SB [Del M: So we need another big hammer really.

(They start again)

C [Dr L: Maybe we should just think about it before...

CY [A M: Yeah, write it down so we don't...

[IV L: I'll just do the circles first (drawing).

[H M: For that one (the previous) we just needed another hammer. Um so if put the eight there...we could try a seven there...

SB [Del L: The eight's always there isn't it? Yeah, an eight, a seven and a nine.

[IV M: Eight, seven...(writing the numbers on one side of the triangle).

L: Nine and a one. [Maybe we should try putting a hammer each on one side so it

[H goes from highest to lowest on each side...

[IV M: So [we've got eight]...

	Ded	L:	[And that leaves the little ones] which are the nails.
	IV Ded	M:	Nine...eight for the side (putting the large numbers in the middle of each side). Well there would be two hammers on this...
SB	IV H	L:	Eight, nine um, seven. I know why don't we put the eight on a different side otherwise there would be two. We'll put the eight [here].
	IV	M:	[Here] The eight, the seven and the nine.
		L:	I'm just writing it in real light...
CY	DF	M:	But we'll have to do kind of um...
C	Dr	L:	Just write it in real small um...
	SIV	M:	So we'll try this one here (focusing on one side). The eight and six are...(looks at Linda).
SB	IV	L:	Um...14.
	Ded	M:	14, and so eight, (whispering) we'll just write it really softly in here, what would be...eight, 16...
	H	L:	A good one there would be to put a little nail.
		M:	A little nail but...
C	CC	L:	The littlest nail.
		M:	No cause it would add equal 15, we need to try and get...
		L:	But we've got this one (another circle in the corner) down here too.
SB	H	M:	We'll put four there (in the corner circle). And a five up there (top corner). Try that.
	Dr		
C	CC	L:	Yeah but then it'll be one and two and three up here.
	Dr	M:	Try that because...
CY	A	L:	(Reluctantly) OK.
		M:	Because there's one up there and a two there.
	IV	L:	OK, five, six, eight, and four (adding up one side and tapping the paper with her pencil as she does so). Um...
		M:	(Adding first two numbers) 11.
SB		L:	11, 19...20, 21...
		M:	YES, THAT'S it! THAT'S it! 23.
	Ded	L:	And this one (looking at the next side) is four, and this one down here is four plus [one plus]
	IV	M:	[One plus]
		L:	Seven, [plus two]
CY	DF	M:	[Plus two] OK so you have four and a, four and a..I know. Alright, [four]
	Ded	L:	[11] 12, 13, that's 14!
SB	H	M:	14. So we need...
		L:	We need higher numbers (laughs).

Appendix E

CY	A	M:	Yeah with these ones here. And if you add those up together (the large numbers) you'll just have the little ones because the little ones are just like...(rolls her eyes upwards) well you have a hammer, you have the big stuff for the house, big hammer (pointing to big numbers) and stuff and then you have the little nails (pointing to the small numbers) to do the job for the um,
SB	H		house.
		L:	(Big breath) So the hammers should go...
		M:	Well the first ones...
		L:	The first ones, like OK...
		M:	By the um... We'll draw it again, do a HUGE triangle. We'll do a GREAT big
C	Dr		one (draws new triangle on new sheet of paper). We'll do this side here first.
SB	H		So we could put an eight as a hammer... And then...
		L:	A one as a nail.
CY SB C	A IV Dr	M:	Right...nine (adding eight and one). Eight, nine, is 17, then you could do a three here and then...
SB	Ded	L:	We need six more...
		M:	And that would be a four.
C	CC	L:	(In a quiet voice to Megan) Yeah but that wouldn't equal 23 that would equal 24.
SB	H	M:	We could do a three there or a one and then a two.
C	CC	L:	Yeah but then that's one, two, three, four, five (pointing emphatically to the series of five numbers on one side of their triangle, tapping on the diagram), there's only supposed to be four!
		M:	Yeah I know (sees the error and scribbles out number two and moves it down
CY	A		to the corner).
		L:	OH you mean that, down here (the two should be on the corner).
C	SC	M:	So that's a two, so that's... oh (laughs)
		L:	Too many numbers! (laughs)
SB	Ded	M:	So we need another big hammer really.
→			(They start again)
C	Dr	L:	Maybe we should just think about it before...
CY	A	M:	Yeah, write it down so we don't...
	IV	L:	I'll just do the circles first (drawing).
	H	M:	For that one (the previous) we just needed another hammer. Um so if put the eight there...we could try a seven there...
SB	Ded	L:	The eight's always there isn't it? Yeah, an eight, a seven and a nine.
	IV	M:	Eight, seven...(writing the numbers on one side of the triangle).
		L:	Nine and a one. Maybe we should try putting a hammer each on one side so it
	H		goes from highest to lowest on each side...
	IV	M:	So [we've got eight]...

Reframing

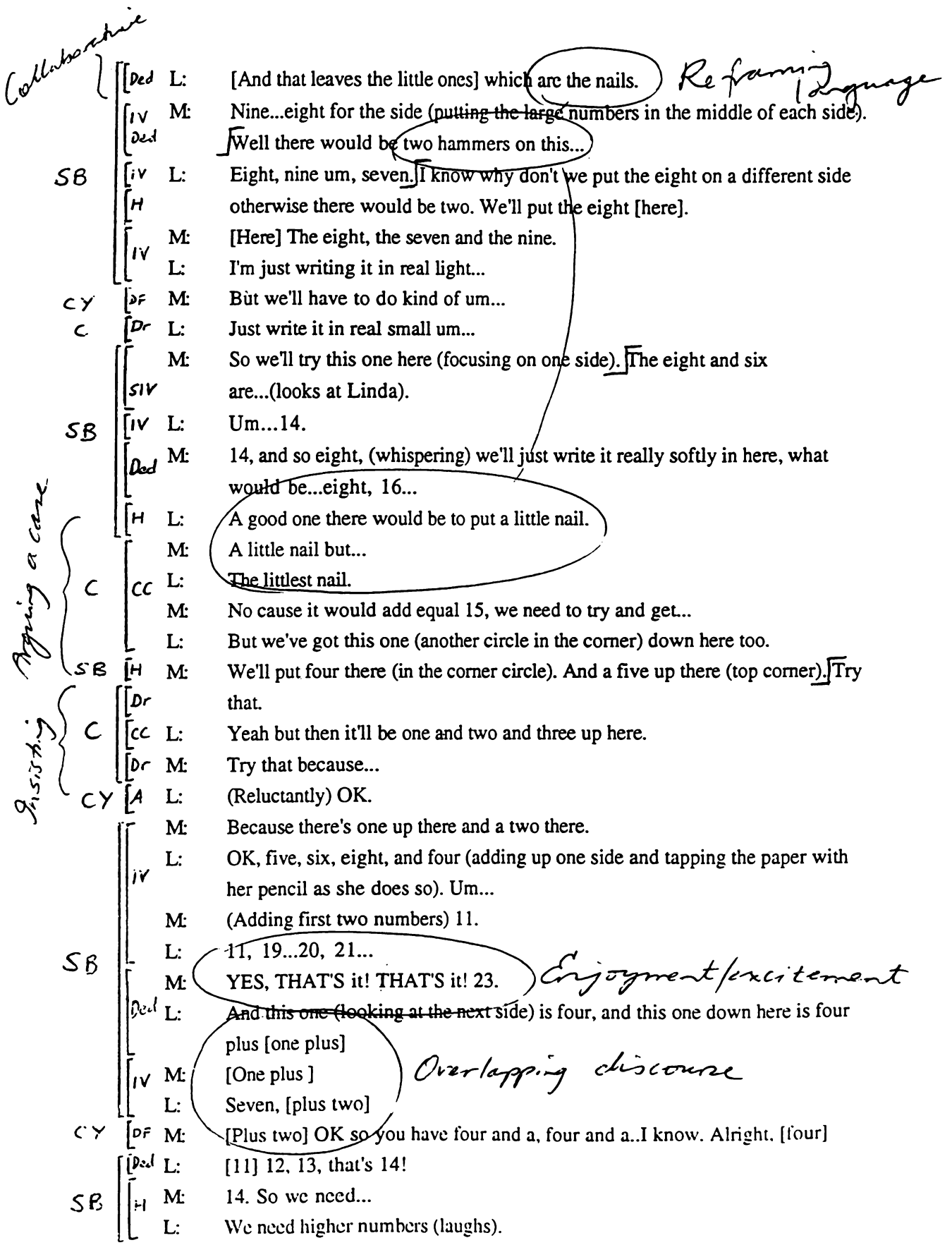
metaphor – hammers & nails

Peer tutoring

Persistence

Collaborative discourse

Adding to / finishing each others sentences



	Ded	L:	[And that leaves the little ones] which are the nails.
	IV Ded	M:	Nine...eight for the side (~~putting the large numbers~~ in the middle of each side). [Well there would be two hammers on this...
SB	IV H	L:	Eight, nine um, seven. [I know why don't we put the eight on a different side otherwise there would be two. We'll put the eight [here].
	IV	M:	[Here] The eight, the seven and the nine.
		L:	I'm just writing it in real light...
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	SIV	M:	So we'll try this one here (focusing on one side). [The eight and six are...(looks at Linda).
SB	IV	L:	Um...14.
	Ded	M:	14, and so eight, (whispering) we'll just write it really softly in here, what would be...eight, 16...
	H	L:	A good one there would be to put a little nail.
		M:	A little nail but...
C	CC	L:	~~The~~ littlest nail.
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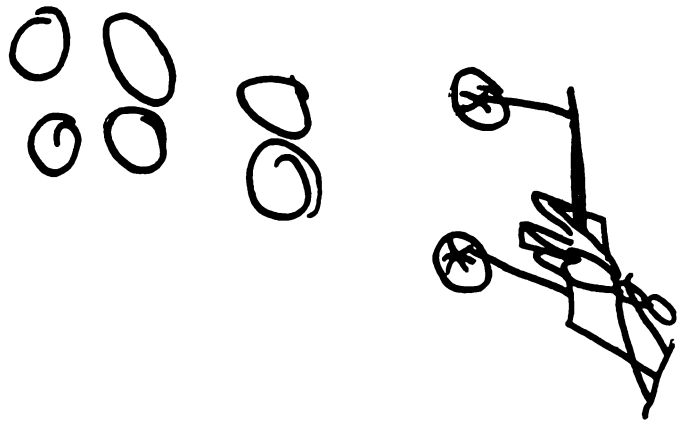
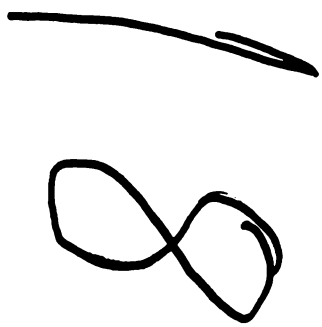
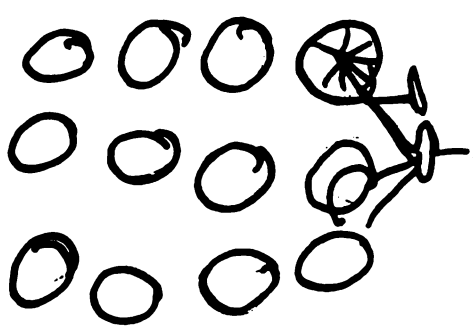
		L:	But we've got this one (another circle in the corner) down here too.
SB	H	M:	We'll put four there (in the corner circle). And a five up there (top corner). [Try that.
	Dr		
C	CC	L:	Yeah but then it'll be one and two and three up here.
	Dr	M:	Try that because...
CY	A	L:	(Reluctantly) OK.
		M:	Because there's one up there and a two there.
	IV	L:	OK, five, six, eight, and four (adding up one side and tapping the paper with her pencil as she does so). Um...
		M:	(Adding first two numbers) 11.
SB		L:	11, 19...20, 21...
		M:	YES, THAT'S it! THAT'S it! 23.
	Ded	L:	~~And this one (looking at the next~~ side) is four, and this one down here is four plus [one plus]
	IV	M:	[One plus]
		L:	Seven, [plus two]
CY	DF	M:	[Plus two] OK so you have four and a, four and a..I know. Alright, [four]
	Ded	L:	[11] 12, 13, that's 14!
SB	H	M:	14. So we need...
		L:	We need higher numbers (laughs).

Appendix F







Appendix G