A descriptive study of the use of a problem solving heuristic in a cooperative small group setting

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Abstract

This research is in the area of small group cooperative learning. Cooperative learning groups range in size from two to eight students and have, as a central focus, students working collaboratively to achieve common goals. Generally members of the group have their individual and group responsibilities and the task is usually not completed unless every member participates in the activity. Exponents of cooperative learning methods claim that student achievement and understanding of the content is equal if not better than learning under traditional methods due to increased social skills, improved self esteem, and the reduced effects of ethnic differences or physical disabilities (Good & Brophy, 1991, p. 415).

This descriptive study builds upon the work of King, Barry, Maloney and Tayler (1994) in analysing student talk in small group work. The research participants are four students in a target group and their teacher, in a class of 29 year seven students, in a government primary school. Seven problem solving lessons form the content for the study which is based on a cognitive psychological framework. The study employs both qualitative and quantitative data collection to analyse the relationship between the teacher's instructional talk and student talk in regard to the use of a problem solving heuristic in problem solving activities.
Results of the study provide a greater understanding of the relationship between the teacher's instructional goals and the students' perception of, and use of this instruction, in small group cooperative learning. It also provides some insight into the implications for teachers' use of the small group learning strategy. In turn this has implications for teacher educators and the professional development of teachers in small group cooperative learning techniques.
Declaration

I certify that this thesis does not, to the best of my knowledge and belief:

(i) incorporate without acknowledgment any material previously submitted for a degree or diploma in any institution of higher education;

(ii) contain any material previously published or written by another person except where due reference is made in the text; or

(iii) contain any defamatory material.

Signed

Date 13th Feb '98
Acknowledgments

First I would like to thank Kevin Barry, from the early days as a lecturer, a neighbour, a friend and now as the supervisor in this study. Effective teachers seem to be all these things. My thanks also goes to the other members of the research team Len King and Scott Zhender. I am grateful for their enthusiasm, their diligence and their professionalism.

As well, I am indebted to my wife, Christine, and my two children Bryce and Amber whom I love dearly. Thankyou for your patient support and encouragement.
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CHAPTER ONE

INTRODUCTION

Overview of the Chapter
This chapter introduces the study and discusses the background, the significance and the purpose of the study. The research questions and the definitions are stated, and the chapter concludes with a summary.

Background to the Study
Investigation into small-groups and learning has been undertaken by a number of researchers over the last 20 years (Johnson & Johnson, 1975, 1994; Schmuck & Schmuck, 1983; Sharan & Sharan, 1984; Slavin, 1983). Much of this research has concentrated on the nature of the task, the reward structures and student achievement but little insight has been provided into the role of the teacher's instruction or the content or the form of the student interactions (Bossert, 1989). In a review of research Meloth, Deering and Sanders (1993, p.5) found that it was rare that teachers were reported as providing "information that would help students attend to and communicate, important lesson content effectively". Furthermore, Meloth, Deering and Sanders (1993, p5) found that fewer than 5% of studies in a review by Johnson, Johnson and Maruyama (1983) "examined the content of peer-group discussions, making it unclear whether the quality of students discussions
contributed to learning gains”. If the goal of small group cooperative activity is to promote student learning then a lack of information about the discussion students are having, and the role of the teacher, are areas for justifiable concern.

**Significance of the Study**

Concern in the areas of student discussion and teacher behaviour is highlighted by the current world wide interest in small group cooperative learning and the claims that suggest students do as well, if not better academically, in cooperative groups than when they are taught by more traditional methods (Slavin, 1983; Sharan & Sharan, 1984; Johnson & Johnson, 1994; King, Barry, Maloney, & Tayler, 1993b; Meloth, 1990). Concomitant with this world wide interest, new syllabi based on cooperative learning are being introduced into Australian schools, for example the Primary Science Investigations.

However, while these developments are taking place there appears to be little information about the connection between teachers' instructional behaviours and small group interactions. Meloth, Deering and Sanders (1993) called for a need to refocus the research to investigate the conditions, discussion and learning connection. Therefore, it would seem appropriate that a study concentrate on these aspects. An understanding of such a
connection would seem significant if we are to expand theory on how and why cooperation works and how cooperation leads to learning.

**Purpose of the Study**

The purpose of the study is to describe the relationship between the teacher's talk and the students' talk. Specifically, the study will concentrate on the teacher's instruction in a problem-solving heuristic and whether this heuristic is reflected in the students' talk and their perception of the lesson(s). The heuristic used is described as a problem-solving heuristic and involves students responding to a problem by generating or proposing an idea, then negotiating and reacting to that suggestion before coming to a final recommendation about whether it should be included in the group's response to the task. Once this has been done, students work the last two steps of the heuristic recording and reviewing the appropriateness of the product. The problem-solving heuristic is shown in Figure 1.
Two research questions guide the study:

1. What is the nature and degree of connection between the cognitive intent and form of small group cooperative learning set by the teacher (conditions) and the kind of peer group interaction and talk (discussions) held by students?

2. What is the extent to which teacher instruction in a problem solving heuristic is reflected in a group of four students' talk during the activity phase of seven problem solving lessons?

Definitions

The terms used in this proposal are defined as follows;
Small group cooperative learning refers to students working in small-groups (typically four to eight students) on related tasks, to produce a group product.

A problem solving heuristic is a list of key words or phrases often supported by diagrams that guide the student in solving the problem. In this study this involves students responding to a problem by generating or proposing an idea, insight, explanation or answer; then negotiating, arguing and reacting to that suggestion before coming to a final recommendation about whether it should be included in the group's response to the task. Following this, students write or record the answer, and look back and check their work.

Learning together is a model of cooperative learning advocated by Johnson and Johnson (1975, 1994) and involves heterogeneous groups of four or five students working together on assigned tasks. The model has four aspects: students are interdependent with one another in the completion of the task, there is face to face interaction among students, each member is individually accountable and the teacher instructs the students in appropriate interpersonal skills.

Groups of Four is a model of small group cooperative learning developed by Burns (1981) and is based on the Learning Together model of Johnson and Johnson (1975, 1994). In addition to the characteristics of the Learning Together model the Groups of Four model is based on the rules:
1. You are responsible for your own work and behaviour.

2. You must be willing to help any group member who asks.

3. You may ask for help from the teacher only when everyone in your group has the same question.

**Stimulated recall** is a branch of introspective methodology in which audio and/or visual cues are presented to facilitate a subject’s recall of the covert mental activity which occurred simultaneously with the presented cue or stimuli (Connors cited in King & Tuckwell, 1983, p.1).

**MAKTAB** is a small group cooperative learning interaction analysis system (King, Maloney, Tayler & Barry, 1993b). Observed student interactions are coded into categories of student talk. The categories of coded observations are analysed using a statistical summary package. A full overview of the system appears in Table 1. Use of the instrument is discussed under the data analysis section in chapter three.

**NUD*IST** is a quantitative data analysis tool used in the analysis of text. The acronym stands for non numerical, unstructured data, indexing searching and theorizing. The tool is described more fully in the data analysis and instrument reliability sections of chapter three.
Table 1
Summary Chart of MAKITAB Small group Learning Interaction Analysis System

<table>
<thead>
<tr>
<th>WHOLE CLASS INTRODUCTION</th>
<th>GROUP TASK</th>
<th>GROUP DYNAMICS</th>
<th>MONITORING GROUP</th>
<th>WHOLE CLASS INTERVENTION</th>
<th>WHOLE CLASS WRAP-UP</th>
</tr>
</thead>
<tbody>
<tr>
<td>IS01 Recaptulating from previous lessons</td>
<td>TS01 Management materials / movement</td>
<td>DS01 Decision-making processes</td>
<td>MS01 Checking progress</td>
<td>NS01 Recaptulating previous activity</td>
<td>RS01 Recapitulating summary / marking / collating findings</td>
</tr>
<tr>
<td>IS02 Explaining task/ content/ procedures/ materials</td>
<td>TS02 Clarifying task directions / requirements</td>
<td>DS02 Assigning roles</td>
<td>MS02 Clarifying or eliciting task content / solution</td>
<td>NS02 Feedback / positive</td>
<td>RS02 Feedback / positive</td>
</tr>
<tr>
<td>IS03 Feedback-positive</td>
<td>TS03 Task feedback-positive</td>
<td>DS03 Task feedback-positive</td>
<td>MS03 Feedback / positive</td>
<td>NS03 Feedback / positive</td>
<td>RS03 Feedback / positive</td>
</tr>
<tr>
<td>IS04 Feedback-negative</td>
<td>TS04 Task feedback-negative</td>
<td>DS04 Task feedback-negative</td>
<td>MS04 Feedback / negative</td>
<td>NS04 Feedback / negative</td>
<td>RS04 Feedback / negative</td>
</tr>
<tr>
<td>IS05 Setting context</td>
<td>TS05 Determining work actions</td>
<td>DS05 Challenging group member(s) / asserting</td>
<td>MS05 Clarifying task procedures</td>
<td>NS05 Checking thinking process(es)</td>
<td>RS05 Reviewing thinking process(es)</td>
</tr>
<tr>
<td>IS06 Explicit teaching of content</td>
<td>TS06 Accepting work actions</td>
<td>DS06 Positive response to challenge</td>
<td>MS06 Giving answer / solution</td>
<td>NS06 Giving explicit teaching of new content</td>
<td>RS06 Looking ahead</td>
</tr>
<tr>
<td>IS07 Recaptulating task content / procedures</td>
<td>TS07 Rejecting work actions</td>
<td>DS07 Negative response to challenge</td>
<td>MS07 Giving explicit directions</td>
<td>NS07 Giving directions</td>
<td>RS07 Giving directions</td>
</tr>
<tr>
<td>IS08 Control / discipline</td>
<td>TS08 Examining, comprehending, clarifying &amp; routine responding</td>
<td>DS08 Seeking approval / feedback</td>
<td>MS08 Control / discipline</td>
<td>NS08 Control / discipline</td>
<td>RS08 Control / discipline</td>
</tr>
<tr>
<td>IS09 Student question / comment</td>
<td>TS09 Sudden ideas / insights</td>
<td>DS09 Self-evaluation - positive</td>
<td>MS09 Student initiated contact</td>
<td>NS09 Student question / comment</td>
<td>RS09 Student question / comment</td>
</tr>
<tr>
<td>IS10 Proposing</td>
<td>TS10 Self-evaluation - negative</td>
<td>DS10 Resolving problems (dynamics)</td>
<td>MS10 Checking progress / marking</td>
<td>NS10 Checking progress / marking</td>
<td>RS10 Checking progress / marking</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SPEAKER</th>
<th>LISTENER</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-4</td>
<td>Female student</td>
</tr>
<tr>
<td>5-8</td>
<td>Male student</td>
</tr>
<tr>
<td>9</td>
<td>Group</td>
</tr>
<tr>
<td>U</td>
<td>Unknown student</td>
</tr>
<tr>
<td>C</td>
<td>Class</td>
</tr>
<tr>
<td>T</td>
<td>Teacher</td>
</tr>
<tr>
<td>H</td>
<td>Helper</td>
</tr>
<tr>
<td>P</td>
<td>Parent</td>
</tr>
<tr>
<td>O</td>
<td>Outsider</td>
</tr>
<tr>
<td>S</td>
<td>Self</td>
</tr>
<tr>
<td>X</td>
<td>Other</td>
</tr>
</tbody>
</table>

CODING NOTES
#9 Non-task related (IS, TS, MS, NS, 9, RS)
0 Cannot code
S Statement - for coding questions substitute
P for a cognitive question
X for all other forms of question
Summary of the Chapter

This chapter has discussed the need to examine more closely the relationship between the teacher's intent and the resulting student discussions that occur in small group cooperative learning situations. The focus of the study on the student use of a problem solving heuristic has been stated in the two research questions that guide the study. Chapter two will examine the literature related to the study.
CHAPTER TWO

REVIEW OF THE LITERATURE

Overview of the Chapter

This chapter considers the growing body of literature addressing small group cooperative learning from the earlier and later periods of research and then examines some of the literature from studies that have begun to identify some of the many factors that affect the dynamic nature of student-student and student-teacher interactions. Literature covering small group discussion, explanations and disagreements has been reviewed on the basis that use of a heuristic in small group activities generally relies on student discussions of some form. Emphasis has been given to studies that concentrated on the area of mathematics and in particular, the use of heuristics, learning scaffolds and frameworks.

Approaches to Small group Cooperative Learning

There is a considerable body of literature concerning the theoretical, research and the practical aspects of small group cooperative learning. Early studies (Sharan & Sharan, 1984; Slavin, 1983; Johnson & Johnson, 1975; Aronson, 1978) considered the nature of cooperative small group learning compared to traditional forms of classroom teaching. Later studies (Johnson, Johnson & Maruyama, 1983; Johnson, Maruyama, Johnson, Nelson & Skon,
1981; Bossert, 1989) examined the benefits of cooperative learning in many areas of learning, ages of students and range of tasks.

In broad terms three approaches are evident. The Learning Together approach (Johnson & Johnson, 1975, 1994) encourages educators to understand the broad concepts and skills of cooperative learning and advocates roles for group members such as facilitator, encourager and praiser. The Student Team Learning approach (Slavin, 1983) has a much higher proportion of inter-team competition and utilises teams and tournaments to learn the material presented in tasks. The Group Investigation approach (Sharan & Sharan, 1984) takes complex curriculum material and divides the material among groups. The groups are self-motivated and study sub-topics within the class topics which are later presented to the whole class and evaluated.

Other models exist (Cohen, 1986; Britton, 1970; McCabe & Rhoades, 1990; Kagan, 1992) but all, including those above, seem to bear similar attributes of:

- Common tasks suitable for group work
- Learning that is done in small group settings
- Behaviour that is cooperative
- Interdependent relationships among student learners and
- Individual and group accountability and responsibility.
Cooperative Learning and Student Achievement

Numerous authors have undertaken research in small group cooperative learning. Of the scientific and professional literature most controlled research studies were undertaken to validate or disconfirm theory (Johnson & Johnson, 1994, p.42). Within the professional literature many studies fall into one of four groups - summative studies asking whether a particular cooperative program produced beneficial results; comparative studies asking which of two or more programs produced the most beneficial results; formative studies examining why a program went wrong or how it could be improved; and survey studies looking at the long term impacts of cooperative learning programs. Johnson and Johnson (1994) claim that since 1898 over 550 experimental and 100 correlational research studies have been conducted.

Johnson and Johnson (cited in Rogers & Kutnick, 1990, p. 18) claimed that their analysis of a number of studies revealed that cooperative learning promoted higher achievement in all subject areas and at all ages. Johnson and Johnson (1994) summarise their view saying:

cooperative learning can be used with some confidence at every grade level, in every subject area, and with any task. ... The research has been conducted in different settings, countries, and decades. The research on cooperative learning has a validity and a generalizability rarely found in the educational literature (p.45).
Slavin (cited in Rogers & Kutnick, 1990, p. 235) examined seventy studies on cooperative learning methods of which sixty three measured the effects on student achievement. Slavin (cited in Rogers & Kutnick, 1990, p. 235) reported that of the sixty three studies, 57% showed significantly greater achievement in the classes based on cooperative methods than in the control classes. Forty one percent showed no difference in the classes and in one study the control group was found to perform better than the experimental group.

Such claims have been questioned by Cotton and Cook (cited in Rogers & Kutnick, 1990, p. 18) who have argued that many of the studies were carried out over very short periods and were not completed under normal classroom conditions. Stallings and Stipek (cited in Wittrock, 1986, p. 749) concurred saying that “the academic superiority of cooperative learning models is not universally found, and there are many factors that undoubtedly mediate the effectiveness of cooperative learning methods”.

**Cooperative Learning and Group Processes**

Johnson and Johnson (1994), Burns (1981) and Good and Brophy (1997) discuss numerous studies addressing the composition and processes that occur within cooperative learning groups. Good and Brophy (1997) summarise the research stating three main points. First, the prior experiences and achievements of the group members significantly affects the group’s achievement. The
experiences and achievement of a peer tutor mediate the quality of explanations given and subsequently affect the learning achieved by students that receive explanations. Second, the quality of the student interactions can be improved by training students in the processes of cooperative learning, including social interaction skills and cognitive role skills of questioning, checking, suggesting and providing detail in explanations. Third, certain combinations of students worked better than others. Groups that had one high achiever and two low achievers, or one high achiever, two average achievers and one low achiever worked better than groups where there were two high achievers with one low achiever or groups of all low achievers.

Mulryan (cited in Good and Brophy, 1997, p. 280) found that the "roles of helping that emerged in ... small groups may not have been useful, especially when the same students played theses roles consistently". She argued that unless teachers began to carefully structure group roles and monitor the role processes within groups, there was a danger of low achieving students continuing to experience low achievement. Good and Brophy (1997, p. 285) conclude by summarising Johnson, Skon and Johnson (1980), saying that students will respond with more effective interactions and use higher levels of cognitive strategies when completing tasks if cooperative groups are effectively structured.
Talk as a Mediating Factor in Cooperative Learning

Doyle (1977), among other authors (Bossert, 1989; King, 1993), argued that more interest should be given to the mediating factors of learning in cooperative groups. Johnson and Johnson (1985) identified several potential factors that mediated small group processes including reasoning strategies, constructive controversy and cognitive processing. Johnson and Johnson (1985) posited that cooperative learning situations gave opportunities for reasoning strategies and the development of higher order thinking skills. Varying views required students to search for information, reconcile differences of opinion and understanding and develop academic problem solving skills. Cooperative learning groups also allowed students to orally rehearse information and provide explanations relevant to the task.

Examination of explanations by Peterson and Swing (1985) found that higher order and specific content related explanations were correlated with higher levels of student achievement. Students reported that clearer, specific responses to requests for help resulted in better explanations. Students reported they knew that they had provided a better explanation, when the student receiving the explanation completed a task or wrote the answer down (1985, p.309).

Interestingly though, studies undertaken by Ross and Cousins (1995) did not concur with the Peterson and Swing (1985) findings.
Ross and Cousins (1995) conducted three studies focusing on student attempts to seek an explanation as a strategy to improve achievement. The examination found that two of the three studies showed no higher levels of achievement when explanations were sought and received. Lack of achievement was attributed to two reasons. In the first instance students did not seek explanations when they needed to and secondly when students did receive explanations the explanations were of a poor quality. Not knowing when to ask for explanations was a result of students not knowing that they were in error or required help in solving problems. The poor quality of explanations was due to insensitive type explanations that simply conveyed the facts rather than teaching the student requiring help or understanding. Ross (1995) also reported that in similar studies, situations where explanations were generated by the structure of the lesson or through the use of generic question and explanation scaffolds, the explanations were rarely genuine and differed in form and function from naturally occurring explanations.

Lindow, Peterson and Wilkinson (1985) also looked at the nature of verbal disagreements during small group cooperative learning. Their study found that boys and higher ability students provided a greater number of demonstrations and answers to discussion points. Their work concentrated on seat work tasks involving time and money. The students that provided more answers and demonstrations were also rated by peers as being competent
students, however, there was no significant relationship found between these identified competent students and student achievement. Providing higher order explanations was found to be not correlated with student achievement. Interestingly, the study identified that young students were able to:

solve conflict when it spontaneously occurred, without having received explicit instructions about how to do it. In addition they usually reached consensus on the correct answer (p.667).

Bossert (1989) also recognised the mediating effects that result from the interactions among the various influences on cooperative learning groups. In particular Bossert (1989) noted the need for “fine grained analysis of students cognitive processing...” and argued that “this would allow researchers to document how peer interactions ... shape the thinking and processing skills of group members” (p. 239).

**Cooperative Learning in Mathematics**

The review of literature now shifts to the mathematics content area and the findings of studies involving cooperative learning techniques. Good, Grouws, Mason, Slavings and Cramer's (1990) study of 33 teachers and 206 mathematics lessons concluded that there were few teachers that regularly used small group cooperative learning approaches and of those that did, a wide variety of forms were evident. Of these some forms actually restricted the potential of the strategy by “limiting the meaningful presentation and assignment of challenging content to students and by eliminating productive
interaction and cooperation among students" (p.774). Good, Grouws, Mason, Slavings and Cramer (1990) also recognised the complex arrangement of variables involved including classroom management and discipline factors that impacted on a teacher's use of the small group learning strategy. Roedel and Nelson (1996) agreed following a study examining video taped evidence of groups of four, year three students in mathematics, stating that "creating successful cooperative learning experiences is not a straightforward process and that desirable outcomes are not guaranteed" (p.1).

In studies focusing on cooperative learning in mathematics lessons Perry, Geoghegan, Owens and Howe (1995) perceived that:

- the student who messes about, will not work or is not interested in the work, will rely on capable students in the group
- bright students will be held back in cooperative learning conditions and
- the teacher has control of all knowledge.

Perry, Geoghegan, Owens and Howe (1995) argued that allowing time, instilling confidence, encouraging communication, and collective ownership of the solutions were valuable aspects to cooperative learning situations. The groups of students were seen as a "community of validators" all participating in the development of the solution. Similarly, Sullivan, Bourke and Scott (1995) studied open ended tasks, where students could develop collective ownership of solutions, and found that the lessons were of benefit for both low
and high achieving students and that achievement was maintained after the program concluded. Interestingly Sullivan, Bourke and Scott (1995) reported that open ended problems were found to be easier for students both before and after the cooperative lessons than closed questions which were found to be comparable.

**Literature on Heuristics**

Biggs and Moore (1993) use the term heuristic to mean self-questioning and Hawton (1992) refers to a heuristic method as one that trains a student in the steps involved in solving a problem. A heuristic is the set of questions or a framework that prompts questions for the learner to check their learning and progress on a task. A heuristic may be applied to a specific context or generalised across learning contexts. Polya's (1945) *How to Solve It* heuristic was initially devised for mathematics tasks and had four steps. Understanding the problem, devising a plan, carry out the plan, and looking back. Learners undertaking the mathematical task would be guided at each step in coming to a solution. Novak and Gowin (cited in Roth & Roychoudhury, 1993, p.243) maintain that “a heuristic has psychological value if it not only encourages meaningful learning, but also helps learners to understand the process by which humans produce knowledge”.
Various other heuristics have been developed in order to aid students in the learning process. Robinson (1946) used study, question, read recite and review for general study. Thomas and Robinson (1982) later added a fourth “r” in reflect. Bransford and Stein (1984) used the acronym IDEAL to remind students to identify the problem, define what the problem is by representing it in some way, explore possible strategies for solving it, act on selected strategies and look back over the solution and evaluate it.

In evaluating student success in the use of heuristics Wong (1985) reviewed 27 studies on self-questioning techniques in reading. Wong (1985) found that the major cause of failure of the technique was due to inadequate time or training in generating questions. Chan (1994) however was less certain in his assessment of the value of heuristics. In a study of the relationship among motivation, strategic learning and reading achievement in grades five, seven and nine students Chan (1994) found that there was support for the claim that younger students “were less likely ... to believe in personal control over learning outcomes through effort and strategy use". Chan (1994) found that grade five students attributed success to ability rather than strategy use, where grade nine students considered a lack of effort and poor strategy use as factors accounting for lower achievement. The findings on the extent of success attributed to the student use of the strategic learning implied
that attribution of success through strategy use was also a function of student maturation.

Novak and Gowan (cited in Roth & Roychoudhury, 1993, p.238) in their study of elementary education majors at a Canadian university, found that using vee mapping and concept maps improved the learning of science teaching processes and attitudes. Vee mapping required the student to diagram learning using the categories of theory, principles, concepts, events, data, transformations and claims to describe the research question. The vee joined the conceptual side to the methodological side (Figure 2) and was pivotal on the events under consideration.

![Vee Map](image)

*Figure 2. Vee Map.*

Roth and Roychoudhury (1993) found that students were more able to express their understanding through using concept maps and Vee maps. Furthermore, the researchers found that students began
to increase the level of integration of knowledge from various sources. The beneficial effects of the group work was echoed in student claims that "...working in a group can sometimes be a challenge because of each person’s different interpretation, but it sure helps in putting different ideas into perspective" (p.241).

Brown and Palincsar (1987) in their work on Reciprocal Teaching found that simple, though, specific roles and processes could guide small group lessons in reading and language learning. The four strategies of questioning, clarifying, summarising and predicting were first modelled by the teacher then later used by students in "teaching" the lesson. Student improvements were found in not only the standardised test scores of learned material but also long term maintenance, transfer and generalisation of the learning processes themselves.

Leighton, Slavin and Davidson (1989) examined the use of heuristic problem solving strategies in mathematics lessons for seventh graders where students worked individually, in groups and in cooperative teams. In particular the cooperative teams used the team practice and student team learning approaches. No significant difference was found among the three groups. However, all three groups out-performed a control group that did not receive instruction in the use of heuristic practices.
However, Hart (1990) in his study of heuristic use in mathematics argued that teaching the problem solving processes of experts to average and below average students may be counter productive and suggested that concentration should rather be on the processes used by average students. The study observed mixed gender groups of three students involved in group problem solving. Hart claimed that the factors affecting problem solving performance included:

- lack of an experiential framework
- imposition of unnecessary restrictions on the problem
- lack of monitoring of cognitive activity and
- unproductive beliefs.

Factors that enhanced problem solving performance included group collaboration, group monitoring and the social norms that prevailed in small group work.

In a similar vein, Sweller (1990), Ahmad, Tarmizi and Sweller (1988) and Sweller and Low (1992) argued that students, particularly novices compared to experts, could be overloaded in solving a problem. Ahmad, Tarmizi and Sweller (1988) examined student achievement where students experienced different levels of cognitive load. The study found that providing learning in a format that did not split attention enabled student performance that was superior to that achieved using a conventional approach. That is, students did not have to concentrate on determining a means-end strategy as well
as the problem in hand. The lower cognitive load allowed cognitive resources for schema acquisition or the development of a cognitive construct that aided problem solving. The results of five experiments provided some evidence that problems involving higher cognitive loads were associated with lower levels of student performance.

From their studies Sweller (1990) and his colleagues (Ahmad, Tarmizi & Sweller, 1988; Sweller & Low, 1992) made two general points. The first point was that in a lesson that requires less aspects to be focussed upon there is greater opportunity for student success. Secondly, helping a student work through a series of problems permits greater student performance than if the student has to solve the same set of problems alone. This appears to be similar to providing a rote patterning for learning from which the student employs a patterned approach to solving new problems. Ahmad, Tarmizi and Sweller (1988) claim that effective mathematicians have developed many thousands of schemas through solving numerous problems. They argue that reducing the cognitive load in the learning stages simply promotes the schema learning process. Consequently, Owen and Sweller (1985) and Owen and Sweller (1989) advocate caution in the use of heuristics and the teaching of problem solving, suggesting that "problem solving skills [in mathematics] can be acquired but on current evidence only by a very detailed knowledge of the relevant subject matter" (1989, p.327). In contrast, however, King, Barry and Zehnder (1996) claimed that students could progress
in their use of a heuristic to aid problem solving. They recognised the need for particular group discussion conditions that encourage higher levels of cognitive talk. A group climate focussed on effective help was seen as an important aspect of success in achieving the group goal.

In studying the teaching of student self-evaluation, Ross, Rolheiser and Hogaboam-Gray (1996) found that students preferred not to use the instruments and procedures developed by exemplar teachers. Instead students modified and adapted the instruments and procedures to maintain the intent of the reflection but not the specific techniques. Ross, Rolheiser and Hogaboam-Gray (1996) cited Sternberg and Horvath’s (1995) term “family resemblance” and argued that research findings were often used in a cluster of ways and that literal adoption of the prepared instruments and procedures was surprisingly absent. Ross, Rolheiser and Hogaboam-Gray (1996) were also quick to point out that the nature of the student sample (chosen for their excellence in cooperative learning and teaching) may have permitted easy reconstruction of the instruments and procedures of others and that literal use of the instruments and procedures may have been more suited to students with less experience in cooperative learning.

Garner (1990) in a discussion of why students need to, yet fail to use learning strategies postulated five possible reasons. These were:

- poor cognitive monitoring
• use of low level routines
• inadequate background knowledge
• attributions and classroom goals that do not support strategy use and
• situations where the strategy becomes stuck in the context.

Garner (1990) argued that these reasons all contributed to a lack of student use of strategies. Garner (1990) suggested that an understanding of the problem solving context was essential in the analysis of student use of strategies and that when the context varied so too did the strategic activity.

Studies Leading up to the Current Study

Aspects of the current study in small group cooperative learning have been studied by various authors. Winnie and Marx, and Wittrock (cited in Bossert, 1989) and Mevarech (1996) have focussed on student cognitive processes, while student talk (Deering & Meloth, 1991; King, Barry, Maloney & Tayler, 1994; Meloth & Deering, 1992; Meloth & Deering, 1992) and the relationship with the teacher's cognitive intent (Meloth, Deering & Sanders, 1993; King, Barry & Zehnder, 1996) have been the attention of a smaller group of researchers.

Teacher effects studied by Meloth and Deering (1992) examined the effects of two cooperative conditions on student peer-group discussion, on reading comprehension and on metacognition. Summary findings suggested that students may not increase their
discussion of the task and its content unless the teacher's instruction, and the cooperative activities, expressly encouraged them to do so. In a study on naturally occurring discussion in cooperative groups (Deering & Meloth, 1991) found there were low levels of task content discussion and limited levels of high cognitive level talk. Overall findings of the Cooperative Reading Project (Meloth, Deering & Sanders, 1994) concluded that there were significant implications for instruction in using a collaborative, constructivist perspective to change, and the subsequent effects this instruction had on student learning in group situations.

In a later study (Meloth & Deering, 1994) students in small group cooperative learning settings were encouraged to improve learning through the use of strategies or through a reward condition. Meloth and Deering (1994) found that both groups demonstrated similar forms of student talk but that the strategic condition group held more focused discussion and exhibited higher levels of metacognitive awareness.

King, Barry, Maloney and Tayler (1993b) in a study of the teacher's role found that the teacher was pivotal to effective small group cooperative learning. The teacher's role was seen to include whole class instruction before, during and after the student activity as well as the monitoring of student behaviours during group work. In a subsequent study King, Barry, Maloney and Tayler (1994) explored the relationship between teacher's talk and student's task
enhancing talk during small group cooperative learning lessons. The study found that teachers could influence the kind and quality of the student talk.

This study extends and builds upon the work of these authors in describing the connection between the teacher's cognitive intent and the kind of peer group interactions evident in the student discussions occurring in the small group cooperative learning setting. Moreover, the study will focus on the extent to which teacher instruction in a problem solving heuristic is reflected in a group of four students' talk during the activity phase of seven problem solving lessons.

**Summary of the Chapter**

This chapter has reviewed broad trends evident in the literature on small group cooperative learning and the findings of previous studies that have led to the current study. In general terms the positive effects of small group interactions on student achievement are evident. In a general way problem solving heuristics were seen as aids to student learning however the effectiveness of particular devices altered in differing contexts and this was evident in studies carried out in the mathematics learning area.
CHAPTER THREE

RESEARCH DESIGN

Overview of the Chapter

This chapter covers the theoretical framework and the design of the study including the sample, the teacher, the lessons, the problem solving heuristic, the observations made and the feedback provided to the teacher. The chapter also covers a description of the data collection and data analysis undertaken in chapter four. This includes the use of the MAKITAB instrument, the reading of the transcripts, the stimulated recall interviews and the NUD*IST analysis. Discussion of the assumptions, limitations and ethical considerations are followed by a section on instrument reliability. There is a list of instruments and equipment used in the study and the chapter concludes with a summary.

Theoretical Framework

Early work in the field of cooperative learning held a social psychological perspective though various authors now perceive alternate theoretical frameworks. Johnson and Johnson (1994) have identified three theoretical perspectives from which the work on small group cooperative learning has developed. These are the social interdependence perspective based on the work of Lewin and Deutsch (cited in Johnson & Johnson, 1994), the behavioural learning theory based on the work of Skinner and Homans (cited in Johnson &
Johnson, 1994), and the cognitive developmental perspective based on the work of Vygotsky (1978), Piaget (1950) and Dewey (1963) also quoted by Johnson and Johnson (1994).

Slavin (1992) in his analysis of the various theoretical frameworks that have guided the study of cooperative learning, lists six perspectives; motivational, social cohesion, practice, classroom organisation, cognitive development and cognitive elaboration. These six views may be broadly grouped to fall into the three categories described by Johnson and Johnson (1994) as shown in Table 2.

Table 2
Overview of Writers and their Theoretical Perspectives

<table>
<thead>
<tr>
<th>Writers</th>
<th>Johnson &amp; Johnson</th>
<th>Slavin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lewin</td>
<td>Social Independence</td>
<td>Motivational</td>
</tr>
<tr>
<td>Deutsch</td>
<td></td>
<td>Social Cohesion</td>
</tr>
<tr>
<td>Skinner</td>
<td>Behaviour Learning Theory</td>
<td>Practice</td>
</tr>
<tr>
<td>Homans</td>
<td></td>
<td>Classroom</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Organisation</td>
</tr>
<tr>
<td>Vygotsky, Piaget &amp; Dewey</td>
<td>Cognitive Developmental</td>
<td>Cognitive Development</td>
</tr>
<tr>
<td></td>
<td>Perspective</td>
<td>Cognitive Elaboration</td>
</tr>
</tbody>
</table>

writers that set much of the groundwork for the cognitive developmental perspective claimed that thoughts and ideas were always tentative and should be tested through application in ways that were not separated from everyday life. Fundamental was the belief that each experience takes something from prior experiences and alters the quality of experiences that follow. Dewey (1963)
posited that a central notion of a scientific method encouraged
students to discover an idea’s validity for themselves.

Vygotsky (1978) argued that learning and cognition have their
origins in the relationships of the learner and the history of the
learning. He maintained that knowledge was constructed from
cooporative efforts of people to learn, understand and solve problems,
through reasoning, correcting and understanding. Vygotsky (1978)
asserted that learning could be described by reference to different
zones and defined the zone of proximal development as the difference
between a student’s potential level of development to solve problems
and the actual level of development to solve problems. He claimed
that when students worked in groups they operated in each other’s
proximal zones, modeling problem solving skills and abilities for one
another. Later on, an individual would take on the skills and abilities
modelled in the group, using them to solve new problems. Vygotsky’s
(1978) work built upon the writings of earlier authors and is
attributed with much of the early work of social and cognitive
psychology.

Piagetian theory (1950) claimed that a child’s cognitive
competence limited the ability to see an alternate perspective.
Central to the theory were the ideas of cognitive structures, cognitive
content and cognitive functions. Piaget (1950) argued that learning
was a modification of the cognitive structures of the individual and
that knowledge was an adaption of these cognitive structures to meet
with reality. His work with small-groups encouraged students to negotiate a second opposing view. Piaget's (1950) view of learning and knowledge differed from previously held views that saw knowledge as copying reality, and learning as the modification of behaviour resulting from experience.

The work of Vygotsky (1978), Piaget (1950) and Dewey (1963) form the theoretical base to this study. The cognitive psychological view focuses on the learning experiences of students as they talk among themselves and with a teacher to test their knowledge as they solve various problems. Such activities as discussion, argument, and presentation of viewpoints are what Slavin (1992) terms cognitive development. Other activities including asking questions, providing explanations, summarising and providing information, Slavin (1992) calls cognitive elaboration.

Meloth, Deering and Sanders (1993) call for a need to refocus the research effort to investigate the conditions, discussions and learning connection. They suggest a cognitive psychological perspective in which the teacher's cognitive intent for a lesson ought to shape the nature of the cooperative learning task (conditions) and the kind and quality of student interaction (discussions) during the small group interaction phase. The resulting student cognitive achievement (learning) may then be a function of a combination of small group processes ranging from intrapersonal student perceptions and
interpersonal dynamics within each group to teacher influences on student cognitive processes across a lesson.

This study seeks to clarify the nature and degree of connection between the cognitive intent and form of small group cooperative learning set by the teacher and the kind of peer group interaction and talk held by students. This connection has been outlined by Meloth (M. Meloth, personal communication, July, 1995) and is shown in Figure 3. Specifically the study will focus on the extent to which teacher instruction in a problem solving heuristic is reflected in a group of four students' talk during the activity phase of seven problem solving lessons.

![Diagram of a Cognitive Psychological Perspective for Small Group Learning](image)

**Figure 3. Diagram of a Cognitive Psychological Perspective for Small Group Learning.**

**Design**

This research is a descriptive study of one target group and a teacher in a year seven class. The study focuses on the student use
of a problem solving heuristic while engaged in small group problem solving lessons. The study involves seven teaching and learning lessons, one lesson per week for seven weeks.

Sample Group

The four students in the target group formed part of a class of 27 year seven students (turning 12 years of age) in a metropolitan government primary school. The group consisted of one high achiever, one low achiever and two average achievers, and was mixed for gender, two boys and two girls. A profile of the students as described by the teacher appears in Appendix E. Achievement levels used for determining group membership were determined by the teacher prior to the study commencing. The target and class groups were newly formed for the study and generally were not familiar with small group cooperative learning methods.

Teacher

The male teacher volunteered to participate in the study. The teacher had used small group methods but had not had any formal training in small group cooperative learning. However, he was keen to see student learning improved through the use of small group cooperative learning techniques. The teacher was told that the purpose of the study was to describe the relationship between the teacher's instruction of a problem solving heuristic and the cooperative talk of students; in particular the student talk that
identified use of the heuristic. Cooperative lessons were to be held on
the agreed days but otherwise the teacher was left to plan other
lessons as he chose. The intent of the teacher was to improve
student cognitive processing through the use of the heuristic.

Lessons

Each lesson was approximately 40 minutes in duration and held
at the same time on the same day each week. Each of the first three
lessons were in different curriculum areas. The remaining four
lessons were in a curriculum area chosen by the teacher in
conjunction with the researchers and after reflection on the earlier
lessons. The curriculum area chosen was mathematics and the
lessons involved problem solving activities suitable for small group
work. A detailed example of a lesson procedure is shown at Appendix
C. Each lesson followed a similar format.

1. The teacher would introduce the lesson through:

- Reading of the problem from the source materials supplied. This involved use of an overhead projector and sometimes text based materials, and in lessons three to seven
- Revision of the rules of interaction for small group work
- Revision of the possible strategies that students could use
- Revision of the problem solving heuristic.

2. Students would begin work on the problem through such activities as:

- reading
- discussing
- arguing
3. At some stage during the lesson the teacher would intervene:
   - on a small group's work or
   - the entire class' work.
4. Students would continue work following the teacher's intervention.
5. The teacher would conduct a lesson conclusion.

The Problem Solving Heuristic

Use of the problem solving heuristic was introduced in lesson four. The heuristic terms were displayed on the classroom blackboard as in Figure 4.

The teacher introduced the terms and held a brief class discussion on the meanings of the terms and how the heuristic could
be used. This was done prior to the beginning of the activity stage of each lesson. The heuristic diagram remained on the board for the entire lesson in full view of all students.

Data collection

Data were collected using five methods:

1. Audio recording of the students while they worked in their group
2. Continuous video recording of the group working
3. A second (backup) audio recording of the group’s work
4. Written anecdotal records (script-taping) of non-verbal interactions, gestures, or interactions that may have been difficult to interpret from the audio and video records
5. Audio recording of the stimulated recall interviews held with students.

Observation Procedure

The procedure for the observation of each lesson was similar. During the lesson the target students were observed using:

- video tape recorder with sound track
- backup audio tape recorder and
- researcher making written notes (script-taping).

A diagram of the room layout showing the position of the video camera, tape recorder and researcher-observer is shown at Appendix B.

Stimulated Recall Interviews

Central to the study was the use of stimulated recall methodology to gather data from students (Peterson & Swing, 1982). Stimulated recall makes use of recorded events to stimulate a subject
to recall thoughts or feelings prevalent at the time of the event. Generally this involves an audio recording or video-taping of an event being played back to the person involved. The interviewer then asks the subject to recall their feelings and/or thoughts experienced during the event. King and Tuckwell (1983) note that effective data collection using stimulated recall is a function of an individual's ability to recall and their willingness to report. These factors in turn are affected by the rapport established with the researcher (1983, p.5).

Peterson and Swing (1985) examined student explanations in relation to student achievement in small group work. They also used stimulated recall as a method of data collection from students. Coded transcripts of the video tapes of the lessons were examined with a focus on the explanations made by students. The higher quality of explanation provided by the students exhibiting higher achievement may have been due to the increased awareness of students to their own explanations. The stimulated recall interviews were also seen as a possible source of student clarification of the nature of their own (student) understanding.

Clarke and Kessel (1995) in their study of small group cooperative learning also intended using NUD*IST to analyse their data and interestingly made careful use of video records of student activity for later use in stimulated recall interviews. Their study of the classroom negotiation of meaning employed two video cameras, one
on the teacher and one on the students, split screen imaging, and involved making notes of small group student learning using computer software. The software linked the typed observer notes made during filming to the tape position on the video. The two video images of the teacher behaviours and the student behaviours were placed on the one screen. The researcher then cued the video record in preparation for the stimulated recall interviews from notes made using the software. The software then searched the video record for the appropriate counter position. At the time of writing Clarke and Kessel (1995) had not reported any results from the NUD*IST analysis of the transcripts of the video records and interviews.

Following each lesson, in this current study, each of the four target students were individually interviewed. The stimulated recall interview was held in a quiet area where the student observed the video taped lesson segments and responded to the researcher's questions. An audio recording was made of the student's responses to the video clips. The interview format and questions is found at Appendix A. The key guidelines used in the stimulated recall were:

- It was made clear to the student that the stimulated recall process was not a test in any way, nor a record of the student's behaviour,
- The recall session was conducted in suitable surrounds within 24 hours of the event and lasted approximately 20 minutes,
- A second recording device was used to note the subjects uttered recall,
- The researcher aimed to establish a relaxed friendly atmosphere and
• Coding of the gathered data into categories and sub-categories reflected the purpose of the research (King & Tuckwell, 1983, p.12).

Reflection and Feedback

Following the completion of the stimulated recall interviews, the classroom teacher, and the research team met to discuss the lesson. This discussion was informal and allowed opportunities for reflection on the progress of the lessons. Expert feedback was given to the teacher in terms of strategies for modifying teacher behaviours, student behaviours and curriculum materials in order to enhance student learning through the use of a problem solving heuristic in a cooperative small group setting. The expert feedback was given by members of the research team whose expertise lay in the field of small group cooperative learning.

Data Analysis

Two groups of data were collected - the transcripts of lessons and the transcripts of stimulated recall interviews. The data from the transcript of the lessons were analysed in three ways:

• Statistical analysis of the coded lesson observations using the MAKITAB Small Group Learning Interaction Analysis System
• Semantic analysis of the reading of the transcripts and
• NUD*IST analysis of the transcripts.
The data from the stimulated recall interviews were analysed by reading the transcripts. Evidence of student reports of the elements of the heuristic were recorded and reported.

MAKITAB Analysis

Several observation systems have been developed by researchers (Cohen & Chatfield, 1991; Brophy & Good cited in Good & Brophy, 1991; Marshall & Weinstein cited in Good & Brophy, 1991) in order to record the numerous interactions that occur in learning situations. The MAKITAB small group learning interaction analysis system was developed by King, Barry, Maloney and Tayler (1993a). The MAKITAB system was inductively developed from observations of groups of year five students participating in small group cooperative learning lessons.

The instrument consists of six areas. Each area contains between nine and fifteen categories of interaction found in small group cooperative learning. The first two areas, group task and group dynamics, include thirty categories into which student talk can be coded. Four other areas address teacher talk. A full overview of the MAKITAB System is shown in Table 1 on page 16.

Observations made through the use of the video and audio records were transcribed. Each separate utterance made by each student, was isolated and coded. The coding categories that describe the problem solving heuristic are;
• TS09 - Sudden insights and ideas
• TS10 - Proposing
• TS11 - Negotiating, arguing and reacting to sudden insights and ideas
• TS12 - Final agreement on an idea
• TS13 - Final rejection of an idea
• TS14 - Representation
• TS15 - Reviewing

Each category is defined [King, Barry, Maloney & Tayler, 1993a] and is quoted in full below.

• TS09 - Sudden Ideas/Insights. A “flash in the mind”, impulse, insight or creative idea which is related to the task but is not a definite recommendation for inclusion in the group task.

• TS10 - Proposing. Interactions in which a group member(s) offers for consideration, acceptance or action a definite recommendation, suggestion, prediction, plan, method, explanation or answer for inclusion in the group task. This offer may take the form of a proposal, an extension of a proposal, or a counter-proposal. A proposal, extension of a proposal, or counter-proposal may be ignored, negotiated over, accepted or rejected.

• TS11 - Negotiating, arguing, reacting to ideas, insights and proposals. Comments and questions in which group members talk, work through or react to ideas, insights or proposals. These interactions normally involve consideration of implications, application of content, examination of different points of view, verbalisation of reasoning processes, critical thinking, or statements for and against a proposal or counter-proposal.

• TS12 - Final Agreement. Interactions in which a group member(s) agrees to final recommendations, suggestions, plan or answers for inclusion in the group task.

• TS13 - Final Rejection. Interactions in which a group member(s) reject final recommendations, suggestions, plan or answers for inclusion in the group task. The rejection is final and dismisses content from further consideration from the group task.
• **TS14 - Representation.** Comments, suggestion of questions associated with *the actual recording or representation of the product or recommendations for inclusion in the group product.* This includes such acts as writing, drawing, colouring, erasing, preparing a chart and performing.

• **TS15 - Reviewing.** Comments and questions related to *going back over developed content in order to check its usefulness, appropriateness or accuracy.* This may involve inquiry, questioning, inspection, reworking, or evaluation of the developed content for the group task. Reviewing also includes the redoing of an experiment to check the accuracy of a result (p. 18-21).

The categories of observed student talk interactions were coded by statement, cognitive question and non-cognitive question and were analysed using a propriety software. The Statistical Analysis System (SAS) data/input verification program generated relative frequencies and cross tabulations of data files for the target student group and facilitated analysis through print-outs arranged by all categories. Analysis of the data relating to the categories defined above provided information on the student talk that indicated elements of the problem solving heuristic.

**NUD*IST Analysis**

The transcripts of student talk were also analysed using the non-numerical, unstructured data, indexing, searching and theorising tool, NUD*IST. Transcribed talk from each of the seven lessons was partitioned into text lengths of approximately 70 characters or less. The resulting lines of text, called text units, were analysed in terms of the total talk, measured in units, for each
student and for evidence of the student use of the problem solving heuristic during the activity session of the lessons. Student use of the problem solving heuristic was undertaken through text searches for the heuristic terms, and synonyms of the heuristic terms, in all of the text units.

**Reading of the Transcripts**

The transcripts were also read for evidence of the problem solving heuristic. This was done to confirm the analysis achieved using the MAKITAB system and the NUD*IST analysis. MAKITAB codings, or NUD*IST search strings of the transcripts may not have clearly identified the nature or evidence of the problem solving heuristic or the manner in which students demonstrated the use, if any, of the heuristic. Alternatively the way in which students went about solving the problem may have been different to that sought by the framework of the MAKITAB analysis, the NUD*IST analysis or the problem solving heuristic itself. The reading of the transcripts aimed to provide further insight into the connection between the small group cooperative learning conditions set by the teacher and the kind of discussions held by students, with particular reference to the student use of the problem solving heuristic.

**Stimulated Recall Interviews**

The data collected from students in the stimulated recall interviews after the lessons was analysed for indications of the
cognitive intent of the teacher and the student use of the problem solving heuristic. Student reports of an idea, discussion, acceptance, rejection, writing and checking were analysed for evidence of the heuristic, portions of the heuristic or cycles of the heuristic.

**Assumptions**

The following assumptions were made in relation to this study:

1. That there is a link between teacher instruction and student talk in small group cooperative learning

2. That there is a link between student talk and learning and student group discussions and learning.

3. That researcher / observer effects or distortion of the data due to Hawthorne effects may occur during the study

4. That some practice effect will be present in the students' ability to verbalise prevailing thoughts probed in the interviews. As the methods used in the interviews do not prompt students to focus on the problem solving heuristic, the ability of students to verbalise the heuristic is assumed to be, though not totally, a result of student understanding and learning. It is recognised that learning occurs also as a result of having to verbalise thinking and that through interviewing students' learning may also be increased.
5. That students are not aware of the research topic or questions that guide the study. If students were to know what the study was describing they may attempt to “provide the right answers” and

6. That the teacher has genuine support for the study or at least has not undermined the study through negative statements to the students.

**Limitations of the Study**

The following limitations applied to the study. The study was open to effects resulting from unexpected changes during the lessons, the interviews or the period during which the series of seven lessons were conducted. These include changes such as a new or different teacher, changes to the target students, or changes to the lessons as planned by the teacher however these situations did not occur.

The pilot nature of the study also limited the generalizability of the findings. The low numbers of students in the target group did not permit generalizability of the findings to larger samples of students involved in cooperative learning, or for students and teachers in learning environments that differed widely to the classroom environment in the study.

The environment in which the lessons and interviews were conducted limited the extent to which students were focussed on the task both during the lessons undertaken and in the stimulated recall
interviews. This was overcome by stipulating that normal classroom conditions should prevail for the duration of the lesson. The teacher’s request for lesson time that was free of interruption were sought through the use of a sign on the classroom door.

The study was limited by lessons that were affected by student absences. Student absences from the target group would have had significant effect if:

- one student was regularly absent
- two or more students were absent on one or more lessons
- three or four students were absent for any one lesson.

However, none of the above absentee conditions occurred in the course of the study, although, there were several lessons where one student was absent. No student was absent for more than one lesson.

Distortion of the study’s findings due to Hawthorne effects (Ary, Jacobs & Razavieh, 1979) were seen to be constant for the duration of the study and were minimised by not informing students of the goal of the study. Students undertook the tasks in each lesson unaware of the researcher’s focus on the student use of the problem solving heuristic.

**Ethical Considerations**

The teacher volunteered for inclusion in the study, however, permission for the teacher and the class to be involved in the study was also sought from the school’s principal.
Permission for the participation of students was sought by the researchers with the help of the teacher. A letter was sent to each student's parents and included an authorisation slip that was to be returned to the teacher. All students voluntarily returned the authorisation slip to the teacher.

Confidentiality of all participants in the study was maintained through careful management of the data and the use of fictional names. Neither the school nor the teacher were identified in the study and all raw video and audio data were destroyed at the conclusion of the study.

**Instrument Reliability**

Reliability tests of the MAKITAB instrument were conducted over a two month period using six reliability exercises. The tests found 80% or more agreement in all categories among four trained researchers (King, Barry, Maloney & Tayler, 1993a). Limitations of the instrument included the difficulty of catching contextual and non-verbal factors, cultural nuances in language and interactions related to written representation. This was overcome by observation notes and script-taping of the target group by the researcher. These notes supplemented the data collected using video and audio recordings of each lesson.

The NUD*IST software acted more as a search and data management tool than a system that provided answers to the
researcher. The reliability and validity of the instrument is a function, firstly, on the accuracy of the transcribed data. Data from the seven lessons were transcribed from the audio tapes then checked using the filtered sound recording of the video-tape and annotated using the video images and the researcher's script-taping. The images and script-tape records confirmed semantic nuances not evident in the audio record and although present during the reading of the text, all annotations were stripped from the transcriptions prior to the NUD*IST analysis.

Secondly, the assumptions and techniques involved in the use of the software must be valid. In this study it was recognised that the text searches for heuristic terms and synonyms although accurate must be considered in the light of the nature of the search terms and the quantity of the terms searched. This aspect is discussed further in chapter six.

Summary List of Instruments and Equipment

- video camera, video player, audio tape recorder, audio tapes (14) and video tapes (7)
- Stimulated Recall Questionnaire (see Appendix A)
- MAKITAB Small group Learning Interaction Analysis System (see Table 1)
- Personal Computer
- SAS Statistical Data Input/Verification Program
- NUD*IST analysis software
Summary of the Chapter

This chapter has discussed the cognitive psychological theoretical framework that bounds the study and the descriptive nature of the study design. Details of the lessons, students, teacher, observations and procedures were discussed. The remainder of the chapter examined the data sources and data analysis. In summary there were two sources from which data were collected and three forms of data analysis. The data sources were the student talk during the lesson and the student interviews after the lesson. The forms of data analyses were the MAKITAB analysis, the NUD*IST analysis and the holistic readings of the transcripts. The chapter included discussion of the assumptions, limitations and ethical considerations that affected the study and concluded with a summary list of the instruments and equipment used.
CHAPTER FOUR

DATA ANALYSIS

Overview of the Chapter

This chapter covers the analysis of the data collected from the videotapes, audio tapes, anecdotal records and transcripts of the seven lessons and stimulated recall interviews. Analysis of the teacher's instructional input is followed by analysis of the student talk data. Analysis of the student talk data examines the kind of peer group interactions and focuses on the evidence indicating student use, or absence of use, of the problem solving heuristic. The analysis is presented in three sections.

The first section reports the teacher's instructional input to the lessons. The second section reports the student talk using three approaches - the MAKITAB statistical analysis, the reading of the transcripts of the lessons and the NUD*IST analysis. The third section reports findings from the stimulated recall interviews held with students after lessons four, five, six and seven. A summary of the data analysis concludes the chapter.

The Teacher's Instructional Input

The teacher's instruction for all lessons followed a similar pattern. This involved the lesson introduction, setting of the task and the monitoring of student discussions. The teacher undertook whole
class teaching where necessary and concluded the lesson with whole class discussion and closure (see Appendix D).

The seven lessons exhibited differences that fell into two broad categories. In lessons one, two, and three the teacher introduced the task as described above. However, in lessons four, five, six, and seven, new elements were included in the introduction section of the lesson. The fourth lesson was different in three ways from the preceding lessons. First, the teacher reminded the class of the group cooperation rules. The rules followed the "Groups of Four" model discussed in chapter one. Second, the teacher introduced for the first time, a boarded diagram of the problem solving heuristic (see Figure 4, p.38), and briefly discussed each step. Third, the teacher listed and briefly discussed the strategies that could be used to solve the problem including examples such as "guess and check", "work backwards", "try an easier problem", and "draw a diagram". The problem was different being more closed in nature and the solution required was specific. Part of the teacher's introduction included clues and suggestions on how to solve the problem.

The teacher's introduction to lessons five, six and seven followed similar lines to the fourth lesson. As in lesson four, the review of group cooperation rules was followed by the boarded review of the problem solving heuristic. This was followed by a discussion of possible strategies that might be used to solve the problem and then the problem itself was introduced. The teacher's intent in discussing
the group rules, the review of the problem solving heuristic and the problem, was to improve the likelihood of students solving the problems successfully.

In most lessons the introductions were brief, approximately five to six minutes after which the students began work on the activity part of the lesson. However, in lesson six, the whole introduction by the teacher took less than three and a half minutes and was followed by the student activity.

**Student Talk**

**MAKITAB Analysis**

The broad picture presented by the MAKITAB analysis (Tables 3, 4, 5, 6, 7 & Figure 5) is of group talk that is relatively high in quantity for the first five lessons and lower in quantity for the last two lessons. Of all lessons the third lesson exhibited the greatest quantity of student talk, where lesson six indicated the lowest quantity of student talk. Lesson three exhibited the highest quantity of group dynamic talk and this accounted for 19% of all student talk within the lesson. Overall, group task talk was also of a high quality with a significant number of interactions in the TS09, TS10, TS11, TS12, TS13 categories reflecting higher cognitive level thinking among group members.
### Table 3
**MAKITAB Group Task and Group Dynamic Interactions over seven lessons**

<table>
<thead>
<tr>
<th>MAKITAB categories</th>
<th>Lesson Total</th>
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<td></td>
<td>1 2 3 4 5 6 7</td>
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<tr>
<td>Group Task Statements</td>
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</tr>
<tr>
<td>Group Task Cognitive Questions</td>
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<td>Group Task Non Cognitive Questions</td>
<td>1 4 4 0 3 1 0 13</td>
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<td>Group Dynamics Cognitive Questions</td>
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<td>Group Dynamics Non Cognitive Questions</td>
<td>0 0 2 3 1 0 6</td>
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<td>Total interactions</td>
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</table>

Note. Figures indicate student interactions.

### Table 4
**MAKITAB Group Task Statement Interactions for seven lessons**

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Table 5

MAKITAB Group Task Statement Interactions for seven lessons shown as a percentage

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Table 6

MAKITAB Cognitive Question Interactions for seven lessons

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Table 7

MAKITAB Non-Cognitive Question Interactions for seven lessons

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Levels of Student Interactions for MAKITAB Group Task Statements

Figure 5. Levels of Student Interactions for MAKITAB Group Task Statements over seven lessons.
Observations of all lessons across the sub-categories of group task (TS), recorded high quantities of student talk in proposing (TS10 - 555 interactions), negotiating and arguing (TS11 - 355 interactions), examining and comprehending (TS8 - 213 interactions) and representation (TS14 - 159 interactions). Figure 5 shows the quantities of student talk by group task statement. Lessons one, two, three and five exhibited high quantities of proposing (TS10) and lesson three in particular exhibited over 60% of student talk as being either student proposals or student negotiating, arguing and reacting to ideas. Lesson six contained the lowest quantity of student proposals and student negotiations, 11 instances of proposing and just one instance of negotiation. The majority of student talk in lesson six appears to have been regarding group dynamics or non-task related talk. Tables 4 and 5 indicate that in four of the seven lessons, student proposals accounted for at least 30% of the lesson statement talk. In lesson two this was as high as 50%. This represents approximately 25% of all student lesson talk. In terms of cognitive talk, student questions were generally low (Tables 6 & 7). Group dynamics related talk was not high and accounted for only 14% of all student talk across all lessons (see also Table 3). With the exception of lesson six where there was a high level of on task talk throughout the lessons (Table 5).
Summary of the MAKITAB Analysis

Clearly student talk was dominated by group task talk of a higher cognitive nature. In the task talk category student talk was dominated by proposals and negotiations, arguments and reactions to proposals. This talk represents a significant portion of the problem solving heuristic in terms of ideas, discussion and checking of solutions. There is also evidence of representation and review (Table 4) and to a lesser extent, acceptance and rejection of ideas. If high levels of on task problem solving talk are related to the heuristic framework it would seem reasonable to expect high levels of student success in these lessons. The discussion now turns to the analysis of the data made from the reading of the transcripts.

Reading of the Transcripts

Transcripts of each lesson were read and considered for evidence of student use of the problem solving heuristic. The context in which use of the heuristic occurred and the nature of the student talk involved in the use of the heuristic was also analysed. Further discussion of the findings is presented in chapter five. It should be noted that teaching and introduction of the heuristic did not occur until lesson four. Appendix C lists the problem solving activities, however, each activity is briefly described prior to the analysis of the lesson transcript. Appendix E lists profiles of the four students arranged by the fictional names Kate, Amber, Nick and Bryce.
Lesson one.

TASK - How many numbers can be written as the sum of two consecutive numbers?

The task was open ended in nature and highly suitable for a problem solving situation. No single answer or answers were obvious and the group did not appear to have any preconceived approach to the problem. The group was quick to begin work on the task. Kate's involvement right from the start was of a low level, making only four recorded verbal contributions to the discussion. Much of the talking was done by Bryce. Talking was of a very quick nature as shown by this 60 second excerpt ten minutes into the lesson. Unless shown otherwise the speaker speaks to the whole group.

| Bryce    | 11, then it will be um |
| Amber    | Yeah that's easy.     |
| Bryce    | That will be 11 and 12.|
| Amber    | Yeah 11 and 12 is 23.  |
| Bryce    | *(Writes)* 11 and 12. |
| Amber    | Is it?               |
| Bryce    | Yeah 23.             |
| Amber    | 12 and 13 is fif...25.|
| Nick     | 25 yeah.            |
| Bryce    | 25, wait, 27 would be 13 and 14 and the next one would be 29 which would be 14 and 15. |
| Amber    | 15 and six...        |
| Nick     | 31 (...teen)         |
| Amber    | Would be 31.         |
| Bryce    | Yeah 31.             |
| Amber    | What's the pattern?  |
| Bryce    | Look it goes up by two. |
Amber  Mmm.
Nick  So it does.
Amber  So the pattern is ...
Bryce  Yeah go on write down the pattern, the pattern *(throws pencil - urgency in voice)*
Nick  31, 33.
Amber  33 is 16 and 17.
Bryce  And 35 is
Nick  *(Possibly says answer - inaudible)*
Bryce  17 and 18
Nick  And 18
Bryce  No it's only between one and 35, we've found them all.
Amber  Ahh. *(satisfaction, then drops pencil)*
Amber  Is...

Note: use of the ellipsis indicates the speaker has paused.

Discussion in this section down to “Yeah 31” appears to be about alternative solutions that meet the criteria - consecutive numbers that sum to 35. A new section begins with the question from Amber asking “What's the pattern?”, Bryce's proposal of “it goes up by two” seems to be suggested as the solution, but the tone and nature of the discussion indicate that no immediate acceptance of the proposal is forthcoming. Instead Amber seems to consider the proposal, Nick offers an affirming judgement and then Amber restates the proposal as being true. The restatement is only half uttered “so the pattern is...” before Bryce interjects, or talks over Amber by saying “yeah go on write down the pattern”. Some further proposals in the form of suggested solutions from Nick, Amber, and Bryce
continue until Nick completes the recording of 17 and 18 being the last two consecutive numbers that satisfy the criteria.

The passage seems to close with Amber's exclamation "ahh" and the dropping of the pencil. This pause is brief, as Amber then begins the next section with a question starting "is...". The passage described from "yeah 31" to "ahh" lasts just over 30 seconds and involves 15 separate student interactions.

The problem solving heuristic had, at this time, not been introduced or taught by the teacher, however, it is clear that there are numerous ideas and proposals in the form of suggested solutions. The example of the final agreement discussed above ("ahh") appears only temporary in nature. That is, there seems to be agreement at this point but this is not evident as being the final agreement on the entire problem.

Negotiating and arguing is also less overtly evident. Reactions seem to be in a far more subtle form as suggested by Bryce's use of "wait". Bryce seems to use the word wait to delay group agreement until there is an opportunity to present more evidence.

Representation of the computed solutions to the problem is evident in the passing of the pencil and the recording undertaken by Amber. Amber finally drops the pencil.
Lesson two.

TASK - Survival in the Desert

This desert survival problem was also open in nature (see Appendix C). Amber is absent during the lesson, leaving two boys and one girl in the group. The teacher's introduction still does not include any reference to the heuristic, however, the teacher makes significant input to the target group immediately following the introduction. Again Kate is quiet in terms of verbal contributions but seems to be paying attention to the group task and the resolution of the task. Seven minutes into the lesson the group is still seeking solutions to the problem of where to find drinkable water. The following passage shows that Kate has been reacting to the ideas presented so far even though she has not made any verbal contribution.

Kate: You know what you can do?
Bryce: What?
Kate: Empty out the salt water, right?
Bryce: Filter it? Yeah, but how you're going to filter it?
Nick: Got no filter (referring to instruments available in picture).
Kate: No, just get the salt water, put it in ...something, and just, ... leave it over the lava and it dries it clean.
Nick: Yeah, good idea.
Bryce: Boils it clean, yeah good idea, (writing) lava boils salt water clean...
Nick: Yah, good idea.
Kate: Aren't I smart (giggles).
Bryce  Boil salt on lava (*writing*).
Kate   Over salt, I mean over lava.
Nick   Good idea.

The passage is very short but exhibits all the characteristics of the heuristic, yet use of the heuristic to guide the discussion neither preceded nor followed this passage. Kate has a sudden insight and starts the passage with a proposal framed as a question. Bryce's second comment "filter it?" indicates some reaction and negotiation about the proposal. Nick also reacts, arguing that there is no equipment to accomplish Kate's proposal. Kate elaborates on the initial proposal, providing an explanation and method for obtaining drinkable water. Nick offers support and agreement. Bryce begins recording the solution while verbalising the reasoning processes. Kate again agrees and utters "aren't I smart" a form of self-monitoring and self-evaluation. Nick's final comment could be further agreement but may also be interpreted as a form of review uttered as he observes Bryce's recording of the solution. In this instance the progression through the steps of the heuristic appear to follow the model, however, as noted no introduction to the heuristic has been made either explicitly or implicitly by the teacher in this lesson.

Substantial portions of the transcript indicate strings of proposals, proposal extension or counter proposals as shown by the
following passage where the students are concerned with making a fire.

| Nick       | You could burn the box. |
| Bryce      | Burn the box?           |
| Nick       | Burn everything here and that. |
| Bryce      | Yeah all of that stuff you could burn but you need to save some... |
| Nick       | And give it a smash *(refers to crushing the combustible materials).* |
| Bryce      | Or you could use the stones to go round the edge of the fire. |
| Kate       | You could use the stones to start the fire. |
| Nick       | You could make it little, you know, like scrunch it up. |
| Bryce      | Did you put that down? |
| Kate       | Yeah *(writing).* |
| Bryce      | What about those other things I said, what were you going to say Nick? |
| Nick       | The steel spanner could crush some twigs to make it little. |

Seven of the first eight statements are proposals, extensions of proposals or counter proposals all contributing to the understanding of the solution. Bryce checks that the suggestions, or a summary of them, was recorded and then goes back to react to previous ideas. Here the leap from proposing to recording has seemed to include the necessary reviewing and negotiating, often in mid-statement like in “but you need to save some” and “you know, like scrunch it up”.

In terms of the heuristic, progress from one step to another has occurred very quickly, almost imperceptibly. Nevertheless, the group consensus is present with the positive contribution of each member and the lack of rejection when Kate records the solution. Reviewing appears to be occurring simultaneously with group discussion, the
review occurring more as responses to counter proposals and proposal extensions rather than a reconsideration of the original proposal. This is not always made us by a verbal statement.

Lesson three.

TASK - to design and build a bridge to span between two desks 50cm apart. The challenge includes making the cheapest, strongest and most attractive bridge. The bridge must support 3 kg in the centre of its span.

From observation of the lesson it appeared that the target students had difficulty conceptualising exactly what the bridge would be required to do. Was it a span simply called “a bridge” that had to support a three kilogram weight or was the structure meant to be a scale model of a bridge that could, if built, carry vehicular and pedestrian traffic? The problem was presented by the teacher without any discussion of possible strategy use, or with any reference to the problem solving heuristic.

Early group discussion concentrated on getting the distances involved and the requirements for materials clear. The open ended nature of the problem seemed to encourage numerous responses yet the clarification of the problem and generation of a solution appeared quite difficult for the students for most of the lesson. This section from the 19 minute mark in the lesson shows that students were still discussing the concept of the bridge. The teacher has made some
suggestions and the passage begins with Nick suggesting a triangular framework as the basis for building the bridge, similar perhaps to the Sydney Harbour Bridge.

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Yeah go on then.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nick</td>
<td>Triangles -3 like that with another piece of wood, down there like that, and another one like that, and that goes all the way, and put 5 across</td>
</tr>
<tr>
<td>Bryce</td>
<td>Wait a minute, wait a minute, see you could stretch, see you could put another piece of wood like that and another piece like that...</td>
</tr>
<tr>
<td>Nick</td>
<td>That's not ...(groans)</td>
</tr>
<tr>
<td>Bryce</td>
<td>That'll stretch as this'll, that'll stretch as this... Say you glue another piece of wood onto that and then it'll go the 50 cm.</td>
</tr>
<tr>
<td>Amber</td>
<td>The bridge is - sort of, too big to go on top of it.</td>
</tr>
<tr>
<td>Bryce</td>
<td>Why is the stick in the way?</td>
</tr>
<tr>
<td>Amber</td>
<td>Well it's not going to be.</td>
</tr>
<tr>
<td>Bryce</td>
<td>True...</td>
</tr>
<tr>
<td>Amber</td>
<td>Things like that's the side of the bridge and it goes like that (demonstrates).</td>
</tr>
<tr>
<td>Bryce</td>
<td>Um well um,...</td>
</tr>
<tr>
<td>Nick</td>
<td>Just try to make triangles - Hmm who had the pencil?</td>
</tr>
<tr>
<td>Amber</td>
<td>Draw it 3D (three dimensional drawing). It looks funny</td>
</tr>
<tr>
<td>Nick</td>
<td>Yeah 3D.</td>
</tr>
<tr>
<td>Amber</td>
<td>It looks funny like...</td>
</tr>
<tr>
<td>Nick</td>
<td>The real thing has to have a real structure or it will buckle up here. One there and one there, then one there...(starts counting).</td>
</tr>
<tr>
<td>Bryce</td>
<td>That's what I was trying to say.</td>
</tr>
<tr>
<td>Nick</td>
<td>3, 4...</td>
</tr>
<tr>
<td>Bryce</td>
<td>That will make it across.</td>
</tr>
<tr>
<td>Nick</td>
<td>5!</td>
</tr>
<tr>
<td>Bryce</td>
<td>That will already make it across.</td>
</tr>
<tr>
<td>Nick</td>
<td>1, 2, 3, 4, 5 and then you put another one across there (apparently ignoring Bryce).</td>
</tr>
<tr>
<td>Amber</td>
<td>That's just the same, that's the side of the bridge, you don't drive your car across that way, that way, that way (zig zag following the structural reinforcement eg. Sydney Harbour Bridge) that's the side of the bridge.</td>
</tr>
</tbody>
</table>
Nick: It's not driving, it's just that the bridge has to weigh that thing (teachers testing weight) there's no driving cars.

Amber: (Giggles - possibly considering that the bridge design can concentrate on strength factors rather than the requirement to drive a car over)

Bryce: No broom broom cars.

Significant trialing of the design, the use of materials and how the bridge might be constructed continues until the 32nd minute. Eventually the attempt to “draw it 3D” or represent the group thinking in the lesson seems to clarify the problem. The group is still coming to terms with the issue of whether the bridge needs to carry cars. Nick’s final comment suggests that their structure will simply “weigh that thing” referring to the teacher’s test of a good bridge being able to hold a three kilogram weight. Amber seems convinced by the thinking and discussion that has occurred so far.

At this time the teacher speaks with the group and asks: “where are the cars going to go?”. The group is thrown into disarray having determined that the bridge was, theoretically, not required to carry cars. The teacher’s monitoring of the group’s concept of the bridge has clarified an important fact. Up until this point the students had been engaged in ideas, negotiating and arguing, agreeing and rejecting, recording and checking. This had occurred in no particular order, for 32 minutes.

From this time on the teacher’s input shifts the students’ concentration from the seeking of a solution that will satisfy the
problem to trying to guess the answer as shown by the following passage. This is evident in Bryce's comment “hey wait, wait, he said it might be the other way round”.

| Teacher  | Yeah, I think you need to have another think. |
| Teacher  | You may have found a bit of a clue in that.   |
| ?        | Sorry.                                        |
| ?        | Don't look.                                   |
| Teacher  | But it may just be around the wrong way. See if you can find... |
| Nick     | Look here.                                    |
| Teacher  | ...and try not to pinch ideas from other people (teacher leaves). |
| Bryce    | Hey wait, wait, wait, he said it might be the other way round. |
| Amber    | (Giggles) cars go like that (indicates on diagram). |
| Bryce    | No other way round.                           |
| Nick     | Straight up... Na. Not that thing, it's not, you know, it's not that flexible. |

Note. Question mark used to indicate that the speaker's identity is not known.

In a sense the teacher's input has changed the nature of the problem to one that is more closed, having a definite solution, a solution that other groups may have already attained, and a solution to which this group are very close. Up until this point the high number of proposals, negotiations and arguments, reviews and recordings had caused a high quality of discussion even though there was error in the concept being developed.

Lesson four.

TASK - Mrs Hannah likes dogs. At present all her adult dogs are spaniels while some of her puppies are spaniels and some are not.
In all she has 11 dogs of which 7 are spaniels and 8 are puppies.

How many spaniels has she?

Lesson four was the first time the teacher introduced the problem solving heuristic. Student discussions in the first section of the lesson were similar to discussions in the first and second lessons. Discussion was rapid and evidenced numerous proposals of possible solutions and suggestions for group consideration. The first evidence of an overt attempt to use the problem solving heuristic occurred at the seventh minute as shown in the following passage.

| Bryce | That's two, that leaves us with five spaniels. |
| Nick  | Four dogs.                                   |
| Bryce | Can't be four.                               |
| Nick  | Cos two are adults must be four hey?         |
| Bryce | Wait no three, no five cos all in total five so... someone write it on the back please. |
| Nick  | No, wait. Let's discuss this. *(Long pause follows as Nick begins to reread the text.)* |
| Nick  | All adult dogs are spaniels so lets say these are adult dogs and all adult dogs are spaniels so take seven away from eleven. |
| Bryce | No look at the picture, she's only got one big dog there. |
| Amber | Two! One's sleeping.                         |
| Bryce | True yeah.                                  |
| Nick  | Look, look, all the adult dogs are sleeping, seven are spaniels, eleven take seven is four. |
| Bryce | Four and there's four being counted twice.   |
| Nick  | Yeah I think it is four.                    |
| Amber | Someone else write it, Kate you've got the neatest writing. |
| Nick  | Yeah but first we have to discuss it about how we have to write it. |
| Nick  | How are you supposed to write that?         |
| Bryce | There's two adult dogs take that off the eleven. |
| Amber | Two adult spaniel dogs *(Starts writing).* |

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Nick: Yeah.
Nick: There's eleven dogs and seven spaniels.
Bryce: Seven off eleven equals four and there's four dogs been over counted

Nick has shown some understanding of the steps of the heuristic by suggesting group discussion prior to the recording of the solution. He states “no, lets discuss this”. Nick rereads the problem aloud and this results in the discussion continuing. However, Nick also suggests that the reason for discussion is to clarify “how we have to write it”. He self-questions with the comment “how are you supposed to do that?”. His understanding of the heuristic appears fragmented and he is unable to advise the group on exactly what to do. Bryce suggests a possible written record and Amber begins writing. Nick appears to conform to this peer pressure and no further mention of the group discussion is made.

In this next passage the students are required to record how they achieved their answer. This is part of the written problem. There is no student reference to the heuristic step “check” and the group is content to record a description of the mathematical processes involved in reaching the answer.
Nick See look adult dogs are spaniels - seven spaniels, eleven take seven is four.
Bryce Yeah so we got the right answer - all right how do you think we got our answer?
Bryce *(Amber is writing)* We came about our answer, no no no wait...all the other dogs are spaniels, other ... dogs... are ... I E L *(spelling spaniels)* and the seven spaniels ... and seven from eleven is four. So there is seven spaniels.

Some three minutes later the solution is again under scrutiny from Nick. Two alternative views could account for the statements. Either the checking process is occurring or this is a continuation of the negotiation and argument.

Nick Let's just figure it out again but wa wa wa...(short for wait).
Amber Are we allowed to write on this bit?
Nick Yeah.
Bryce He said to.
Nick Hey! Eleven dogs seven are spaniels. Right?
Bryce Yeah.
Nick Eight are puppies.
Bryce *(Yawns)* ahump *(meaning yes)*.
Nick Eight are puppies. You can't have, eight are puppies. We've done something wrong.

Clearly Nick has questioned the recorded solution. With Amber he continues to discuss what may have been done incorrectly, each providing different reasons. Immediately after this the students move off task and return to effective group discussion for only brief periods for the remaining 15 minutes of the lesson.
It appears that although the solution was reached, it was reached early in the lesson. The students did not seem to be clear about the mathematics or the process involved in reaching the solution. The evidence of students returning to the documented solutions, the notes and the drawings suggest that the steps of the heuristic were not employed in any formal manner. Overt use of the "discuss" aspect of the heuristic is present but perhaps recognised by Nick alone.

 Lesson five.

 Task - There is a total of 41 pigs and chickens on a farm. Together, in all, they have 100 legs. How many chickens are there?

 Lesson five was characterised by numerous proposals being made, as in lessons one, two and three. After nine minutes the teacher came to the group to monitor progress on the problem. A long confusing dialogue between the teacher and Kate followed, during which it was evident that Kate had very little knowledge of how to solve the problem. Nick and Bryce seem to have understood more. The final stage of the discussion with the teacher indicated some student recall of the problem solving heuristic.
Bryce states that the proposed solution (122) to the problem should be rejected, a term specific to the problem solving heuristic. It should be noted also that the teacher was the initiator of the rejection. Nick makes the next proposal immediately. However, no mention is made that Nick’s input is the start of the next cycle through the heuristic or that the input constitutes the next idea. Six minutes later the teacher asked “at what stage in the problem solving heuristic were they up to?”. The students suggested that “idea” was the stage they were up to, as shown in the following passage.

Bryce doesn’t come out.
Bryce Ok.
Teacher So there’s one guess that’s tried. So you can forget that one.
Bryce Reject!
Nick Wait um what about the chickens look five times four...

Teacher What stage are you at there?
Bryce I don’t know?
Nick Um idea.
Teacher Still at the idea stage and you ... have you discussed your idea or haven't you got off first base yet?
Nick Trying...
Bryce Haven't got off last base (humour?).
Nick We got it but it was 104 legs
Bryce We've tried some ideas, we tried some ideas (talking over the top of each other to the teacher) and had some rejects
Bryce again shows understanding of the heuristic in answering the teacher's question but does not include "discuss" as a stage the group moved through in order to arrive at rejection of some of the ideas. Furthermore, the teacher's comment suggests that the teacher's view of the heuristic does not recognise the cycle that exists within the steps of "idea", "discuss", "reject", "idea". As indicated by Bryce the group has "tried some ideas and had some rejects" and the group, in contrast to the teacher's comment has clearly "moved off first base". The group works on the problem for 24 minutes using a diagramming strategy. At this time Bryce says "yessss" stating a belief that the solution reached was the correct one.

<table>
<thead>
<tr>
<th>Amber</th>
<th>34 chickens.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nick</td>
<td>We've done it!</td>
</tr>
<tr>
<td>Bryce</td>
<td>YESsssssssi (sic)</td>
</tr>
<tr>
<td>Nick</td>
<td>We did it.</td>
</tr>
<tr>
<td>Nick</td>
<td>Chickens and pigs.</td>
</tr>
<tr>
<td>Bryce</td>
<td>Cos we worked out with a hundred there and we didn't count that pig and we had two chickens there.</td>
</tr>
</tbody>
</table>

A record of the solution is made on paper.

<table>
<thead>
<tr>
<th>Bryce</th>
<th>Make a drawing or graph <em>(reads portion of problem).</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Nick</td>
<td>That's what we just did.</td>
</tr>
<tr>
<td>Bryce</td>
<td>I know.</td>
</tr>
<tr>
<td>Amber</td>
<td>Don't look at me.</td>
</tr>
<tr>
<td>Kate</td>
<td>I'm not doing it.</td>
</tr>
</tbody>
</table>

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The students have used a diagram to reach a solution. They have drawn 100 legs and have circled groups of four legs to indicate a sheep and groups of two legs to indicate a chicken. Moments later an error is recognised in the working through of the recorded solution.

<table>
<thead>
<tr>
<th>Bryce</th>
<th>Seven fours aren't 24 ... they're 28  eight and eight are 16 put down the six carry the one... 90 96 legsssss. We are wrong ong (sic)/(bangs table).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nick</td>
<td>But this is right wait ... one (starts counting all the way to 42)  \</td>
</tr>
<tr>
<td>Bryce</td>
<td>Hang on let me see (starts counting all the way to 42)  \</td>
</tr>
<tr>
<td>Nick</td>
<td>38 what? (simultaneously girls are working on the problem)  \</td>
</tr>
<tr>
<td>Bryce</td>
<td>38 animals. (counts the circles and legs and again all the way to 42)  \</td>
</tr>
<tr>
<td>Nick</td>
<td>One, two, three, four, (counts the circles and legs and again all the way to 42)  \</td>
</tr>
<tr>
<td>Bryce</td>
<td>We thought we had it but we don't have it.  \</td>
</tr>
</tbody>
</table>

In this case Bryce summarises by saying that the group's solution is not correct, even though it was thought to be correct and was being recorded. This shows that the steps from the heuristic are occurring but are not being verbalised by the members of the group, or Bryce, who has assumed a leadership role.

Lesson six.

TASK - The Smith and Jones families, twelve people in all, live next door to each other in Maths Street. Each family has a mother, father and some children. Five of the people are males. The Smiths have no sons. How many boys and girls does each family have?

During the introduction the teacher suggests that 'before you try to solve the problem decide as a group which problem solving strategy you will use. When you have done this put your hand up to
tell me”. This appears contrary to the heuristic in that solving the problem begins with an idea. The “idea” stage of the heuristic is not specific. Any idea could be the start of a discussion. Here the teacher has specified that the first idea or set of ideas should focus on the problem solving strategy to be used. This is shown in the following passage. Note that Nick is absent.

<table>
<thead>
<tr>
<th>Bryce</th>
<th>Do you want to <em>(discussing “make a drawing or graph” as the problem solving strategy to use)</em> is that all right?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kate &amp; Amber</td>
<td>Yup.</td>
</tr>
<tr>
<td>Bryce</td>
<td><em>(Puts up hand waiting for teacher)</em></td>
</tr>
<tr>
<td>Teacher</td>
<td>Where are you up to?</td>
</tr>
<tr>
<td>Bryce</td>
<td>We’re going to do the “make a drawing or graph” <em>(strategy)</em></td>
</tr>
<tr>
<td>Teacher</td>
<td>Ok, I reckon that would probably work.</td>
</tr>
<tr>
<td>Kate</td>
<td>[Chris] <em>(another student possibly male)</em> is staring at us <em>(smiles)</em></td>
</tr>
<tr>
<td>Bryce</td>
<td><em>(Starts writing)</em> Five males... females</td>
</tr>
<tr>
<td>Amber</td>
<td>Stop laughing <em>(discussion possibly about [Chris] staring had caused Kate to laugh)</em></td>
</tr>
<tr>
<td>Kate</td>
<td></td>
</tr>
<tr>
<td>Teacher</td>
<td>What stage of the [heuristic] model are you at, up there <em>(teacher points to blackboard)</em></td>
</tr>
<tr>
<td>Bryce</td>
<td>Ar ... idea</td>
</tr>
<tr>
<td>Teacher</td>
<td>Idea stage?</td>
</tr>
<tr>
<td>Bryce</td>
<td><em>(Continues on with writing problem details)</em> female and there are seven females.</td>
</tr>
<tr>
<td>Teacher</td>
<td><em>(observing Bryce recording some details i.e. Bryce has the pencil)</em> he’s doing it all again, he always does it doesn’t he?</td>
</tr>
</tbody>
</table>

Within one minute of the students reporting which strategy they will use in solving the problem the teacher asks which point in the heuristic the students are up to. Clearly Bryce understands the
teacher's request for "what stage are you up to?". Yet he is jokingly chastised for taking a leadership role in solving the problem. The "what stage are you up to?" question seems to be redundant considering the time frame and dialogue that has just occurred. The choice to use the "make a drawing or graph" strategy is a form of idea. However, it is an idea that has been contrived by the teacher's initial request to determine a strategy to use before beginning the problem. Some discussion occurs on the number of people and gender involved in the task. Seven minutes later Bryce states:

| Bryce | I know. I've found some now you see if you can find another one... now shouldn't we think, we should check it (having overheard teacher's reference to the heuristic for another group) let me think. There's 12 people altogether take away five is seven take away four is three. 12 take four is eight and eight, five equals... so ... |

The clear reference to the "check" stage of the heuristic may have been prompted by the teacher's comment to another group. At this time the teacher was talking and gesturing toward the blackboarded heuristic while asking another group at what stage of the heuristic they were up to. Nevertheless, Amber begins writing down the solution. Low level discussion continues, some on task, some off task, for seven minutes until the group reports to the teacher that they have completed the task. The teacher gains the attention of the class and encourages students to attempt to use other problem solving strategies to prove the validity of their solutions. The target
group attempts to use other strategies but discussion and apparent motivation is lower now than earlier in the lesson.

It appears that Bryce's understanding of the problem solving heuristic has answered any questions raised by the teacher. Bryce is also keen to reach a solution on the problem and apparently tries to hurry Kate and Amber to discover alternative solutions and provide a check on the work completed so far. Evidence of student use of the problem solving heuristic is present, however, the students do not seem to be prompted or encouraged by the knowledge of the heuristic to explore the problem deeply.

During the remaining 20 minutes of the lesson the teacher talks to the class for 12 minutes and students work for eight minutes. Of these eight minutes there are two weak attempts by the group to solve the problem using another strategy. There is very little discussion and a brief record is made of the work. This occupies approximately five minutes. The remaining time is off task behaviour.

Lesson seven.

**TASK** - Two men and two boys wish to cross a river their small canoe will carry only one man or two boys. What is the least number of canoe trips needed to get everyone across?

Discussion in the early part of the lesson suggested a great enthusiasm to solve the problem. The students moved quickly into
creative and lateral suggestions for the solution, such as tying a rope on the boat and pulling it back after each trip across. Nick thought he had done this problem before but it was Amber that made the first suggestion of going across and dropping some people on the other bank. A pattern begins to form where boys and adults are used in different combinations to move people across the river. The first part of the solution is found *i.e.* *two boys go over and one comes back, one dad goes over and the other boy comes back*. There is agreement that this seems to be part of the solution, but the agreement is not explicit, and neither stated or recorded. There is evidence that the students have accomplished sections of the heuristic, that is "idea", "discussion", "acceptance" and yet have not made a pencil and paper record, and furthermore do not recognise that they have in fact passed through these stages of the heuristic. This occurs 10 minutes into the lesson.

Upon the teacher's intervention and discussion with the group, the students attempt to answer what problem solving strategy they are using. They answer "guess and check". This is clearly wrong. They have not guessed at the number of trips and then tried to prove the answer. A more appropriate answer would have been "logical steps" as a choice from the strategy names on the list.

In the first part of the lesson they are working on the process for moving people across the river. By the 13th minute in the lesson, the students are beginning to use scrap paper to draw the movement of
the canoe. Two minutes later there is a clearly stated agreement as to the answer. The students decide to demonstrate the answer to the teacher using drawing pins to represent people. The group dialogue has been rapid and focused as shown by this excerpt.

<table>
<thead>
<tr>
<th>Bryce</th>
<th>...then one guy goes across, then little boy comes back. Nick how'd you do it?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nick &amp; Bryce</td>
<td><em>(talking over the top of each other)</em> the boys come back...you got it,</td>
</tr>
<tr>
<td>Bryce</td>
<td>You got it, nah.</td>
</tr>
<tr>
<td>Nick</td>
<td>I was right Bryce.</td>
</tr>
<tr>
<td>Bryce</td>
<td>Show us how you got it then.</td>
</tr>
<tr>
<td>Amber</td>
<td><em>(interjects and starts explaining)</em> 2 boys go across, 1 boy comes back,</td>
</tr>
<tr>
<td>Nick</td>
<td><em>(interjects)</em> One man comes across ...</td>
</tr>
<tr>
<td>Bryce</td>
<td>That's one <em>(man)</em></td>
</tr>
<tr>
<td>Amber</td>
<td><em>(carries on no break)</em> one man goes across</td>
</tr>
<tr>
<td>Nick</td>
<td>One boy comes back</td>
</tr>
<tr>
<td>Amber</td>
<td>And one boy comes back <em>(echoes Nick)</em></td>
</tr>
<tr>
<td>Nick</td>
<td>Two boys across</td>
</tr>
<tr>
<td>Amber</td>
<td>Two boys go across <em>(echo)</em></td>
</tr>
<tr>
<td>Nick</td>
<td>Then two boys go across</td>
</tr>
<tr>
<td>Amber</td>
<td>And one boy comes back <em>(states this step independently)</em>.</td>
</tr>
<tr>
<td>Nick</td>
<td>One comes back <em>(echoes Amber)</em></td>
</tr>
<tr>
<td>Amber</td>
<td>One man goes across <em>(initiates new statement)</em></td>
</tr>
<tr>
<td>Bryce</td>
<td>That's two <em>(men)</em></td>
</tr>
<tr>
<td>Nick</td>
<td>One boy back.</td>
</tr>
<tr>
<td>Amber</td>
<td>Then one boy goes back and <em>(echo)</em></td>
</tr>
<tr>
<td>Nick</td>
<td>Two across</td>
</tr>
</tbody>
</table>

The dialogue shows only the audible, literal, words uttered by the students. Of course many other sounds, gestures and non-verbal movements are made that contribute to the communication between
and among the members of the group. The speed at which the dialogue occurs is astounding. Many thoughts and contributions are made often with split second timing, the difference between heading in one direction and another is often only effected by a short “burst” of talk, a word or part of a sentence. Much like a “willy willy” (an Australian term meaning miniature hurricane) the group revolves at incredible speed but travels forward at a much lesser speed. Sometimes it seems as though students are tuned into the thoughts of others in their group and know where the discussion is heading and when their contribution is accepted as part of the solution and when it is not. The problem solving heuristic seems to be in use but not in an overt and explicit manner.

Having demonstrated the process of moving all people to the other side of the river the students now set out to record exactly how many trips are needed. No counting of trips has been done up until now. Concentration has been on the process. At this time (18 minutes) there is clear group agreement as to the validity of the process. This agreement aligns with the heuristic term “accept”. The group now begins to count the exact number of trips. Still there is no verbal recognition of the stage in the heuristic that has been reached yet the initial idea, the discussion, the acceptance and the record of the correct process are all complete.

The correct solution is reached some three minutes later. Amber, Nick and Bryce do most of the talking, reciting each piece of
the process. At least Nick and Bryce keep an accurate count of the number of trips. At the 23rd minute mark in the lesson the teacher visits and asks “what stage are you at according to the diagram?”, referring to the problem solving heuristic. The students’ answer is surprising as shown below.

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Can I ask something before you tell me, what stage are you at according to that diagram?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nick &amp; Bryce</td>
<td>Ah... accepting I think</td>
</tr>
<tr>
<td>Teacher</td>
<td>Accepting?</td>
</tr>
<tr>
<td>Nick</td>
<td>Or maybe rejecting.</td>
</tr>
<tr>
<td>Bryce</td>
<td>Accept and reject.</td>
</tr>
<tr>
<td>Teacher</td>
<td>Wellyllll...but you’ve told me that this is the right answer.</td>
</tr>
<tr>
<td>Nick</td>
<td>Yeah we've finished.</td>
</tr>
<tr>
<td>Teacher</td>
<td>So if you’re telling me that it is the right answer...</td>
</tr>
<tr>
<td>Bryce</td>
<td>So this is check.</td>
</tr>
<tr>
<td>Teacher</td>
<td>You could be, but you could be accepting ...</td>
</tr>
<tr>
<td>Bryce</td>
<td>Yeah Ok.</td>
</tr>
<tr>
<td>Teacher</td>
<td>You could be here (accepting)?</td>
</tr>
<tr>
<td>Bryce</td>
<td>Yeah.</td>
</tr>
</tbody>
</table>

The initial response, accepting, is tentatively put forward by Nick and Bryce. The students revise their answer as the teacher seeks clarification and further reasoning. This shows that at least the boys do not comprehend what the group has achieved in relation to the problem solving heuristic. Bryce's attempt at “accepting and rejecting” emphasises the lack of understanding. The group cannot be accepting and rejecting simultaneously. The teacher seeks further clarification and allows the students to rethink their answer. Finally,
the teacher suggests an answer saying "you could be but you could be accepting". Bryce quickly agrees with the teacher. For the remainder of the lesson the group describes the solution and the process used to reach the solution.

Summary of the Reading of the Lesson Transcripts

This section has described the data found from the transcripts of the lessons and the interpretation of that data within the context of the transcribed dialogue. Brief discussion on the possible reasons for particular student outcomes have been made and this will be amplified in the next chapter.

NUD*IST Analysis

Quantities of student talk.

The NUD*IST analysis initially examined the quantity of student talk. Raw student talk data were formatted to display each student's talk in text lines of 70 characters, or less if the talk was brief. This resulted in a line of text, called a text unit, that provided a standard unit for comparing lessons. The total number of text units in each lesson is shown in Figure 6.
Figure 6. Total Numbers of Text Units of Student Talk in each lesson.

There is more talking occurring in lessons one, three and five. The lesson with the least talk is lesson six with lesson seven exhibiting talk at a level of about half that of lesson three. The relative quantities of each student's talk is shown in Table 8. Table 8 does not indicate the different purposes for student talk.

Table 8
Relative Quantities of Student Talk for each lesson

<table>
<thead>
<tr>
<th>Speaker</th>
<th>Lessons</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Bryce</td>
<td>156</td>
<td>135</td>
<td>191</td>
<td>103</td>
<td>129</td>
<td>44</td>
<td>73</td>
<td>831</td>
</tr>
<tr>
<td>Nick</td>
<td>91</td>
<td>83</td>
<td>157</td>
<td>94</td>
<td>106</td>
<td>absent</td>
<td>64</td>
<td>595</td>
</tr>
<tr>
<td>Amber</td>
<td>118</td>
<td>absent</td>
<td>87</td>
<td>64</td>
<td>54</td>
<td>23</td>
<td>34</td>
<td>380</td>
</tr>
<tr>
<td>Kate</td>
<td>3</td>
<td>55</td>
<td>absent</td>
<td>13</td>
<td>29</td>
<td>17</td>
<td>5</td>
<td>122</td>
</tr>
</tbody>
</table>

The four students exhibited similar proportions of talk across each of the seven lessons, Bryce, the high achiever having the most talk followed by Nick, Amber and then Kate, the low achiever. Bryce has exhibited the most talk in each lesson, even though in lessons
four, five and seven Nick has had similar levels of talk. Bryce talked the most in lesson three and very little in lesson six.

Of all the lessons Nick also talked the most in lesson three. He was absent in lesson six, but maintained a consistent level of participation in most other lessons. Nick's level of talk was least in lesson seven.

Amber talked more than Nick in lesson one, however, she was generally less talkative than Nick. Her quantity of talk generally decreases over the series of lessons, though the proportion of total lesson talk contributed in lesson six was high.

Kate, the low achiever, was very quiet in most lessons. Her most talkative lesson was lesson two, while Amber was absent. Her second highest talk level was in lesson five and she contributed a considerable proportion of the talk in lesson six, even though the lesson exhibited low overall levels of talk.
Heuristic talk.

Secondly, the NUD*IST analysis focused on the subjects’ use of the heuristic during the activity stage of the lessons. The analysis concentrated on key phrases of the heuristic and searches were made on two sets of words:

- formal terms of the heuristic and
- informal terms or synonyms.

The label synonym is used here to describe words that could reasonably be expected to signify an intent similar to that of the formal term. For example the formal term “idea” could also be represented by a student stating “I have an ‘idea’” or “I’ve thought of something” and the formal term ‘accept’ could also be represented by a student stating “Yes, that's the answer” or “great, we’ve got it”. The analysis is shown diagrammatically in Figure 7 as the part of lesson talk that was attributable to student activity talk and was associated with the heuristic terms and the heuristic synonyms. The two shaded portions of the venn diagram indicate the student talk that uses the specific terms of the heuristic and the student talk that uses the synonyms of the heuristic.
A list of synonyms was developed for each formal term, from talk that was perceived as typical in the transcripts of the lessons. The synonym lists are not exhaustive, are not balanced in number of items or form, and are intended only to act as an indicator of student use of the problem solving heuristic or the type of thinking intended by the heuristic. The synonym lists are shown in Table 9.
<table>
<thead>
<tr>
<th>Heuristic terms</th>
<th>Discuss</th>
<th>Accept</th>
<th>Reject</th>
<th>Write</th>
<th>Check</th>
</tr>
</thead>
<tbody>
<tr>
<td>Idea Synonyms</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Found it</td>
<td>get ready</td>
<td>correct</td>
<td>No</td>
<td>nice</td>
<td>is this answer</td>
</tr>
<tr>
<td>I thought of something</td>
<td>talk</td>
<td>take it</td>
<td>Nup</td>
<td>writing</td>
<td>right</td>
</tr>
<tr>
<td>I found an answer</td>
<td>cooperate</td>
<td>like this</td>
<td>I don't want to put it</td>
<td>put it</td>
<td>down</td>
</tr>
<tr>
<td>think of more</td>
<td>what do you want to do</td>
<td>like it</td>
<td>I don't want it</td>
<td>there</td>
<td>why would you want</td>
</tr>
<tr>
<td>I got it</td>
<td>hang on</td>
<td>yep</td>
<td>I don't like it</td>
<td>pencil</td>
<td>are you sure</td>
</tr>
<tr>
<td>what if</td>
<td>question</td>
<td>yes</td>
<td>I hate it</td>
<td>pen</td>
<td>is that right</td>
</tr>
<tr>
<td>wait, wait</td>
<td>what does it mean</td>
<td>if you want to</td>
<td>not</td>
<td>rubber</td>
<td>huh?</td>
</tr>
<tr>
<td>why don't we</td>
<td>have you got it</td>
<td>thank you</td>
<td>wrong</td>
<td>paper</td>
<td>Oh</td>
</tr>
<tr>
<td>I'm trying to think</td>
<td>just use that</td>
<td>answer</td>
<td>bad one</td>
<td>scrap</td>
<td>Is this good</td>
</tr>
<tr>
<td>got it</td>
<td>say</td>
<td>we're going good</td>
<td>very bad</td>
<td>paper</td>
<td>what</td>
</tr>
<tr>
<td>How about</td>
<td>something</td>
<td>this is great</td>
<td>nah</td>
<td>lined</td>
<td></td>
</tr>
<tr>
<td>I know</td>
<td>get going</td>
<td>fantastic</td>
<td>neatly</td>
<td>nicely</td>
<td>can you</td>
</tr>
<tr>
<td>Ahh!</td>
<td>I've got something</td>
<td>too good</td>
<td>we're done</td>
<td>who</td>
<td></td>
</tr>
<tr>
<td>think about it</td>
<td>think about another one</td>
<td>great</td>
<td>when</td>
<td>do you think so</td>
<td></td>
</tr>
<tr>
<td>hey!</td>
<td></td>
<td>Ok</td>
<td>what do you reckon</td>
<td>this is good</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>very good</td>
<td>I don't think so</td>
<td>is this possible</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>terrific</td>
<td>what is that got</td>
<td>I don't think so</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>that's good</td>
<td>to do with it</td>
<td>what's that got</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>whoopee</td>
<td>what are you doing</td>
<td>to do with it</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>yeah</td>
<td>why</td>
<td>what are you doing</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>this is the best</td>
<td>why</td>
<td>why</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>what next</td>
<td>what next</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>I don't know</td>
<td>I don't know</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>oh</td>
<td>oh</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>yeah, but</td>
<td>yeah, but</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>aw</td>
<td>aw</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>why not</td>
<td>why not</td>
<td></td>
</tr>
</tbody>
</table>
Text searches.

Text searches were completed on the formatted student talk data for evidence of each of the heuristic terms including the term's synonyms, for each lesson. Overall totals for heuristic talk including synonyms, are shown in Table 10.

Table 10
Overall Totals of Heuristic Talk Terms and Synonyms

<table>
<thead>
<tr>
<th>Term including synonyms</th>
<th>Lessons</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Idea</td>
<td></td>
<td>15</td>
<td>31</td>
<td>32</td>
<td>4</td>
<td>20</td>
<td>8</td>
<td>7</td>
<td>117</td>
</tr>
<tr>
<td>Discuss</td>
<td></td>
<td>16</td>
<td>20</td>
<td>21</td>
<td>24</td>
<td>9</td>
<td>7</td>
<td>6</td>
<td>103</td>
</tr>
<tr>
<td>Accept</td>
<td></td>
<td>7</td>
<td>16</td>
<td>30</td>
<td>18</td>
<td>17</td>
<td>8</td>
<td>16</td>
<td>112</td>
</tr>
<tr>
<td>Reject</td>
<td></td>
<td>7</td>
<td>11</td>
<td>17</td>
<td>10</td>
<td>10</td>
<td>5</td>
<td>3</td>
<td>63</td>
</tr>
<tr>
<td>Write</td>
<td></td>
<td>27</td>
<td>20</td>
<td>13</td>
<td>24</td>
<td>8</td>
<td>14</td>
<td>9</td>
<td>115</td>
</tr>
<tr>
<td>Check</td>
<td></td>
<td>26</td>
<td>32</td>
<td>54</td>
<td>40</td>
<td>39</td>
<td>13</td>
<td>28</td>
<td>232</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>98</td>
<td>130</td>
<td>167</td>
<td>120</td>
<td>103</td>
<td>55</td>
<td>69</td>
<td>742</td>
</tr>
</tbody>
</table>

The term “check” and the synonyms of “check” were noted almost twice as many times as other terms and synonyms. The terms “idea”, “write” and “accept” and their synonyms were also noted often. The term “discuss” exhibited a slightly lower level of use and least used of the heuristic and its synonyms was the term “reject”. These results, however, should be qualified. The number of synonyms listed for each of the heuristic terms is different and therefore when text searches were carried out on the data heuristic terms with higher numbers of associated synonyms were more likely to have been found more often (see Table 9). However, valid comparisons were still carried out among lessons and among students. This was possible
because the number of text terms and synonyms searched for in the
data remained consistent for all students and for all lessons.

Quantities of heuristic talk.

Lesson three exhibited the highest use of the heuristic terms and
synonyms, however, lessons two, three, four and five, all contained
significant evidence of the heuristic terms and synonyms, with the
term accept, and its synonyms, being used very often in lesson three
(Table 10). It should be noted that the problem solving heuristic was
not introduced until lesson four.

The student talk was analysed for evidence of heuristic talk, by
student and by lesson. The number of text units identified as
containing heuristic terms or synonyms, for each student, is shown
in Table 11.
Table 11

The Number of Text Units Identified as Containing Heuristic Terms or Synonyms in each lesson for each person.

<table>
<thead>
<tr>
<th>Speaker</th>
<th>Lessons</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Bryce</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Idea</td>
<td>9</td>
<td>14</td>
</tr>
<tr>
<td>Discuss</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Accept</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>Reject</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Write</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>Check</td>
<td>8</td>
<td>14</td>
</tr>
<tr>
<td>Total</td>
<td>40</td>
<td>61</td>
</tr>
<tr>
<td>Nick</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Idea</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Discuss</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Accept</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Reject</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Write</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Check</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>14</td>
<td>11</td>
</tr>
<tr>
<td>Amber</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Idea</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Discuss</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Accept</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Reject</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Write</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Check</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>28</td>
<td>17</td>
</tr>
<tr>
<td>Kate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Idea</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Discuss</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Accept</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Reject</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Write</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Check</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>Total</td>
<td>3</td>
<td>23</td>
</tr>
</tbody>
</table>

Note: Vertical column of 'O' indicates absent student

Bryce has clearly dominated every lesson and all heuristic type talk. He has performed higher than all other students in each area.

He has exhibited high levels of heuristic talk in lessons one, two, three and five and was higher than all other students in every lesson.
Nick has exhibited high levels of heuristic talk in lesson three, but far less in most other lessons. Amber's best lessons were one, three and four and in lesson four Amber indicated levels of heuristic talk higher than Nick. She was absent for lesson two. Amber's level of heuristic talk was always higher than that of Kate but when Amber was absent Kate recorded her highest score and that occurred in lesson two. Kate was absent for lesson three.

**Heuristic and non-heuristic talk.**

The proportion of student heuristic talk across all lessons was calculated by dividing the total counts of student heuristic talk by the total student talk. Overall the analysis indicates an approximate average of 35 percent of all student talk is heuristic talk. This occurs as either statements that use the precise heuristic terms or utterances that are synonyms for the heuristic terms. The talk includes both intentional and unintentional heuristic talk. This is shown in Table 12.
Table 12

Proportion of all Student Talk attributed to Heuristic Terms and Synonyms shown as a Percentage

<table>
<thead>
<tr>
<th>Terms &amp; synonyms</th>
<th>Lessons</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Idea</td>
<td>3.8</td>
<td>9</td>
<td>6</td>
<td>1.26</td>
<td>5.8</td>
<td>9.2</td>
<td>2.8</td>
<td></td>
</tr>
<tr>
<td>Discuss</td>
<td>4.2</td>
<td>4</td>
<td>4</td>
<td>6.8</td>
<td>2.2</td>
<td>6.8</td>
<td>1.8</td>
<td></td>
</tr>
<tr>
<td>Accept</td>
<td>1.8</td>
<td>4.6</td>
<td>5.8</td>
<td>5.4</td>
<td>4.6</td>
<td>9.2</td>
<td>6.8</td>
<td></td>
</tr>
<tr>
<td>Reject</td>
<td>1.8</td>
<td>3.4</td>
<td>3</td>
<td>2.8</td>
<td>2.8</td>
<td>5.8</td>
<td>1.36</td>
<td></td>
</tr>
<tr>
<td>Write</td>
<td>7.0</td>
<td>5.6</td>
<td>2.4</td>
<td>7.2</td>
<td>2.2</td>
<td>16</td>
<td>3.6</td>
<td></td>
</tr>
<tr>
<td>Check</td>
<td>6.6</td>
<td>8.4</td>
<td>10.6</td>
<td>12.2</td>
<td>10.6</td>
<td>12.6</td>
<td>11.4</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>25.2</td>
<td>35</td>
<td>31.8</td>
<td>35.66</td>
<td>28.2</td>
<td>59.6</td>
<td>27.76</td>
<td></td>
</tr>
</tbody>
</table>

The lowest proportion of heuristic talk was found in lesson one and was similar to that of lesson seven. Several lessons indicated proportions of heuristic greater than 30 percent and the highest proportion was found to be in lesson six.

Much of the talk counted as heuristic talk resulted from the use of the synonym search strings. This was mainly due to the numerous synonyms used in the searches but also the nature of the heuristic terms themselves. Student talk seemed to be more colloquial, more informal and less likely to use the specific terms of the heuristic. This is discussed in more detail in the next chapter. The actual counts of student talk exhibiting heuristic talk attributable to either the heuristic terms or the heuristic synonyms are shown in Table 13.
Table 13

Actual Counts of Heuristic Terms and Heuristic Synonyms for each Term.

<table>
<thead>
<tr>
<th>Heuristic term count</th>
<th>Heuristic synonyms count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Idea</td>
<td>27</td>
</tr>
<tr>
<td>Discus</td>
<td>14</td>
</tr>
<tr>
<td>Accept</td>
<td>5</td>
</tr>
<tr>
<td>Reject</td>
<td>5</td>
</tr>
<tr>
<td>Write</td>
<td>43</td>
</tr>
<tr>
<td>Check</td>
<td>21</td>
</tr>
</tbody>
</table>

Some interesting trends are evident in the heuristic data. Table 12 indicates that lesson six exhibited the highest proportion of heuristic talk followed by lessons four, two, three, five, seven and one, yet as is shown in Table 10, actual counts indicate that lesson three exhibited the highest level of heuristic type talk shown in graphical form (Figure 8).

Figure 8. Total Count of Heuristic Terms and Synonyms for all lessons.
Lesson four and five data are of interest. Lesson four is the first lesson where the problem solving heuristic is introduced, all students are present in the lesson and the lesson has the fourth highest level of overall talk (see Figure 6). Added to this the lesson exhibited the third highest level of heuristic talk (see Figure 8) and this represented the second highest proportion of heuristic talk for all lessons (see Table 12). Lesson five has a total talk level that is higher than lesson four yet exhibits lower counts of total heuristic talk and slightly lower proportions of heuristic talk.

In lesson six it seems that low levels of total talk and slightly higher levels of heuristic talk result in a high proportion of heuristic talk. In contrast, lesson three where total talk was the highest, the level of heuristic talk was almost double to that lesson six but represented a much lesser proportion. This is also of particular interest due to the absence of the low achieving student, Kate. Further it should be recalled, that at this time the problem solving heuristic had not been introduced to the students.

Interestingly, lesson two had the second highest level of total student talk yet exhibited heuristic talk that was greater in proportion to that of lesson three and similar in proportion to lesson four. There was also one student absent and the problem solving heuristic had not been introduced at that time.
Summary of the NUD*IST Analysis

This section has described the NUD*IST analysis undertaken through the use of the heuristic terms and phrases or synonyms of the heuristic terms. The section discussed the findings of the analysis including levels of student talk, levels of student talk that employed the heuristic terms and synonyms and the proportions of total student talk attributable to the heuristic terms and synonyms. The chapter now turns to an analysis of the student self-reports undertaken in the stimulated recall interviews.

Student Self-reports

First set of stimulated recall interviews.

Stimulated recall interviews were held with each student after lessons four, five, six and seven. The schedule of questions asked of each student appears at Appendix A. Very little evidence exists to show that the students consciously invoked use of the heuristic. Amber in her first interview recalled that

I was thinking we sort of got the right answer at that time we were looking up the picture (sic) [a drawing of dogs and puppies] and at that time we didn't know that the picture didn't have anything to do with it so we had to start again, we had to look at the words again.

This seems to show that Amber was clear that some reworking of the answer was necessary. Use of the pronoun "we" indicates that this was a group responsibility and she would not do it by herself. A similar response to the same section of video tape was made by Nick.
Amber, Nick and Bryce were able to recall that the teacher’s introduction included group rules for cooperative behaviours, clues and strategy discussion but did not recall any detail at all regarding the diagramming of the problem solving heuristic. However, in the following excerpt Bryce describes his thoughts while listening to the teacher. The video tape is showing the teacher’s introduction of the problem solving heuristic. The heuristic diagram is in the background of the monitor picture. The researcher asks “what were you thinking there?”

<table>
<thead>
<tr>
<th>Bryce</th>
<th>What when I said “yes”?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Researcher</td>
<td>Mmm</td>
</tr>
<tr>
<td>Bryce</td>
<td>Like reject the idea or take it into account like you might have a very good idea so you might put it up on the board to help the group, like some ideas are not going to work so you’ve got to figure it out, so I thought that then - it was a good idea and um when you figure it out it’s just going to reject.</td>
</tr>
</tbody>
</table>

Clearly the student is thinking about the material presented by the teacher regarding the problem solving heuristic but is unable to describe his intended use of the model because the problem for the lesson had not been introduced at this time. Bryce’s response to the research question “what were you thinking?” was entirely appropriate considering he lacked any context in which he might apply the heuristic model.
Second set of stimulated recall interviews.

Kate answered the first interview question saying that the teacher’s introduction included “how to solve a problem and how to think about it in a group” but did not respond to any portion of the taped lesson with evidence that suggested understanding, recall, or use of the heuristic.

Amber was able to elaborate on the purpose of the heuristic saying “I was looking at the stuff on the board thinking how we might, or how can we go along with that and finish the problem”. This seems to indicate that Amber did not see the heuristic as an aide or description to solving the problem, rather more as another framework in which the problem had to be solved. When asked, what she understood from the teacher’s introduction of the lesson Amber replied “that you had to try and work out how many pigs there were and what [problem solving heuristic] step you were doing” (see Lesson four, Appendix C). In a later comment on the teacher’s introduction of the problem solving heuristic she noted “I was bored with that because he did it last week”.

Nick was unable to recall any evidence of the problem solving heuristic either from the lesson introduction or from viewing the video of the lesson. Bryce, however, remembered the “idea thing” as being something helpful that the teacher did. On viewing the video Bryce stated that during the introduction he was “thinking about the
idea - about what ideas we could have but we didn't have the question then". Clearly, Bryce sees the heuristic as helpful but is unable to mobilise his thinking at this time having not received the problem on which to work.

Third set of stimulated recall interviews.

Kate's recall of the lesson lacked detail and she often responded with "I can't remember" or "I don't know". The following excerpt shows Amber's response when asked "what did the teacher do today that helped you?".

| Amber          | Well, what he said was the same as what he always says. He is just like telling you what you can do on the board, like strategies, ... I don't learn anything, like he is just telling you, you can use those, like decide in the group you know which strategies you want to use so you just do that...strategies you should use first. |
| Researcher     | What did you learn from that, when he was talking all about that stuff? |
| Amber          | (laughs) I didn't learn anything ...because there is nothing to learn about ...because he is just telling you to use some, to choose one, ... |

It is possible Amber is expecting some factual content that she needs to remember or learn and cannot see the value of the problem solving heuristic process that the teacher is attempting to clarify during the introduction. Amber is adamant that she has not learned anything in this early part of the lesson. During the section of the teacher's introduction that covered the problem solving heuristic Amber was asked "what were you thinking?".
Amber: Oh I was just listening.
Researcher: Mmm, are you thinking while you are listening?
Amber: (shakes head) No
Researcher: What are you thinking then? (teacher is saying “I will be asking you at what stage are you in the [problem solving heuristic] model?”)
Amber: Just thinking about what stage we'd be at.

The difficulty the student had in clearly articulating her thinking appears to be increased by the lack of content in the problem, or context in which to imagine how the heuristic could be helping her solve the problem.

Both Amber and Bryce could not remember what they were thinking either when the teacher was talking about the problem solving heuristic, or when they were previewing the problem. In both instances the students answered they were “just listening” or “just reading”. When Bryce specifically referred to the heuristic he called it “that diagram that he [the teacher] had up on the board, you know idea, reject accept, discuss and that - that diagram”. The lack of order applied to the terms of the heuristic may mean that the student did not hold a high regard for the model.

**Fourth set of stimulated recall interviews.**

In the first of the interviews of this lesson Bryce is viewing the video tape covering the introduction of the problem solving heuristic. In this excerpt he states his answer to the question “what were you thinking at this time?”. 
Bryce: I don't think the system that, wait on, I think the system is working that we've been using, the idea one, like we rejected a couple, and also accepted a couple. We found about three ways to do it.

Researcher: So do you think this system helps you or not?

Bryce: Yeah.

Researcher: How?

Bryce: Just helps by which stage we're at, like you know which stage you're at in your discussion, like if you're discussing you can turn around and look and ask yourself what stage you're at, like could be writing down and check what we think.

The answer is appropriate had the group showed any sign of actually asking what stage they were up to, but there does not appear to be any significant proof that the students did this. The following extract shows Bryce's response when questioned specifically on the utility of the problem solving heuristic.

Bryce: It helps us because you choose the um - if you have discussions and all this in here with out it you're just totally mixed up and your answer would most likely be wrong, because you'd just be guessing, and with this it helps you to discuss, write it down and check it. Cos they don't, they just take a guess and that, right, they would like check it.

Researcher: Mmm so in terms of what you did with your group in trying to solve the problem did you actually use this?

Bryce: A couple of times we did.

Researcher: How?

Bryce: Just by discussing, um I had a look up there a couple of times, and I asked myself what stage are we at and when I had a look at the paper we were writing it down, and after we'd finished that I had a look to see if everything was right, like check it, then we went back to see if we could find another way, another idea, and either accept or reject it.
Bryce's response indicated use of the problem solving heuristic but he did not provide clear examples of how it was actioned. When questioned further Bryce indicated that he was not sure how particular segments of the lesson were related to the diagram or how the segments could be viewed in terms of the diagrammed process. Bryce emphasised the value of discussion saying "we'd use this [heuristic] ... because it's more, ... it helps you to get the answers. Without it we would have just gone right down and we couldn't have got the answers. It's helped us to discuss".

It is possible Bryce felt obligated to provide this response to the researcher for there is little evidence that his understanding of the problem solving heuristic actually promoted the quality of discussion.

Nick was precise in saying that the heuristic had not provided any help. While the teacher introduces the "discuss" stage of the problem solving heuristic the researcher asks Nick "what were you thinking there?".

<table>
<thead>
<tr>
<th>Nick</th>
<th>Oh discussion stage... ... oh nothing ... just discussion stage.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Researcher</td>
<td>Yeah - what about it?</td>
</tr>
<tr>
<td>Nick</td>
<td>Oh nothin'.</td>
</tr>
<tr>
<td>Researcher</td>
<td>Did you think anything particular about that part of the lesson?</td>
</tr>
<tr>
<td>Nick</td>
<td>No it was just ordinary.</td>
</tr>
<tr>
<td>Researcher</td>
<td>Yeah, just ordinary?</td>
</tr>
<tr>
<td>Nick</td>
<td>Yeah cos they keep doing it every week, every Tuesday.</td>
</tr>
<tr>
<td>Researcher</td>
<td>Yeah, yeah every Tuesday that's right.</td>
</tr>
<tr>
<td>Nick</td>
<td>Like I already know that thing.</td>
</tr>
<tr>
<td>Researcher</td>
<td>Which things?</td>
</tr>
</tbody>
</table>
Nick has difficulty in giving the problem solving heuristic a name. He is adamant that it was of little use to the problem solving situation. Later in a section where aspects of the heuristic are evident Nick makes no mention of the model.

When questioned specifically about the utility of the problem solving heuristic, Nick initially follows the same response as Bryce,
however he changes his mind. The researcher asks “is the problem solving heuristic of any use in solving problems”?

<table>
<thead>
<tr>
<th>Nick</th>
<th>Yeah it is.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Researcher</td>
<td>Why is that?</td>
</tr>
<tr>
<td>Nick</td>
<td>If you've got an idea you can discuss it, and you can like accept it, I guess, yeah, and write down the solution and check it. (Reading from diagram) It's not really any use.</td>
</tr>
<tr>
<td>Researcher</td>
<td>Not really any use?</td>
</tr>
<tr>
<td>Nick</td>
<td>Na not really ... the truth in it (laughs)</td>
</tr>
</tbody>
</table>

Nick explains that his own method of solving problems is very similar to the problem solving heuristic. He continues saying:

<table>
<thead>
<tr>
<th>Nick</th>
<th>Yeah ... no not really, cos that's what we always do.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Researcher</td>
<td>You always do what?</td>
</tr>
<tr>
<td>Nick</td>
<td>We used to do that, we always do all this...</td>
</tr>
<tr>
<td>Researcher</td>
<td>Yeah?</td>
</tr>
<tr>
<td>Nick</td>
<td>We always get an idea then we discuss it and we get the solution and then we write it down and we check it.</td>
</tr>
</tbody>
</table>

Nick seems to recognise a natural problem solving cycle in his own behaviour and the group's behaviour. He attributes validity to the diagram in that “that's what we always do” but denies any need to refer to it in any reflective capacity or monitoring of cognitive processes.

Amber in her interview, described the teacher's introduction as including accepting or rejecting ideas. She could describe the problem solving heuristic but admitted difficulty in remembering the
details of the process. Often Amber would state she was simply listening to the teacher. When the teacher had requested that each group determine which strategy they would use prior to solving of the problem, Amber stated she was trying to think of which strategy she used in the previous week.

When asked specifically about the problem solving heuristic Amber responded that she “hadn’t actually looked at it”. She stated that “our group just does what ever happens Ö but we use the strategies. We’ll end up doing that anyway, and like when we reject it, um, we do go back to ‘ideas’”. She recalled one lesson where she reached the end of the lesson before she found a solution to the problem and thought that she “must have gone through lots of ideas”.

Kate found difficulty in recalling any specific detail or thought that she had during the lesson. Answers such as “just listening” or “just watching” were often repeated. In relation to the diagram of the problem solving heuristic Kate stated “it helps you a lot” and was she able to explain the steps of the heuristic. However, she was unable to provide a specific example of using the model claiming, “sometimes it was just too hard”. Kate stated that the most helpful part of the model was “discuss”. However, when she was viewing a portion of the video where the group was checking the problem and writing down the solution, Kate was unable to describe how the group's activity related to the model.
Summary of the Interviews

This section has described the data from the stimulated recall interviews and the interpretation of that data within the context of the transcribed dialogue. Brief discussion on the possible reasons for particular student views have been made and these will be amplified in the next chapter.

Summary of the Chapter

This chapter has described and analysed the data collected from the transcripts of the video tapes, audio tapes and the stimulated recall interviews. The chapter was presented in three parts; data relating to the cognitive intent and the instructional input of the teacher, data from the student talk occurring during the activity stage of the lessons and the data from the stimulated recall interviews held immediately following the lesson. Data from the student talk during the activity stage of the lesson was analysed using the MAKITAB small group learning interaction analysis system, the reading of the transcripts and the non-numerical, unstructured data, indexing, searching and theorising tool, NUD*IST. The brief discussion of the results presented will be expanded and developed in chapter five.
CHAPTER FIVE

DISCUSSION OF RESULTS

Overview of the Chapter

This chapter discusses the results of the data analysed in chapter four. Chapter five presents an overview of the data and examines it under nine observed conditions. It is suggested that these nine conditions have a significant impact on the nature and degree of the connection between the cognitive intent of the teacher and the kind of small group interactions that occur. In particular the nine conditions focus on the student use of the problem solving heuristic during the activity phase of the lessons. The chapter concludes with a summary.

Overview of the Data

The data revealed that the teacher's behaviours during the small group cooperative learning were consistent with a cognitively oriented set of conditions. It is clear that the students operated in a cooperative group on tasks set by the teacher and did so with success. The students responded positively to the direction of the teacher in cooperating and working within a group to produce a group product by implementing a range of problem solving strategies in a series of open and closed problems. In terms of problem solving skill, the group was quite successful in effecting satisfactory solutions to each task. However, the connection between the teacher's
instructional intent, in the form of teaching a problem solving heuristic, and the kind of interaction and talk within the group was not so clear.

In lessons one to three there was no attempt by the teacher to instruct students in the use of the heuristic but a considerable amount of evidence was found of heuristic related student talk being used naturally, and covertly. The NUD*IST analysis indicated that in these three lessons an average of 30% of all student talk was heuristic related talk (i.e. terms and synonyms) and in the remaining lessons heuristic talk accounted for an average of approximately 38%. It should be noted, however, that the percentage of heuristic talk is affected by the total quantity of student talk in a lesson.

After the heuristic had been introduced by the teacher in the fourth lesson there was continuing strong evidence of the use of heuristic associated talk by three of the four students but there was little evidence that students consciously, or overtly, invoked the use of the heuristic. The overt use of the steps in the problem solving heuristic was limited and incidental, and mainly associated with the high achiever and hardly at all with the low achiever. The exception to this trend was lesson six where in a low interest level problem there was evidence that student use of the heuristic by Bryce may well have provided the necessary guide to successful problem solving. In post-lesson interviews there was generally an awareness of the
heuristic, and its place in the lesson, but little understanding of how it could have been explicitly applied to the problem solving process.

In seeking to explain the limited overt use of the heuristic by these students in the small group cooperative learning setting, the study provides evidence of nine mitigating conditions.

**Condition One**

*Portions of the heuristic were occurring naturally in student talk both before and after the introduction of the heuristic and students may not have seen the relevance of it. As one student stated, “we always do that anyway”.*

The student discussions in lessons one, two and three exhibited as much, if not more, evidence of the elements of the problem solving heuristic than the lessons that followed. This clearly cannot be attributed to the teaching of the heuristic and may provide an insight into the untrained processes used by the students. The evidence indicated that in conditions that did not explicate a problem solving heuristic or framework, students can demonstrate effective problem solving through verbal discussions, however, this is affected by the lesson content among other things.

The lessons (Appendix 3) planned by the teacher fell into two broad categories. Lessons one, two and three were of a more divergent nature permitting a variety of solutions and allowing students to explore numerous paths in seeking the solution. These
early lessons invoked longer and more intense discussion among the group particularly where the content was clearly practical in nature, like the survival adventure in lesson two and building the bridge in lesson three. This was evident in the MAKITAB analysis, the NUD*IST analysis and also in the transcripts of the student discussions.

Good, Grouws, Mason, Slavings and Cramer (1990) posit that lessons that do not provide opportunities for interaction, further limit an already complex small group learning situation. This appears to be consistent with the evidence from the later lessons that were more closed in nature and restricted in the number of strategies students were able to use. The problems required specific solutions, were less practical in their application and possibly resulted in the reduction in student statements, questions, group monitoring, proposing, negotiating and arguing, particularly in lessons six and seven. Collective ownership of the solutions may have also been weakened as claimed by Sullivan, Bourke and Scott (1995).

One view (D.J. Clarke, personal communication, April, 1996) posits that students that are good problem solvers may naturally make use of problem solving heuristics. That is, good problem solvers have developed, either intentionally or unintentionally, a method or framework for solving problems. In like manner, if the study of problem solving processes results in the development of problem solving heuristics, frameworks and guiding questions, then it is not surprising to find these processes already occurring. Had
the study sought to develop a problem solving heuristic one source of data may have been the analysis of untrained student problem solving.

As was apparent in the post lesson interviews of lessons five, six and seven, most students indicated that there was nothing more to learn about the problem solving heuristic yet there seems little can be done to make the heuristic more relevant. If students understand the essential elements of "idea", "discussion", "acceptance", "rejection", "writing" and "recording" and the interaction among those elements, then there may be little else that can be highlighted that will help students to solve problems. As one student stated "we always do that anyway".

It is feasible then to suggest that students may already hold a framework for solving problems. If a problem solving heuristic is specified by the teacher, students may have difficulty in reconciling or assimilating two models, however, there was no evidence in the literature reviewed that focussed on student difficulty reconciling similar or competing heuristic frameworks. Consequently, problem solving heuristics and frameworks developed by students could provide rich information on how students perceive the problem solving process. This issue will be discussed further in chapter six.

The first three lessons indicated that in the absence of the problem solving heuristic, students tackled the problem
enthusiastically and unintentionally echoed the steps of the heuristic. It is also not surprising that portions of the heuristic were seen to occur naturally. The heuristic was developed from the MAKITAB Small group Interaction Analysis categories and followed a similar reflective cycle to other problem solving heuristics (Polya, 1945) and the MAKITAB categories were in turn, inductively developed through the observation of student interactions in small groups (King, Barry, Maloney & Tayler, 1993). Overt use of the problem solving heuristic was more evident in the later lessons when it was used intentionally as a supportive and guiding framework.

Condition Two

Students preferred to use their own procedures and prior knowledge in problem solving.

The heuristic was first overtly used in lesson four, however, the attempt to guide the problem solving process by students was confused. In later situations where use of the heuristic may have aided the problem solving process students did not attempt to utilise the model. In situations where the solution to a problem was reached early in the lesson, the students did not appear to have a clear recollection of the process by which the solution was obtained. These findings are supported by Ross, Rolheiser and Hogaboam-Gray (1996) who found that students preferred to use their own procedures and instruments, rather than those developed by exemplar teachers.
Given a choice, students may prefer to follow their instincts in solving problems.

**Condition Three**

*Group discussion during problem solving took place at high speed with many tacit, non-verbal understandings, half completed sentences and changes of direction where a single idea or proposal was followed by a burst of ideas, counter suggestions and negotiations.*

The literature reviewed on cooperative learning included observations by Bossert (1989), Clarke and Kessel (1995) and King, Barry, Maloney and Tayler (1994) concerning the need for further study of group dynamics. Lindow, Peterson and Wilkinson (1985) found that higher achieving students, and boys in particular, provided a greater number of demonstrations and answers to the discussion points. It is clear that in this study, most of the group discussions occurred at high speed and more often involved greater participation by the boys. This was particularly obvious in lessons one to four where students spoke relatively quickly in stating ideas, propositions or engaging in negotiation. Quite often only half sentences were spoken and yet other students seemed to know what was meant, and quite often responded with more suggestions, ideas and propositions. Furthermore, talking in the group activity seemed to occur in strings or runs. A single idea or proposal would often be followed by a burst of ideas, counter suggestions and negotiations.
On occasions when use of the heuristic apparently was covert or unintentional, it appeared that the students moved through the steps very quickly. Most often the shift from one step to the next was very smooth. It was also evident that unintentional use of the heuristic occurred with no clear adherence to the order of the steps as diagrammed for the students (see Figure 4).

**Condition Four**

*The lineal steps in the heuristic model did not reflect the rapid, naturally occurring portions and micro-cycles of heuristic talk within the group discussions. Several steps of the heuristic appeared to be occurring in combination and almost simultaneously.*

At times, several steps of the heuristic appeared to be occurring simultaneously. This may have been due to a weakness of the heuristic itself, however, students naturally seemed to employ complex combinations of ideas, discussion, acceptance, rejection, writing and checking in order to arrive at suitable solutions. Garner (1990) has argued that learners who have high or adequate background knowledge do not need to employ general learning strategies when solving problems. Garner (1990) argued that effective problem solving occurs when a student monitors their own learning, holds a sufficient knowledge base, recognises that effort and performance are valued and is able to transfer and adapt strategies from earlier contexts. The findings of this current study would
suggest that some or all of these conditions were met in the early lessons and hence generated the student activity evident of the problem solving heuristic. This would imply that the heuristic was a product of effective problem solving rather than a tool to assist problem solving.

Rigid adherence to the steps of the problem solving heuristic would be problematic for students. If students had rigidly adhered to the problem solving heuristic steps, the natural flow of ideas and discussions may have been disrupted. In addition the students would have had to maintain their own reflective capacity to acknowledge the steps of the heuristic as they were passed. This would seem to be an impractical imposition for students if they are already broadly aware of the problem solving process.

Literature reviewed regarding the structure of heuristics (Robinson, 1946; Thomas & Robinson, 1982; Bransford & Stein, 1984; Roth & Roychoudhury, 1993) appeared to imply relationships among the terms that were generally lineal. Each step of the heuristic would be completed prior to the next step and so to the completion of a problem. Given the evidence from chapter four, the concept of a lineal model does not always seem appropriate. As discussed earlier, student talk in lessons one, two and three was rapid and complex.
Evidence in the transcripts of student talk, the MAKITAB analysis and the NUD*IST analysis all seemed to show that the heuristic elements occurred in both random micro-cycles and larger macro-cycles. For example, students would propose an idea only to have the idea rejected in a single line of discussion. Small cycles of ideas, proposals, counter proposals, discussion agreements, disagreements, rejections, acceptances, making written records and checking would be nested within the larger cycle represented by the problem solving heuristic. The data suggested that any element of the problem solving process may trigger any other element or series of elements. The concept of order in the elements did not appear as important as the worth and validation of ideas. Students were not discouraged, if after recording an apparently worthwhile idea, further discussion resulted in the idea being rejected. The group moved generally from the initial setting of the problem to a group consensus of a suitable solution, or a solution that appeared suitable at that time.

This would imply that if the heuristic model is linear, it is linear only in a very broad sense and that the current structure does not truly reflect the problem solving processes occurring at the micro level. Although the heuristic model elements are part of the descriptive terminology of the MAKITAB instrument it should be noted that the instrument does not indicate a lineal relationship among the elements. An alternative model diagramming the micro
level processes might be constructed on a wheel concept such as shown in Figure 9. Figure 9 shows a dynamic relationship among the elements of the problem solving process.

![Figure 9. Dynamic Problem Solving Heuristic.](image)

Each point on the model can be accessed from any other point. No direction or order is specified and no starting point or finishing point is specified. In this way the essential elements of the problem solving heuristic are maintained yet the flexibility within the model is improved and is more likely to reflect the actions of good problem solvers. The implications of this model for teachers and students are discussed in chapter six.
Condition Five

Students were overloaded with information and tasks in the problem solving lessons and found it difficult to focus on more than one process at a time.

Sweller (1990), Ahmad, Tarmizi and Sweller (1988) and Sweller and Low (1992) argued that students could be overloaded in problem solving situations. This assertion is supported by the data from the post lesson interviews. The interviews suggested that students thought the heuristic model was a useful aide, but were unable to provide clear examples of their use of it. Some interview data indicated that the heuristic model was seen more as another framework in which the problem should be solved, but not an effectual aide to reaching the solution. In interviews following lessons five, six and seven, students sometimes claimed that they had “done it last week”. This suggests that students considered that learning from the model was complete, there was nothing else to be learned from it and therefore the overload experienced could be reduced by ignoring the heuristic.

In lessons four to seven, extra tasks also appeared to overload students. In lessons one, two and three the students were simply presented with the problem and asked to provide a solution. In later lessons students were required to understand the problem, choose from the list of problem solving strategies, solve the problem, while demonstrating an awareness of the problem solving heuristic and
employing cooperative group learning skills. The components listed for the latter lessons appeared to compete for the students' attention and may have had the effect of crowding the learning environment.

Often during the student interviews, on sections concerning the teacher's introduction of the lesson, the respondent would claim that they were "just listening, not thinking anything". The interview data gave no indication as to the meaning of "not thinking anything". It is possible that students found it difficult to focus their thinking on two or more issues simultaneously. That is, students found difficulty in focussing on the information being received through listening, the expected cognitive activity of solving the problem and the metacognitive activity of reflection on effective problem solving (Sweller & Low, 1992). Alternatively, students may have found difficulty in verbalising or recalling the thoughts that had occurred during the lesson (King & Tuckwell, 1983).

A third alternative could be that the thinking most likely to occur, at the time the teacher introduced the problem solving heuristic, was affected by the order of the lesson components. The components introduced were the problem solving heuristic, followed by the group cooperation skills, the list of problem solving strategies and finally the lesson problem. Thinking that focussed on solving the problem would not be encouraged if the problem was last in the series of information delivered by the teacher. In lessons four to seven the problem was presented last out of all the lesson components.
components. It is not surprising that students reported difficulty in thinking about the strategies they should use. Stating the problem as a final part in the lesson introduction, forced students to try and think about strategies and the problem solving heuristic without a problem context in which to apply them. This sentiment was evident in the transcripts of the stimulated recall interviews. Listening, as reported by students, may have been simply taking in information and was a strategy used by students to manage the apparent overload of information.

**Condition Six**

*Students did not have a range of suitable learning strategies for actioning the heuristic. For example, there was little evidence of the use of effective strategies for actioning the "check" step of the heuristic and this in turn hindered the finding of "correct" solutions to problems.*

The results of the data analysed indicated that the heuristic term "check" and its synonyms was often found in the students' talk, however, reading of the transcripts showed that students did not regularly and thoroughly use alternative checking strategies. Instead, students merely repeated the strategy used in solving the problem to check the solution found. If students have little opportunity or lack skills in the examination of disconfirming evidence, either through the group discussions, the checking process or the actions of the teacher, they will unwittingly arrive at incorrect
solutions having acted in accordance with the problem solving heuristic. If students have suitable strategies for effective checking of a solution then it is more likely that appropriate solutions will be found.

Heuristic models reviewed in the literature exhibited different levels of support for students. For example the Polya (1945) model of understand the problem, devise a plan, carry out the plan and look back, provides high level overview support similar to the problem solving heuristic used in this study. The SQ4R (Thomas & Robinson, 1982) model provides a far more strategic level of support directing students to study, question, read, recite, review and reflect. The difference in the two levels, overview and strategy, will affect the model's utility for both teachers and students. Lesson four data indicated that even if students followed the heuristic steps it was still possible to conclude the problem solving process with a result that was incorrect. Incorrect solutions imply that there is insufficient checking occurring at that stage of the heuristic.

The heuristic used in this study assumes that a group's corporate wealth will include the strategies that enable problem solving. That is, strategies for ideas generation, discussion strategies, strategies for determining acceptance or rejection of an idea, writing or recording strategies and strategies for checking solutions. A total lack of any one subset of these strategies would cause the problem solving process to falter. Conversely, where there exists at least one
strategy the problem solving process would continue. This strategy
may be a naturally occurring one as found by Lindow, Peterson and
Wilkinson (1985) in their study of verbal disagreements when they
found that students spontaneously used conflict resolution and
consensus agreement strategies.

**Condition Seven**

*There was insufficient modelling by the teacher of how the heuristic
might be used in problem solving tasks. Also group monitoring
behaviours to support the use of the heuristic, which on the surface
appeared to be effective, were occasionally parried by the group.*

The heuristic was modelled by the teacher at the beginning of
each lesson through reference to the boarded diagram. Questions
about the diagram were directed to each group in the class. The
model was also referred to while the teacher was monitoring
behaviours and in the conclusion of each lesson. At the time this
was thought to be adequate but on reflection, and for the target
group of four students, the teacher's modelling does not seem to have
been particularly effective.

During the activity part of the lessons the teacher asked
questions of the target group in relation to the heuristic. The
students were required to indicate on the heuristic model where the
group was operating, however, generally this did not result in any
significant discussion and did not provoke any further reflection from
the teacher or the students. Conversely, students were aware that if they did not achieve success in a task the teacher was quite likely to help them with clues or possible strategies. On a few occasions the teacher refocussed the students on the problem solving heuristic and the stage at which the students were operating. This had the effect of guiding the students in the solving of the problem, for example, by suggesting that if the group was satisfied they had completed the discussion of an aspect then they should seek agreement to accept or reject the idea. However, it was apparent that the level of teacher modelling was insufficient.

Brown and Palincsar (1987) argue that teacher modelling and the definition of specific roles and strategic tasks, provides a firm foundation for student learners. Results of studies found that long term maintenance, transfer and generalisation of learning was accomplished for students that had received the teacher modelling. Personal experience of the writer in the use of the reciprocal model (Palincsar & Brown, 1989) has found that students easily undertake the specific roles following teacher modelling.

Had the teacher in this study rigidly and frequently modelled the implied processes and strategies of the heuristic, students may have achieved even higher levels of problem solving success. For example, if the teacher had suggested that students ought to monitor their progress according to the heuristic on a regular basis or that students should take an active leadership role in solving the problem
through directing the problem solving processes of the group, higher levels of problem solving success may have been achieved by students. Teacher modelling of regular reflection on the group's position on the model may have also encouraged students to take on a group monitoring role. Regular reflection may also have encouraged higher levels of recording and questioning.

Furthermore, it appeared that at times, the group needed to be allocated traditional cooperative group roles (Johnson & Johnson, 1975, 1994; Burns, 1981) such as leader, questioner, recorder and researcher. This was most evident in the sixth lesson where Nick was absent and the role of questioner, even though not formally allocated, was missing from the group. Nick often appeared to question the answers of other group members and hence promote discussion and reflection. Absence of the student and the role was associated with much less group discussion, lower levels of reflective talk and lower quantities of task talk altogether.

However, it is also apparent that the students swapped roles frequently and that this swapping of roles was done according to the interaction of numerous factors. These included such aspects as:

- who was present in the group,
- how individuals were feeling,
- the nature of the problem,
- the availability of expert knowledge in the group,
• the teacher's interaction,
• the success or functioning of other groups and
• previous problem solving experiences of group members.

Exhaustive discussion of the factors above is beyond the scope of this descriptive study, however, it is evident that there are numerous interrelated and complex factors acting within the cooperative learning situation. Central to each of these factors is the teacher's role within the classroom and the activity of the lesson (King, Barry, Maloney & Tayler, 1993b). In this study the focus has been on the teacher's cognitive intent and specifically in the teaching of a problem solving heuristic. While it has been argued that the teacher's modelling was one aspect that may have led to less effective use of the heuristic, other authors attribute lower achievement in the use of heuristic devices to poor strategy use (Chan, 1994), a lack of student knowledge (Garner, 1990) and low skill levels in question generation (Wong, 1985). Hart (1990) claimed that modelling the problem solving processes of experts for low achievers overloaded the low achieving students. Low achievers were better served by the models from average students.

Alternatively, Leighton, Slavin and Davidson (1989) used heuristics in cooperative groups and consistently found that the cooperative groups out performed the control groups. This could mean that the effectiveness of the problem solving heuristic is
maximised for low achieving students through the modelling effect of the average and high achieving students in the cooperative groups. If low achievers receive the heuristic modelling from average and high achieving group members, the heuristic could remain a productive device in the small group learning situation. This would imply that the teacher's modelling would cater more for the needs of the higher achiever in the group and that there exists a flow-on effect from this modelling.

Lesson data in this study suggests that by not frequently refocussing on the problem solving heuristic, and opting to give clues to the solving of the problem, the teacher may have inadvertently regained control of the problem solving process. As a result student ownership and student investment in seeking a justifiable solution may have been weakened by the absence of understanding and the attempts at guessing solutions. In effect the skills required to solve the problem, including use of the heuristic, could have been undermined by teacher hints and clues.

**Condition Eight**

The lower achieving student was disadvantaged not only by having little understanding of the heuristic but also by a lack of knowledge of how the steps in the heuristic might be actioned. However, the lower achieving student appeared to be well aware of the status of the discussion and the group activity.
It is possible that lower achieving students could be unaware that the solving of a problem involved a framework of ideas generation, discussion, acceptance or rejection of ideas and the recording and checking of a solution. If so, it would be unlikely that they could effectively self-monitor and assess the point at which the group was having difficulty. For example, a group's inability to discuss their ideas will not be helped by reference to the problem solving heuristic that indicates discussion should follow the generation of ideas. The group will need strategies for developing discussion such as taking turns, stating opinions or looking for positive and negative aspects of an idea.

A lack of strategies available to an individual, particularly in respect to the discussion of ideas may have significant impact on a student's participation. In contrast to active students in the target group, the passive student Kate appeared much less involved in all discussions but still appeared to follow the ideas, reactions and counter-ideas of the group members. Although the transcripts, MAKITAB and NUD*IST analyses indicate low levels of input to most discussions, video evidence suggested that Kate was well aware of the status of the discussion and the group activity. She did not often put forward her ideas, however, it may be incorrect to assume that her quieter involvement implied less thinking, or less problem solving ability.
One explanation could be that she lacked the confidence and skills to participate (King, 1993). This would include group social skills, discussion skills and negotiation skills to make her contributions heard, as for example in lesson one. In lesson two, however, personal experience of camping or outdoor activity seemed to boost her confidence and resulted in higher levels of verbal involvement. It is possible that teacher expectation effects and self-fulfilling prophecies may have exacerbated the situation, particularly if the teacher had assumed that Kate's passivity could not be addressed within the classroom environment. If Kate thought that the researcher held low expectations of her recall ability these effects may have also been present in the stimulated recall interviews.

However, effective problem solving is most likely a function of the student and the model among other variables. If a student's understanding of the elements of the model and the nature in which those elements interact, affects the quality of the problem solving, then it is clear that students need to develop this understanding. It appears unlikely that students would hold a strong understanding of the heuristic if they were unable to describe how the element of the heuristic could be actioned. Such would be the case if a student attempted to rote learn the elements of the heuristic. The data examined supports the view that Kate held the weakest understanding of the problem solving heuristic and was least likely to have contributed strategies for inclusion in the problem solving
process. If the problem solving heuristic is to be of greatest use to low achieving students then skills in self-monitoring of cognitive activity (Hart, 1990), management of unproductive beliefs (Hart, 1990) and knowledge of useful strategies (Garner, 1990; Wong, 1985) seem important. This view is discussed further in chapter six.

**Condition Nine**

*In the case of low student motivation or low levels of task talk, the problem solving heuristic could act as a framework to facilitate, guide and prompt discussion and problem solving.*

In lesson six it appeared that the students were less motivated to state ideas, propositions and discuss insights as possible solutions to the problem. The student behaviour on this occasion seemed to imply that getting the answer to a problem could be more straightforward with no excursions into error, retrial, rethink or reject. This attitude was contrary to the attitude displayed in lessons one, two and three where students employed numerous approaches to solving problems with little or no hesitation. The apparent lack of motivation seemed to be linked with the problem content and the personal motivations of the students. In this lesson, however, the NUD*IST analysis indicated that a higher proportion of the student talk could be attributed to the problem solving heuristic terms and synonyms. This would suggest that in the case of low student motivation or low levels of task talk, the problem solving heuristic could act as a
framework to facilitate, guide and prompt discussion and problem solving.

The teacher’s specific actions in lesson six to redirect leadership roles toward Kate and Amber and away from Bryce may have been an attempt to avoid a common criticism of small group cooperative learning, namely that lower achievers rely on higher achievers, which in turn hold back the high achievers (Perry, Geoghegan, Owens & Howe, 1995). If this was the case, the evidence suggesting higher proportions of heuristic use in lesson six could possibly be attributed to the high achieving student continuing to model the problem solving heuristic, or lower achievers using the heuristic steps as a result of modelling by other students in the earlier lessons. Further, the express direction of the teacher to use the problem solving heuristic may have directed students to extend discussions beyond that which may have occurred (Deering & Meloth, 1991).

Summary of the Chapter

The chapter has discussed the data analyses undertaken in chapter four in terms of nine conditions. It was suggested that these nine conditions significantly impacted upon the nature and degree of the connection between the cognitive intent of the teacher and the kind of small group interactions that occurred. In particular the nine conditions focused on the student use of the problem solving heuristic during the activity phase of the lessons.
CHAPTER SIX

CONCLUSIONS, IMPLICATIONS AND RECOMMENDATIONS

Overview of the Chapter
This chapter concludes the study and summarises the findings in terms of the results and implications and makes recommendations for further research. The conclusions drawn cover the outcomes and the design of the study. The implications for teaching and teacher education institutions are discussed and the recommendations for further research focus on the beliefs of students in regard to heuristics and problem solving frameworks. The chapter ends with a final summary.

Conclusions

Outcomes
The study was guided by two research questions.

1. What is the nature and degree of connection between the cognitive intent and form of small group cooperative learning set by the teacher (conditions) and the kind of peer group interaction and talk (discussions) held by students?

2. What is the extent to which teacher instruction in a problem solving heuristic is reflected in a group of four
students' talk during the activity phase of seven problem solving lessons?

In responding to these two questions it is emphasised that the study was a small descriptive piece of research, and subject to the limitations outlined in chapter three. In regard to the first question the study revealed that the teacher's behaviours during the small group cooperative learning phase were consistent with a cognitively oriented set of conditions. It is clear that the students operated in a cooperative group on tasks set by the teacher and did so with success. Numerous, rapid discussions occurred during the seven lessons as students completed the solutions to open and closed problems. The discussions that resulted exhibited high levels of cognitive processing and in particular high levels of student proposals and negotiations. The students responded positively to the direction of the teacher in cooperating and working within a group, to implement a range of problem solving strategies and produce a group product, in a series of open and closed problems (mainly mathematical). In terms of problem solving skill, the group was quite successful in effecting satisfactory solutions to each task although their problem solving strategies were rather narrow and focussed on the content (the answer) rather than the process. Throughout the lessons the group worked harmoniously and cooperatively although there were some interesting problems in regards to group roles and high and low achievers. On balance though, it can be said that in
terms of problem solving outcomes, group work and the teacher's
instructional intent as demonstrated in the lesson introductions,
monitoring behaviours and lesson conclusions, were realised.

However, the connection between the teacher's instructional
intent, in the form of teaching a problem solving heuristic, and the
kind of interaction and talk within the group was not so clear and
this formed the focus for the second question, and major part, of this
study.

In lessons one to three there was no attempt by the teacher to
instruct students in the use of the heuristic but a considerable
amount of evidence was found of heuristic related student talk being
used naturally, and covertly, in small portions or micro-cycles. There
was no clear adherence to the order of steps in the proposed
heuristic. The NUD*IST analysis indicated that in these three lessons
an average of thirty percent of all student talk was heuristic related
talk (i.e. terms and synonyms) and in the remaining lessons heuristic
talk accounted for an average of approximately 38%. It should be
noted, however, that the percentage of heuristic talk is affected by the
total quantity of student talk in a lesson.

These data suggest at least two hypotheses: one that the
heuristic was little more than a formalisation of naturally occurring
problem solving talk anyway, and two, that the heuristic may have
been a reflection of previously existing problem solving frameworks.
After the heuristic had been introduced by the teacher in the fourth lesson there was continuing strong evidence of the use of heuristic associated talk by three of the four students but there was little evidence that students consciously, or overtly, invoked the use of the heuristic. The overt use of the steps in the problem solving heuristic was limited and incidental, and mainly associated with the high achiever and hardly at all with the low achiever. The exception to this trend was lesson six where in a low interest level problem there was evidence that student use of the heuristic may well have provided the necessary guide to successful problem solving. In post-lesson interviews there was generally an awareness of the heuristic, and its place in the lesson, but little real understanding of how it could have been explicitly applied to the problem solving process.

In seeking an explanation for the limited overt use of the heuristic by these students in the small group cooperative learning setting, the study provides evidence of the following mitigating conditions:

1. Portions, of the heuristic were occurring naturally in student talk both before and after the introduction of the heuristic and students may not have seen the relevance of it: or as one student stated “we always do that anyway”
2. Students preferred to use their own procedures and prior knowledge in problem solving (Ross, Rolheiser & Hogaboam-Gray, 1996)

3. Group discussion during problem solving took place at high speed with many tacit non-verbal understandings, half completed sentences and changes of direction where a single idea or proposal was followed by a burst of ideas, counter suggestions and negotiations

4. The lineal steps in the heuristic did not reflect the rapid, naturally occurring portions, and micro-cycles, of heuristic related talk within the group. Several steps of the heuristic appeared to be occurring in combination and almost simultaneously.

5. Students were overloaded with information and tasks in the problem solving lessons and found it difficult to focus on more than one process at a time (Sweller & Low, 1992)

6. Students did not have a range of suitable learning strategies for actioning the heuristic. For example, there was little evidence of the use of effective strategies for actioning the heuristic step of “check” and this in turn hindered the finding of “correct” solutions to problems

7. There was insufficient modelling by the teacher of how the heuristic might be used in an actual problem solving task.
Also group monitoring behaviours to support the use of the heuristic, and which on the surface appeared to be effective, were in effect parried by the group

8. There was a range of prior knowledge and ability within the group. For the higher achieving student Bryce, a pre-existing understanding or naturally occurring framework may explain his higher involvement in discussion, proposal and negotiation. A similar situation may possibly have existed for the students Nick and Amber, however, the low achieving student Kate may not have had any prior understanding of the problem solving process nor held any problem solving frameworks. Kate also appeared to be disadvantaged not only by having little understanding of the heuristic but also by a lack of knowledge of how the steps in the heuristic might be actioned (Wong, 1985; Garner, 1990). However, she was well aware of the status of the discussion and the group activity.

Overall, and within the limitations of this study these findings and conditions, have important implications for teachers and these will be taken up in a later section of this chapter.
Evaluation of the Research Design

Overall the research design was effective in facilitating the study of a group of four students while they engaged in problem solving tasks in a cooperative learning setting. Specifically the collection and analysis of data provided rich evidence of the connection between the cognitive intent of the teacher and the student discussions occurring in the small group.

Use of video and audio records of the activity portions of the lessons permitted verbatim transcriptions of student discussions without any apparent Hawthorne effect resulting. The triangulation of data from the NUD*IST and MAKITAB analyses and the reading of the transcripts, allowed detailed analysis of the nature of connection, the form of small group cooperative learning and the kind and quality of student interactions. The lessons and stimulated recall interviews were conducted in suitable surrounds and with sufficient resources. There were no disturbances or interruptions to the observed lessons and although there were several single student absences these did not seem to adversely affect the study.

A larger sample of curriculum area lessons may have provided a wider variation of outcomes, particularly in regard to the use of the problem solving heuristic. The lessons chosen by the teacher, and more particularly lessons four to seven focussed on the mathematics curriculum area, nevertheless, the study stands firm on these being teacher chosen lessons and more than likely, typical of many
teachers in Western Australian primary schools. The contrast with the open nature of lessons one, two and three with the closed nature of the remaining problem solving lessons provided an insight that may not have been gained had the lessons been pre-chosen and organised by the researchers.

As stated in the assumptions the aim of the study was not revealed to students. This was done so as to avoid the possibility of students providing answers they thought the researcher was looking for. However, it was apparent that students seemed to experience some difficulty answering during the stimulated recall interviews possibly because they did not know why they were being interviewed. An interesting follow-up study could be undertaken without this confidentiality aspect and this is discussed later in this chapter.

A limitation of the study’s findings resulted from the synonym list developed for use in the NUD*IST analysis. Synonyms used in the study to search for student use of the problem solving heuristic, should have exhibited a vocabulary known to be more typical of student use. Further, the synonyms of the heuristic terms should have been balanced in number so that the descriptions of student heuristic talk might have been more accurate. A pilot study of terms and synonyms used by students in relation to solving problems may have improved the specificity of the study’s findings.
**Implications**

The implications and recommendations flowing from this study principally concern the teacher and the teacher's ability to achieve a cognitive intent. Nine conditions have been discussed in chapter five and listed in the conclusions earlier. The implications of these conditions are discussed in terms of teaching, teacher monitoring and modelling, teaching passive students and teacher education.

**Teaching**

The findings of the study imply that teachers must work with students in order to develop effective problem solving skills and in this instance the effective use of a problem solving heuristic. Specifically teachers need to determine what pre-existing heuristics and frameworks are held by students. Such questions as “how do people solve problems?” and “what are the steps involved in solving a problem?” may elicit starting points for student discussions on understanding problem solving heuristics and frameworks. This makes the model part of a negotiated curriculum rather than a framework provided by the teacher in which students should operate.

Where possible teachers should encourage students to develop, adapt or copy heuristic devices and frameworks that are seen by students to aid the problem solving process. Central to this strategy is the notion that student ownership of heuristic devices will promote greater use and cognitive interaction during the problem solving
process if the device is tailored to specific circumstances of student need. It is important that students have the opportunity to integrate their understanding of the heuristic with the problem solving strategies and the problem in context.

Models employed by the teacher should be generated through teacher-student discussion as described above or where diagrammed examples such as the Problem Solving Heuristic (Figure 4) and the Dynamic Problem Solving Heuristic (Figure 9) are used, they should be used having received some form of student warrant. Furthermore the heuristic device should only be seen as part of the problem solving process and should be supplemented with the teaching and learning of problem solving strategies.

To avoid the cognitive overload, but maintain the teacher’s cognitive intent it is suggested that teachers develop problem solving strategies in harmony with the agreed problem solving heuristic. It would seem that effective use of a problem solving heuristic may be improved through student knowledge of strategies that apply to each heuristic step. The strategies students used in lessons four to seven were essentially content oriented. For example, the strategy “draw a diagram” will stimulate the generation of ideas, promote discussion and may be used as a checking strategy but cannot be used in the broader group dynamic processes of participation and management. Not only will students need an understanding of the content
strategies but also the strategies that manage problem solving. Some example strategies are shown in Table 14.

Table 14

Some Problem Solving Strategies grouped by the Problem Solving Heuristic Steps

<table>
<thead>
<tr>
<th>Heuristic step</th>
<th>Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ideas generation</td>
<td>draw a diagram, work backwards, look for patterns,</td>
</tr>
<tr>
<td></td>
<td>try a simpler problem</td>
</tr>
<tr>
<td>Group discussion</td>
<td>asking questions, taking turns, good/bad points,</td>
</tr>
<tr>
<td></td>
<td>listening skills</td>
</tr>
<tr>
<td>Decision making</td>
<td>seek consensus, hand up, add up, good and bad points,</td>
</tr>
<tr>
<td></td>
<td>look for justification</td>
</tr>
<tr>
<td>Recording</td>
<td>write report, build model, develop simulation,</td>
</tr>
<tr>
<td></td>
<td>draw a diagram, take photograph</td>
</tr>
<tr>
<td>Checking</td>
<td>try a simpler problem, draw a diagram, work</td>
</tr>
<tr>
<td></td>
<td>try under other conditions</td>
</tr>
</tbody>
</table>

As strategies are taught to students, the relationship of the strategy to the broader heuristic framework should be made explicit. Teaching strategies within the contextual framework of the problem solving heuristic and using specific content would promote;

- an overview and learning context
- use of the strategy in suitable practice problems and
- higher levels of teaching, monitoring and evaluation of the strategy by the teacher.
It is suggested that a two stage learning process would facilitate this strategy development. In a two stage learning process, stage one would involve the teaching and learning of strategies in a suitable problem context and within the framework of a problem solving heuristic. In stage two these strategies are applied in an environment characterised by reduced teacher intervention and involving broader problem solving situations with less emphasis being placed on the overt use of the heuristic. In essence the majority of the teachers' cognitive intent is undertaken in the first stage of the process, but fully realised in the process overall. This is shown in Figure 10.

![Diagram of a two stage learning process]

Figure 10. A Two Stage Learning Process.

Teacher Monitoring and Modelling

Teachers should also develop an understanding through observation of the variety of discussions that students create. This
understanding impacts upon teacher planning of time for activities, the content of lesson problems, the need for student expertise and experience and the general culture that needs to be created in order to foster rich problem solving discussions. Clearly the open ended problems in this study resulted in significant discussions, sometimes required specialised knowledge and lasted for considerable time.

The majority of the teacher's monitoring and modelling would also be accomplished in the first stage of the learning model described above. In making teacher thinking open and explicit teachers can model for students the thought processes and strategy use associated with solving problems. Teacher-student interactions during the first stage would be far more structured so as to promote effective monitoring of student success in problem solving.

In stage two the teacher would demonstrate awareness of the group dynamics. The teacher needs to monitor the activity of the group in order to stay away from the group when student discussions exhibit on task behaviour or only a minor distraction from the task, and to intervene when the group has reached a stalemate. Had the teacher in this study maintained the Groups of Four (1981) cooperative group rules, intervention would have only occurred when all the students in the group requested him to do so. Failing this, the delicate balance of when to intervene seems dependent on the heavy demands being made on the teacher in monitoring a class of students, on the teacher's prior knowledge of the group and the
careful awareness of the group's success on achieving the task. Failure to recognise an appropriate time to intervene, and careful modelling of the heuristic process, as in lesson three, seems to distract students in the problem solving process and perhaps encourage students to attempt guessing the answer. However, having said this, it must be acknowledged that effective monitoring is a difficult task.

Teacher awareness of the students' ability to action the heuristic steps, in a fast moving, complex classroom, may be developed through the two stage learning process. In stage one the teacher could actively test to see if students can recall suitable strategies aligning with various heuristic steps. In stage two of the process the teacher is able to unobtrusively observe the success students have in actioning the steps of the heuristic with suitable strategies.

Teaching Passive Students

There are also implications in this study for the assumptions made by teachers in respect of quiet students and student passivity (King, 1993). Teacher produced effects associated with quiet students may well encourage student passivity, however there may exist a legitimate role of "listener" in group work. It is clear that students do listen to the contributions of other students and the teacher, yet some students seem to attract a greater proportion of the listening role. The resultant lower achievement levels so often
correlated with passive students were also suggested in this study. Clearly teachers need to manage the group consistency so that one student does not regularly accept a majority of the listening role. Second, teachers need to vary the lesson content to draw on a wide variety of student personal experiences. As shown by Kate's interactions in lesson two, a background knowledge that is appropriate to the lesson content or an absence of intra-group competition, may be areas in which a teacher can influence the group's dynamic, and the involvement of passive students.

Third, as discussed earlier, it may be necessary for teachers to teach and model participation strategies as part of discussion and decision making skills. The culture of the classroom should recognise the listener's responsibility and right to participate in group discussions. Difficulties may arise if the onus for the participation of passive students rests with the passive student.

Teacher Education

The education of teachers should ensure a conceptual approach to problem solving that draws on the history and development of heuristics and problem solving frameworks. Fundamental to this approach is the understanding developed from this study and others, that heuristics and frameworks themselves are derived from observations of natural contexts and effective workers in action. The frameworks do not exist of their own right but are generalisations of
the processes effected by successful students. It is therefore necessary to remind preservice and inservice teachers that it is likely some students will demonstrate both intentional and unintentional use of problem solving frameworks and mandating one framework over another may cause confusion for some students. This would include the various projects of the Western Australian Education Department. Examples such as First Steps (Education Department W.A., 1994) writing scaffolds that include reports, narratives and expositions, teach students to write using the scaffold. However, if teachers neglect to teach each strategy within larger, broader frameworks, a rote learning of strategies and a concomitant loss in understanding of the writing purpose, process and audience may result.

Recommendations for Further Research

Areas of future research suggested by this study focus on student understanding of heuristics, problem solving processes and problem solving strategies. If students are to achieve the cognitive intent set by teachers then it is important that further research concentrate on the beliefs that students hold about solving problems and their use and understanding of the frameworks that support problem solving strategies. This would involve an explicit statement of a study's focus to participating students and in turn would result in more focussed interviews and researcher-subject discussions.
Questions for further research include:

1. What beliefs do students hold regarding the frameworks they have used?
2. What explanations do students provide for the way in which they solve problems?
3. What perceptions do students hold regarding how other students solve problems?
4. What is the nature of student developed problem solving heuristics intended for their own use or for use by others?
5. What do students believe about the transfer of a heuristic for use by another student?
6. If students hold personalised problem solving heuristics, or problem solving frameworks, how does the understanding of the framework develop?

It is evident that this study has explored a number of issues focussing on the cognitive intent of the teacher and the student use of a problem solving heuristic. The questions posed above once again focus on the student as the source of data and should aim to involve the student in open communication and discussion of effective learning relating to heuristic models and frameworks.

Summary of the Chapter

This chapter has discussed conclusions drawn from the study including a review of the outcomes of the study and an evaluation of the research design. The implications for teaching, for teacher modelling and monitoring and the teaching of passive students were discussed followed by the implications for teacher education. Recommendations for further research focussed on the beliefs held by students in regard to heuristics and problem solving frameworks and
the need for future research to develop open communicative styles
with student subjects.
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and Kegan Paul.


Appendices

Appendix A - Stimulated Recall Questionnaire

Stimulated Recall Questionnaire

Student I.D. ___________  Video Tape Number ___

Date ___________  Lesson Number ___

Counter Position _____  Interview Time Start ___

Finish: ___

Questions asked prior to showing of the video clip.

1. What did you learn about today?
2. Can you explain it to me? (i.e. content of question 1.)
3. What did you understand from the teacher's introduction of the lesson today?
4. What things did the teacher do that helped you understand the lesson that you did today?

Questions asked during replay of the video clip.

All questions are asked in relation to an identified sequence on the video clip. Students are asked to simply narrate what they are thinking as the clip is shown. If the student fails to do this voluntarily the researcher asks;

• What were you thinking when this happened? (or ... at this time? or ... here?)
• Why were you thinking that? (or what made you think that?)
• Why were you thinking that? (or what made you think that?)

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Process is repeated as long as probing reveals understanding into the student's thinking. The tape is paused as often as necessary during the replay of the clip in order that the student is given ample time to tell of his/her thinking.
Appendix B - Room Plan

Key
1. Blackboard
2. Teacher's desk
3. Overhead projector
4. Video camera
5. Others group
6. Display bench
7. Audio record

A. Bryce
B. Nick
C. Amber
D. Kate
E. Researcher
Appendix C - Lessons Topics

<table>
<thead>
<tr>
<th>Lesson Number</th>
<th>Lesson Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>How many numbers between 1 and 35 can be written as the sum of consecutive numbers?</td>
</tr>
<tr>
<td>2</td>
<td>Survival in the Desert.</td>
</tr>
<tr>
<td>Day One</td>
<td>On the first day you decide to search for water. Use the diagram on page 4 to work out where you would find drinkable water. Solve the problem with the solar still.</td>
</tr>
<tr>
<td>Day Two</td>
<td>On the second day you decide to cook some of your food to preserve it. You want to keep the rest cool. Use the materials on pages 5 &amp; 6 to work out how to light a fire, how to make a solar cooker and how to keep your food cool.</td>
</tr>
<tr>
<td>Day Three</td>
<td>On day three you try to solve your other main problems; how to say cool during the day and how to stay warm at night. Use the materials on pages 5 &amp; 6 to solve these problems.</td>
</tr>
<tr>
<td>3</td>
<td>The Great Bridge Challenge. The challenge is to design and build a bridge to span between two desks 50cm apart. The challenge includes making the cheapest, strongest and most attractive bridge. The bridge must support 3.0 kg in the centre of its span.</td>
</tr>
<tr>
<td>4</td>
<td>The Farmer's Problem. There are a total of 41 pigs and chickens on a farm. Together, in all, they have 100 legs. How many chickens are there?</td>
</tr>
<tr>
<td>5</td>
<td>Mrs Hannah's Dogs. At present all Mrs Hannah's adult dogs are spaniels while some of her puppies are spaniels and some are not. In all she has 11 dogs of which 7 are spaniels and 8 are puppies. How many spaniel puppies has she?</td>
</tr>
</tbody>
</table>
6 **The Neighbour's Challenge.** The Smith and Jones families, twelve people in all, live next door to each other in Maths Street. Each family has a mother, father and some children. Five of the people are males. The Smiths have no sons. How many boys and girls does each family have?

NOTE: Before you try to solve this problem decide as a group which strategy you will use. When you have done this, tell your teacher.

7 **The River Problem.** Two men and two boys wish to cross a river. Their small canoe will carry only one man or two boys. What is the least number of canoe trips needed to get everyone across the river?
Appendix D - Example Lesson Plan

Learning Objectives

Each student will:

- Cooperate in a group to identify numbers between 1 and 25 that can be written as the sum of consecutive numbers.
- Cooperate in a group to discover a pattern or patterns, in the numbers between 1 and 25 that cannot be written as the sum of consecutive numbers.

Preparation

- arrange desks into clusters of 4
- organise mixed ability groups
- boarded problem
- paper for group work

Method

<table>
<thead>
<tr>
<th>Time Allocation</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 minutes</td>
<td>Introduction</td>
</tr>
<tr>
<td></td>
<td>Assign students to groups</td>
</tr>
<tr>
<td></td>
<td>Introduce problem</td>
</tr>
<tr>
<td></td>
<td>Check for student understanding</td>
</tr>
<tr>
<td></td>
<td>Discuss example of number 9. 9=4+5. 4 and 5 are consecutive numbers. 2+3+4=9. 2, 3, &amp; 4 are consecutive numbers. 3 &amp; 6 are not consecutive even though 3+6=9.</td>
</tr>
<tr>
<td>30 minutes</td>
<td>Activity</td>
</tr>
<tr>
<td></td>
<td>Set students to begin work</td>
</tr>
<tr>
<td></td>
<td>Monitor group activity</td>
</tr>
</tbody>
</table>

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10 minutes

Conclusion
Whole class discussion of results, processes and records made.

Evaluation of objectives, lesson content, lesson processes and outcomes.
Appendix E - Student Profiles

Data gathered from the teacher included brief written profiles of each student obtained prior to the analysis of the data. The profiles are listed by fictional name.

**Kate**

Low academic ability. Particular problems with mathematics. Struggles with problem solving. Very good social skills. Seen as attractive to both genders. Quite pre-occupied with “boy-girl” relationships. Would usually be passive in small group work unless working with friends. Tall athletic, Mauritian/ Australian.

**Amber**

Above average student. Very diligent worker. Meticulous work habits. No apparent social problems; appears mature. Usually quiet in class. Would possibly become passive in group work, though could also become assertive due to task motivation. Works well in friendship groups. Taiwanese/Australian

**Nick**

Bryce