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An investigation in the use of collaborative metacognition during mathematical problem solving.
A case study with a primary five class in Scotland

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Abstract

The main aim of the research reported in this thesis was to investigate the use of collaborative metacognition by learners during primary school mathematical problem solving. Whereas individual metacognition has been researched for many decades, relatively little is known about how metacognition is used during collaborative interaction. Through a review of current research and theoretical understandings, this thesis provides the first clear conceptualisation and operationalisation of the term collaborative metacognition.

Data were gathered in a naturalistic setting in which students worked in groups of four during their normal classroom problem solving sessions. Data were gathered for three groups over three sessions lasting around 90 minutes evenly spaced over 15 weeks. Three data sets were triangulated in order to provide a rich understanding of the use of collaborative metacognition in group problem solving: content analysis of group interactions, teacher focus group data and critical recall interviews with students.

Findings showed that overall, a very small proportion of talk constituted collaborative metacognition. Results from the content analysis tentatively suggested that higher proportions of collaborative metacognition were associated with success in solving the problem. The critical recall interviews provided evidence that simply quantifying levels of collaborative metacognition was insufficient to understand its use. Data analysis using Activity Theory demonstrated that contradictions in rules, mediating artefacts, and division of labour in the student-to-student activity system hindered collaborative metacognition, even when problem solving was successful. Content analysis also showed a tendency for increased collaborative metacognition when the teacher was present, possibly explained by increased teacher-to-student interaction rather than student-to-student interaction. Teacher focus group data indicated two areas which may have contributed to teachers adopting an approach that influenced collaborative metacognition in this way: initial teacher training and subsequent professional development; and classroom and school factors that affected teacher decisions to promote collaborative group work skills.

Synthesis of the findings led to the emergence of a common theme which may help to explain the findings: the allocation of a fixed role of ‘holder of knowledge’ to one member of a group – either by students or the teacher – appears to have a negative impact on student-to-student collaborative metacognition.

Some tentative implications might be drawn from these findings: the novel research approach was effective in providing a rich insight to the use of collaborative metacognition and these results may be used to guide initial teacher training and professional development to incorporate a focus on the impact of group processes on metacognition. Furthermore, current theoretical understanding of the use of individual metacognition may not transfer to a group situation due to the impact of social processes that influence group interaction.

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Author's Declaration

I declare that, except where explicit reference is made to the contribution of others, that this dissertation is the result of my own work and has not been submitted for any other degree at the University of Glasgow or any other institution.

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Chapter One: Introduction

The purpose of this study was to investigate the use of collaborative metacognition by students during problem solving in mathematics. The study addressed three main issues:

1. The conceptualisation and operationalisation of collaborative metacognition for research purposes
2. The relationship between collaborative metacognition and successful problem solving
3. The impact of the teacher on the use of collaborative metacognition

In this introductory chapter, I will firstly provide a background to the study, covering both my own personal interest in the area and moving on to the educational and theoretical justification for the work. I will then introduce the main research questions and provide an overview of the thesis structure.

1.1 My personal interest in educational research

Embarking upon a PhD is not a task to be taken lightly and it is therefore important that any individual considering it should know exactly why they are doing so. It may be argued that one purpose of a PhD is to ask and then answer a research question which will further knowledge in a particular area. If that is the only purpose, then this thesis might fulfil that requirement. However, the extent to which that would have been a positive use of time and resources would be questionable. Within the area of educational research, as I am sure is the case for other disciplines, research for the sake of research is a questionable pursuit. I believe that it is vital, indeed an ethical requirement, to justify any attempt at empirical research within the domain of compulsory education. When a researcher, whether a qualified teacher or not, embarks on a research study which might impact the learning environment of children, it must be absolutely clear that the results should have the potential to be of benefit in some manner, either theoretically or practically. This benefit may not occur during the data collection, or even on completion of the thesis. Nonetheless even if further research is required, I believe there should be a clear path to providing insight which has the potential to be practical and applicable.

The justification for my research study comes both from my own personal experience of my children's schooling and, as will be seen in the next section, from a very well developed and influential area of educational research. Furthermore, the research is particularly relevant to the recent introduction of a Curriculum for Excellence (Scottish Government 2013) in the Scottish Education system where collaboration and mathematical problem solving are promoted.

My personal interest in child development and education arose primarily from my undergraduate degree in Psychology. My interest was fuelled tremendously when my own children began school. I was intrigued with the way in which my children spoke about school. I was particularly interested in the way they spoke about interactions with their peers as well as with their teacher. I was surprised by the influence peers had in the classroom and also by the way in which my children interpreted what the teacher said or did. Similarly, I was surprised at the way the teacher spoke about my children and what the teacher viewed to be important. In particular, social interactions were of paramount importance to my children, whereas academic achievement and cognitive ability were of paramount importance to the teachers. I often wondered, and still do, how it is possible to achieve a specific educational outcome when one half of a relationship (i.e. the teacher) seems to have a completely different focus from the other half (i.e. the pupil).

From watching the educational experiences of my own, and friends' children, I have developed a strong interest in the way in which different goals or focus may impact learning. Learning is not a question of information passing from one person to another. It may be that sometimes, but generally the process of learning is far more complicated. Furthermore we, as individuals, learn in many ways. There have been many theories of learning over the years and it is probably fair to say that all of them are true to some extent yet none of them is able to fully explain the learning processes. We can learn facts by absorbing them from books, television, and other people – including teachers. We can learn processes by being told how to do them, by watching others do them, by reading how to do them by doing them ourselves.

There are some aspects of learning that we prefer to work at on our own and there are other things we like to do in a group. I would imagine if I asked a room full of children or adults what they prefer, they would say 'it depends'. It depends on the task, it depends on the other people involved, it depends on how we are feeling on the day… Our preference to work with others or on our own depends on many issues and therefore the outcome may be affected by these issues.

Similarly if I asked a room full of educational researchers ‘do people learn better on their own or in groups?’ the answer again would probably be ‘it depends’. It depends on the task, it depends on who is in the group, it depends on any number of issues.

I am not compelled to try and ascertain the efficacy of one teaching strategy over another. Rather, taking a pragmatic view, I appreciate that students are sometimes required to work on their own and sometimes they work with others. This, of course, mirrors wider life. There is not often a choice involved and therefore it is important that educators do what they can to ensure that *all* students have positive outcomes from whatever mode of learning they are engaged in.

As previously mentioned, my Psychology degree fuelled an interest in child development and learning. As well as this, it also introduced me to the process of research. I was, and continue to be, fascinated by research design, ethics in research, analysis of research data and the process of making claims from results. This interest, together with my interest in education, led me to apply for a PhD studentship at the University of Glasgow. One condition of the studentship was that the research was to be placed within the area of mathematics education and so it is within this area that my research is positioned.

Although my initial interest in education was developed through personal experience of my children, there is also a strong educational justification for studying the interactive processes used by students during learning, as well as issues which may impact this. This justification is provided in the next section.

1.2 Educational justification for my study

Mathematics is an important part of the school curriculum as well as being important in every day life. This importance is recognised in the recent introduction of A Curriculum for Excellence in the Scottish education system:

> *“Mathematics equips us with the skills we need to interpret and analyse information, simplify and solve problems, assess risk and make informed decisions”*
>
> (Scottish Government [accessed 2013]).

Curriculum for Excellence puts three areas at its core – numeracy, literacy and health and wellbeing. This is not to say that other subject areas are less important, rather, these three areas are seen as essential building blocks in preparing all children to participate fully in society. These three subject areas now permeate every aspect of the school curriculum. No longer will they be 'boxed' into their own teaching time and kept separate from other subjects (Scottish Government, 2009).

Within a Curriculum for Excellence, numeracy skills are designed to allow individuals to *"fully participate in society"*. Such skills include financial awareness, effective money management, the ability to assess risk and make informed decisions, the ability to apply skills and understanding creatively and logically to solve problems within a variety of contexts (Education Scotland, accessed March 2013).

Experiences and outcomes within the curriculum highlight very clearly, and at a very early stage in educational experiences, the importance of being able to communicate ideas effectively with others. This is seen in the following excerpts from the *estimation and rounding* early stage experiences and outcomes and the fourth stage *measurement* experiences and outcomes:

> *I am developing a sense of size and amount by observing, exploring, using and communicating with others about things in the world around me.*
>
> *(MNU 0-01a,*Education Scotland accessed March 2013 *)*

> *I have explored with others the practicalities of the use of 3D objects in everyday life and can solve problems involving the volume of a prism, using a formula to make related calculations when required.*
>
> *(* MTH 4-11c, Education Scotland accessed March 2013)

Clearly, the ability to interact effectively with others, sharing ideas and thoughts, is viewed as an important aspect of learning mathematics. Furthermore, the Scottish Qualifications Authority (SQA) has developed a framework proposing five core skills which are required to promote success in learning and life. These skills are communication; information communication technology; problem solving; working with others and numeracy skills (SQA accessed March 2013).

The ability to work and communicate effectively is therefore viewed as an important aspect of learning mathematics specifically, but these skills are also important for life in general. Being able to work in a group is not only about being able to get along with others. This of course helps, but it is not a requirement that individuals must be best of friends in order to work effectively. *Cooperative* working skills are clearly important. If we are to ask students to work together, they should be aware of the impact of their actions and interactions on others. Such skills might be taught under the term ‘social skills’.

However, there is another set of skills which, I believe, is important in group learning and which has perhaps been given less importance in the classroom. That is the type of talk which is likely to draw other members of a team *into* the discussion. It is the type of talk which highlights that students are listening to one another and thinking about what is being said – and more importantly – reacting to that.

Such abilities are not developed from learning formulae and applying them to specific types of problems. Rather, they require an understanding of the issues specific to the task in hand, as well as an understanding of the tools and information available to help with the task. Such is the nature of society that tasks and problems encountered within the school environment will have changed by the time students have been out of full time education for only a few years. It is the ability to respond to these changes and create new ways of dealing with problems which are the crucial skills which a Curriculum for Excellence was designed to promote.

Such skills may be termed ‘thinking skills’ or ‘problem solving skills’ and require the student to think about the problem and how they might solve it. Some researchers have proposed problem solving strategies within the area of mathematics education (e.g. Polya 1945, Schoenfeld, 1985). However, these skills only go part of the way to helping students understand and solve problems. Whilst having a list of strategies to solve a particular problem is helpful, it is also crucial that students are able to understand their own thinking processes. For example, whilst encountering a mathematical word problem, the student must be able to read and understand what the problem is about before attempting a solution. This requires them to think about their own understanding of terms contained within the problem. They must then think about how they would solve it and what type of resources they may have and may need. These are not only physical resources but cognitive resources also. It is such skills that many educators report are lacking in students and which need to be given a higher profile. Therefore students need to develop the ability to think about their own thinking. This ability has been termed ‘metacognition’ (Flavell 1979).

Many researchers separate metacognition into *knowledge of cognition* and *regulation of cognition* (e.g. Schraw 1998). Knowledge of cognition refers to *what* a student knows, be that declarative knowledge, procedural knowledge or condition knowledge. Regulation of cognition refers to the ability to use knowledge in an appropriate manner towards a goal. This might include the ability to plan, monitor and evaluate progress.

Research in the area of metacognition and problem solving suggests that higher levels of metacognition are a factor in effective problem solving (Artz & Armour-Thomas 1999). Furthermore, interventions, where students are ‘taught’ metacognitive skills, improve learning outcomes (e.g. Mevarech & Kramarski 2003, Kramarski 2004).

The area of metacognition therefore shows promise in developing an understanding of how students solve problems. However, as previously mentioned, I am interested in the way in which students *interact* when problem solving. As well as promoting the area of numeracy throughout the curriculum, a Curriculum for Excellence also promotes the use of collaborative learning as a pedagogy through which to enhance mathematical learning (Scottish Government 2009). Research evidence suggests that when children work collaboratively in the school setting there are benefits both in terms of educational achievement and in social development. This benefit may be produced by a number of factors. Firstly, when children work in groups it gives them the opportunity to discuss beliefs and understandings explicitly with their peers. It requires children to be aware of their beliefs and ideas, and be able to defend them. This process of being aware of beliefs is akin to the thinking skills referred to in ‘metacognition’ (Flavell 1979). Secondly, it allows them to experience the thoughts and understandings of others. This provides a greater level of information to become available to learners in pursuit of their learning goal. A final positive aspect of collaborative working is that motivation to learn is often increased (Schraw, Crippen & Hartley, 2006).

Collaborative learning may therefore be a powerful pedagogy in raising motivation, providing an arena for metacognitive development and increasing achievement outcomes. However, not all collaborative learning is equal. When children are merely placed in groups, the quality of learning is not necessarily improved, nor is the level of metacognitive interaction. It is these very processes, the use of metacognition during collaborative problem solving that will be addressed in this thesis.

Much of the research in metacognition has been based within the tradition of cognitive and developmental psychology such as Piaget's stage theory of cognitive development (Inhelder & Piaget 1958). However, more recently, researchers in metacognition have adopted a socio-cultural view to understanding the development and use of metacognition (e.g. Larkin 2009, Schraw 1998). A socio-cultural view suggests that learning occurs through the process of social interaction. When children work with their peers to solve a problem, metacognitive awareness may be enhanced through the need for children to explain their reasoning to their peers, or critique a suggestion made by a peer (e.g. Schraw et al 2006).

However, research concerning metacognition and group work within mathematics, with the exception of a few studies, has tended to measure individual learning outcomes, rather than focus on the way in which the collaborative learning environment may mediate, or otherwise, the use of metacognition. Since metacognition is vital to the problem solving process, it is important to understand the use of metacognition in social situations.

Studies which have focussed on metacognition during group work suggest that those students who show more advanced patterns of metacognitive processes have greater involvement in discussions and subsequent solutions (Hurme, Palonen & Jarvela 2006). Furthermore, during group work students can act as regulators of one another's cognition. They do this by questioning one another's thinking and ideas and choosing appropriate strategies for success (Goos, Galbraith & Renshaw 2002).

Although research suggests that group work may act as a platform to mediate the use of metacognition during problem solving, findings suggest there are often very low levels of metacognition present during group work (e.g. Larkin 2009). This paradoxical finding suggests that there may be other issues present during group work which may impact on the levels of metacognition recorded.

The pattern of research in recent years in the area of metacognition has been to produce interventions aimed at improving achievement. However, there is a scarcity of research which considers these previously mentioned issues – beyond development ones – which may impact the use of metacognition by students. It is only natural that researchers should want to address issues which may *improve* learning, rather than potential barriers to learning. It is perhaps easier to promote improvements within the educational sector through the development of interventions, rather than point out what might be wrong.

However, it is vital that when interventions or guidelines are produced for use by teachers, it is made clear to them in what circumstances such interventions have been shown to be effective. For example, if a teacher spent many months developing individual metacognitive ability through the use of metacognitive questioning, it cannot be assumed that these new skills which students have developed will be transferred automatically to a group situation. This is due to the complex social interactions which occur during group work. I believe that it is vital for researchers who aim to improve learning to acknowledge the role of the *micro* world of the individual and all the complexities therein.

School learning occurs in a social environment and social environments are complex. Students and teachers bring something different of themselves into the classroom each day. They may bring the happiness from the birthday presents they opened that morning. They may bring the worry that a parent is a member of the armed forces and working in a dangerous situation. They may bring the joy and excitement of the rehearsal for their school show. They may bring worry that most of the other children in the class don't treat them well.

Even these issues in themselves represent a *macro* level of issues which are constantly with them throughout the day. When students are asked to work collaboratively on a problem, the *micro* level of issues which occur solely out of that situation come to the fore. It is precisely these issues which this thesis will address. Furthermore, when the teacher is present during the group work, students may change the way in which they interact. The presence of the teacher often brings *authority* and *expected behaviour patterns* not seen when students work on their own.

If a research study requires that students are removed from their familiar classroom surrounding to engage in a research project concerning their learning, the role of the teacher may be overlooked. However, the teacher plays an important and very complex role within the classroom. As well as being seen as an authoritative figure, the teacher is also a mentor, carer and to a certain extent friend.

It is crucial, therefore, in any quest to study the interactions of students during the learning process that they are, as far as possible, kept within their normal environment. Similarly, when attempting to understand the situation, information must be sought from the various sources which may impact the learning process.

1.3 Aims of the research

The aims of this research are as follows:

1 To attempt to define collaborative metacognition as something distinct from individual metacognition during collaborative problem solving.
2 To try to ascertain if it is possible to isolate instances of collaborative metacognition during problem solving in larger groups
3 To try to understand the types and distribution of utterances during collaborative problem solving.
4 To develop an understanding of the use of collaborative metacognition during problem solving.
5 To investigate the relationship between collaborative metacognition and successful problem solving.
6 To investigate the relationship between collaborative metacognition and the presence of the teacher.
7 To identify some potential barriers which may influence the use of collaborative metacognition.

1.4 Research questions

In order to investigate these aims I will address the following research questions:

1. How can collaborative metacognition be conceptualised and operationalised in a way that is both conceptually rigorous and empirically tractable?
2. To what extent do students use collaborative metacognition during problem solving?
3. What proportions of talk that could be categorised as collaborative metacognition are displayed during successful versus unsuccessful problem solving?
4. What proportions of talk that could be categorised as collaborative metacognition

are displayed when the teacher is present compared to not present?

5. What explanations exist for the patterns of collaborative metacognition displayed during problem solving sessions?

In order to address these research questions, I firstly conducted a literature review in order to ascertain if there was a suitable conceptualisation and operationalisation of the term collaborative metacognition. Having concluded that there was not, I proposed a conceptualisation, and then operationalised it. Whereas individual metacognition is a property of one statement made by an individual, collaborative metacognition is a characteristic of a chain of length two. In other words, collaborative metacognition is only identifiable between two statements. In order to ascertain the usefulness of this concept, I conducted statistical analysis to ascertain if there was a relationship between talk which could be classified as collaborative in nature and talk which could be classified as metacognitive in nature, according to my coding scheme. The chi square test for association showed that a higher proportion of metacognitive statements occurred following a collaborative statement compared to a non-collaborative statement. Also, a higher proportion of collaborative statements occurred following a metacognitive statement compared to other statement types. These differences were statistically significant. The data for the study were gathered through the use of a case study at a primary school in Scotland.

Students were filmed working in groups during their regular problem solving sessions. Their verbal interactions were used to highlight instances of collaborative metacognition. I conducted critical event recall interviews with the students in order to highlight issues which might have impacted their use of collaborative metacognition. I also conducted a teacher focus group in order to understand the historical perspective of collaborative problem solving during mathematics.

1.5 Outline of the thesis

Before I provide an outline of the structure of the thesis, I would like to make clear the nature of the research contained therein. The research contained in this thesis was investigatory and no hypotheses were tested. Part of the process of the research was the conceptualisation and operationalisation of the concept *collaborative metacognition*. I therefore view the research and findings contained within this thesis as an illuminative phase of a larger research project. During an illuminative phase of a project, concepts and methods might be developed and used in order to ascertain their efficacy and also to illuminate potential issues, both methodological and with interpretation of findings, which might be addressed in later stages of the research project.

A strength of an investigative approach is that hypotheses are not be proposed prior to the commencement of the research and the findings emerge from the data. However, this in turn results in claims which are primarily supported by confirmatory evidence. The method of analysis which I chose resulted in particular patterns being highlighted. These patterns were confirmed from a number of data sources within the research design. However, importantly, I did not seek out specific evidence in support of my claims as the claims themselves were developed inductively from the evidence.

The result of this approach was that disconfirmatory analysis was not conducted since the data collection phase of the study was completed prior to patterns emerging during the analysis. I did not therefore look for cases or evidence which disconfirmed my interpretation of findings. This is addressed in the future research section of chapter nine.

The thesis will be outlined as follows. I will address the concept of metacognition in chapter two. This literature review will cover the history of the term, together with application and research findings. I will highlight gaps in the current literature and position this research within specific gaps. The next chapter will address the first research question and provide an account of the study I conducted in order to produce a definition of collaborative metacognition. Following from this I will provide an account of the methodologies which have informed my approach to the research. I will then go on to the methods section, giving in-depth details regarding the study and data collection and analysis. There are three findings chapters combining both quantitative and qualitative analyses. The first one is concerned with the proportions of collaborative metacognition displayed during the problem solving sessions and compares successful versus unsuccessful sessions. This chapter provides a quantitative analysis of the proportions of talk displayed by students. The following chapter provides a qualitative account of students' critical event recall interviews. It is this chapter which aids the interpretation of the previous quantitative chapter. Following on from this I will then provide an analysis of the data which concerns the presence of the teacher. I will provide a comparison of the use of collaborative metacognition when the teacher was present compared to when she was not present. Again, in order to provide a more meaningful interpretation of these data, I will present qualitative findings from the teacher focus groups. The qualitative sections will focus on *issues* which might impact the use of collaborative metacognition. I will then move to a general discussion of the findings, drawing the data together to provide an understanding of the use of collaborative metacognition during problem solving. Finally, the conclusion and future plans for research will be presented.

Chapter Two: Review of the Literature

2.1 Introduction

The purpose of this chapter is to give an account of the theoretical notion of metacognition, including precursors to metacognition in the literature. It will then go on to provide empirical evidence for metacognition in learning. The development of metacognition will then be discussed followed by a critical analysis of research issues within the research domain.

When students are presented with a problem during a mathematics lesson there are a number of processes which have to be completed before the problem can be solved. Firstly, they must be able to read the problem and decipher what it is asking them to do. They must then decide if they have the knowledge and ability to complete the problem. If they do, they must implement any procedures they deem appropriate, whilst at the same time being aware of their goal in order to monitor whether or not they are getting closer to it. Once they believe they have a solution, they must check this against their original problem statement to ascertain if it does indeed answer the problem. In other words, students need to read, analyse, plan, execute, monitor progress and finally decide if their answer is correct (e.g. Metes, Pilot & Rossini 1981, Davidson & Sternberg 1998). Whilst this undoubtedly requires cognitive ability, it also requires *metacognition*. Metacognition is a term first used by Flavell (1979) in his studies on the memorial abilities of children. He used it to refer to an individual's knowledge of their own cognitions and also their ability to monitor those cognitions. Flavell, Friedrichs & Hoyt 1970 had found that when children were asked to predict their ability to recall a list of items, older children were more accurate in their predictions. Flavell et al (1970) concluded that this was because they were more aware of their cognitive abilities than younger children.

Metacognition has been researched in the areas of developmental and cognitive psychology. More recently its popularity in educational research has seen a plethora of papers published on the subject. Some researchers believe that metacognition is associated with intelligence (Borkowski, Carr, & Presley, 1987) and refer to it as a *higher order thinking skill*. A simple definition of metacognition is *thinking about thinking* or *cognition of cognition* (Flavell, 1979; Brown, 1987).

However a simple definition of metacognition is difficult to produce. Researchers have yet to reach a consensus regarding what the term actually refers to with many variations found within the literature. For example, some researchers have used alternative terms to describe metacognition (e.g. self-regulation, Pieshl, Stahl, & Bromme, 2008; Sperling, Howard, Stanley, & Dubois, 2004), or a feature of that metacognition (e.g. meta-memory, Kuhn, 2000) which adds to the confusion. Despite this, there is evidence in support of the concept of metacognition as well as its role in effective learning.

2.2 Precursors to metacognition

Hacker (1998) notes that the apparently simple assertion that memory and learning are inextricably linked has fuelled research within the domain of psychology for decades. This research has utilised different paradigms and theoretical frameworks (e.g. Nelson & Narens 1994). Hacker (1998) suggests that despite the plethora of research articles produced over many years, by the 1970s progress towards understanding memory seemed slow and disjointed. In reply to the apparent lack of progress, Tulving and Madigan (1970) suggested that one area of study which may be fruitful in understanding memory processes would be the study of "*one of the truly unique characteristics of human memory: its knowledge of its own knowledge*". (p477). One of the earliest theorists and empirical researchers of this knowledge of memory was Flavell (1979) who studied the memorial abilities of children. However, prior to his work, cognitive psychologists had already identified various manifestations of metacognition. Furthermore, concepts akin to metacognition can be seen in the writings of learning theorists such as Piaget and Vygotsky.

Indeed, Flavell's work in metacognition was firmly grounded in Piaget's stage theory of cognitive development, specifically, Inhelder and Piaget's (1958) formal operational stage of cognitive development (Hacker 1998, Shaughnessey 2008). Piaget proposed a stage theory of cognitive development whereby children developed skills and abilities at specific ages. Although there were many stages of development, it was during the formal operational stage that Piaget proposed an ability which is akin to metacognition (Fox & Riconscente 2008) might develop. Piaget proposed that during the formal operational stage children would progress from a concrete understanding of the world to being able to think in abstract terms. They would be able to form and test hypotheses and think of hypothetical outcomes in problem situations (Smith, Cowie & Blades 2003).

Piaget suggested that in order that children might develop an understanding of themselves and others they had to develop "*a consciousness of oneself as a subject, and the ability to* *detach subject from object*" and "*to cease to look upon one's own point of view as the only possible one and to coordinate it with that of others*" (Piaget 1959, p277). This would allow children to become independent of those around them and begin to realise that they, and those around them, were capable of their own thoughts. Beyond this, at the formal operational stage, Piaget suggested that the specific requirements of attaining this included the child being able to

> *"mentally execute possible actions on [objects] and reflect on these operations in the absence of the objects which are replaced by pure propositions. Concrete thinking is the representations of a possible actions and formal thinking is the representation of a representation of a possible action"*
>
> (Piaget 1964, -1968 p 63).

In others words, to enter the formal operational stage, a child would have to develop the ability to think about their own thoughts.

Lev Vygotsky was another theorist whose work showed a clear reference to a concept akin to that of metacognition. Vygotsky's (1986) sociocultural theory was developed through his concern with the development of language in relation to thought. Vygotsky proposed that language and thought had separate ontologies. Only through social interaction could the two develop in a way which produced interaction between them. Vygotsky suggested that the psychological tools required for learning were acquired and then used through social interactions. Language is Vygotsky's prime example. The predisposition of humans to be able to use language to communicate he termed a 'natural function', so too was the predisposition for internal thought and reflection. However, it is only through social interaction that these two functions may interact to produce 'higher order functions' such as speech, or language and thought. Children internalise psychological tools such as language and gestures and then use them to develop 'higher order' skills such as problem-solving. These internalised tools are then used creatively in order to achieve goals.

Vygotsky drew the distinction between spontaneous concept development and scientific concept development. He argued that the former concepts were developed through everyday life and experience whilst the latter through formal schooling. According to Vygotsky, scientific concepts were abstract and systematised in nature – they belong to other concepts and generalisations. These concepts would be learned as 'abstract' generalisations and children would then learn to bring them to 'concrete' level in order to understand and take control over them. Vygotsky noted that "*the conscious use of concepts simultaneously implies that concepts can be controlled voluntarily*" (Vygostky, 1986 p174). This bears close resemblance to the idea of metacognitive knowledge and regulation where children are aware both of their knowledge and when it should be applied. Vygotsky viewed these two abilities as intertwined, rather than separate entities – to know you know something implies you have control over it. According to Vygotsky, when a child is able to understand a concept they are also able to articulate this: "*consciousness denotes awareness of the activity of mind*" p170.

The idea of metacognition therefore was present in the learning theories of Vygotsky and Piaget. However, it was in the field of cognitive psychology that empirical evidence was sought for a definition and components of metacognition, through the study of cognitive monitoring and cognitive regulation. *Cognitive monitoring* occurs when an individual is able to explicitly access their cognitions. *Cognitive regulation* occurs when an individual is able to use that knowledge of their own cognition in a relevant manner in a specific situation (Hacker 1998).

2.2.1 Cognitive Monitoring

Research in the area of cognitive monitoring has considered individuals' knowledge of their own thought processes, as well as their ability to monitor them (Kluwe 1982; Schoenfield 1987). In order to show that individuals do have explicit awareness of their cognitive processes, cognitive researchers have used a number of metacognitive phenomena. Such phenomena include tip-of-the-tongue experiences; feeling-of-knowing judgements; serial recall; allocation of study effort; seen judgements; judgements of learning and ease-of-learning (Hacker 1998).

Research which considered the 'tip of the tongue' phenomenon has provided evidence that individuals have an awareness of their own knowledge. First examined experimentally by Brown and McNeill (1966), tip-of-the-tongue occurs when an individual tries unsuccessfully to recall a piece of declarative knowledge. Brown and McNeill presented participants with a dictionary definition of a relatively rare word and asked them to recall the word. They found that participants would typically report that the word was on 'the tip of their tongue'. The individual was aware that they knew the word, yet was unable to recall it.

The ‘feeling of knowing’ phenomenon differs slightly in that the participant does not have such a strong awareness of the answer to the question, yet they do feel that they would recognise it if they were shown. Hart (1965) asked individuals questions such as “who was Richard Nixon’s vice president before Gerald Ford?”. For the questions that participants answered incorrectly they were asked to judge the likelihood of them being able to choose the correct answer in a recognition test. Effectively, individuals were being asked to judge how well they could monitor their declarative knowledge.

Research in the area of cognitive monitoring has provided evidence that individuals, even at a young age (e.g. Larkin 2006), are able to monitor their own cognition and provide some level of feedback regarding their own cognitions.

2.2.3 Regulation of Cognitive Processes

Kluwe (1982) described the study of cognitive regulation as the study of “*regulation of one’s own thinking processes in order to cope with changing situational demands*” (p210). Experimental research in this area has been concerned with ascertaining the extent to which participants are able to transfer strategies for solving problems. Lodico, Ghatala, Levin, Pressley and Bell (1983) taught children strategies for solving problems and then presented them with a structurally similar problem to ascertain if they would be able to transfer the strategies. Lodico et al (1983) found that those participants who received training on the efficacy of strategy monitoring were more likely to transfer the strategy to the new problem. Furthermore, they were more likely to assign their success to their ability to successfully choose the most efficient strategy.

The concept and components of metacognition have therefore been present within the literature for many years prior to the term first being used. However, it was Flavell who proposed the first formal model of the concept. Other researchers have followed to provide alternative models as well as alternative conceptualisations. However, those proposed by Flavell (1979) and Brown (1987, although developed by Schraw, 1998) occur most frequently in the literature. These will be examined in the next section.

2.3 Flavell’s Model of Metacognition

Flavell’s seminal work on metacognition provided a definition of the concept through a study which considered children’s perceptions of the functioning of their own memory.

Flavell, Friedrichs and Hoyt (1970) asked children of different ages to learn a set of items until they were confident that they could recall them. They found that older children were more accurate in their confidence ratings than were the younger children. This led to speculation that younger children were not as aware of their own cognitive functioning as were older children and also were not able to monitor this functioning well. In other words they did not yet realise that learning a long list of words would place demands on their memory and they were also unaware of useful strategies that may assist them (e.g. mnemonics). Flavell named this knowledge of cognition *metacognition* and suggested that this knowledge was necessary for the process of monitoring cognitive activity.

The model proposed by Flavell (see figure 2-1) focussed on the process of cognitive monitoring which he suggested occurs through an interaction of metacognitive knowledge, metacognitive experiences, goals and actions.

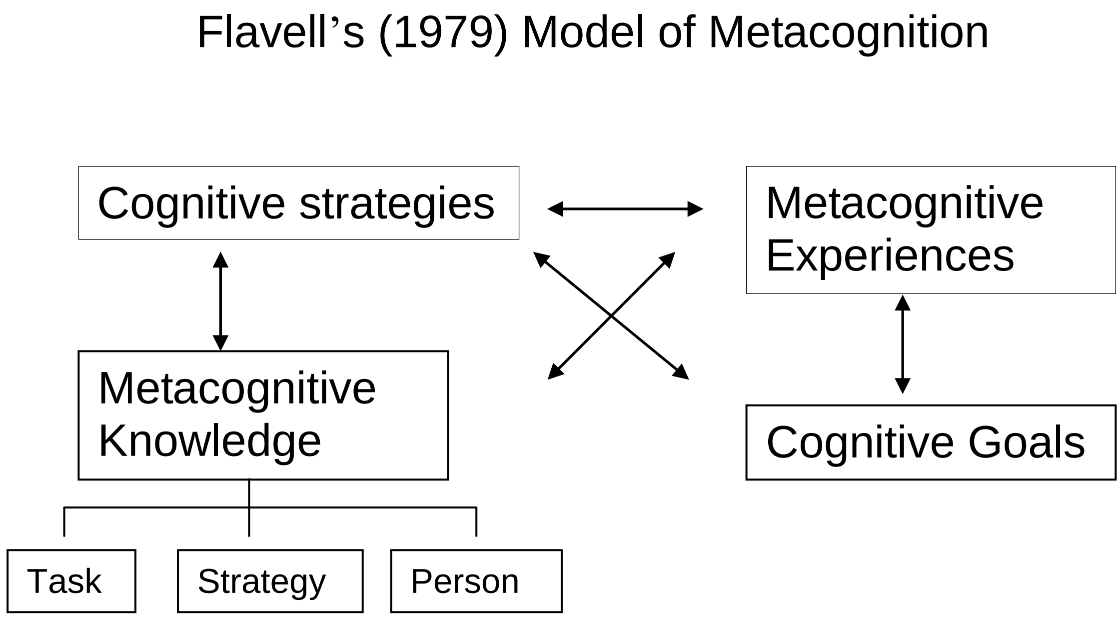


Figure 2- 1 Flavell's (1979) Model of Metacognition (redrawn)

Metacognitive knowledge is knowledge or beliefs an individual holds regarding the way in which specific variables might interact to affect the outcome of a situation. This was further sub-divided into person, task and strategy categories. The *person* category included an individual's beliefs regarding the nature of their and others' cognitive processing. The *task* category included information available in the course of encountering a specific problem. This information may be incomplete or inaccurate and Flavell suggested that it is the ability to recognise that information is incomplete which is crucial. The *strategies* category included the specific actions or strategies that are available in order to achieve the goal (e.g. mnemonics). Flavell suggested that all of these elements of metacognitive knowledge can be activated implicitly or explicitly.

The second component in Flavell's model, *metacognitive experiences*, was described as '*items of metacognitive knowledge that have entered consciousness*' (Flavell 1979 p908). For example, during the problem solving process an individual may suddenly remember a previous problem which was similar. This type of experience suggests an awareness of cognition as well as control of that cognition. Such experiences may impact on metacognitive knowledge, goals and actions. For example, if an individual thinks they are struggling with a problem, this may prompt them to change strategy or ask for help. The goal itself may change at this point. This in turn may require the activation of specific metacognitive knowledge and lead to the implementation of different tasks. Thus, there is a constant interaction between metacognitive knowledge, metacognitive experiences, goals and strategies.

Flavell proposed a definition of metacognition as follows:

> "*Metacognition refers to one's knowledge concerning one's own cognitive processes and products or anything related to them, e.g. the learning-relevant properties of information and data"* and
>
> "*Metacognition refers among other things, to the active monitoring and consequent regulation and orchestration of these processes in relation to the cognitive objects or data on which they bear, usually in the service of some concrete goal or objective*" (1976 p232)

Perhaps the most salient point of Flavell's model is the distinction between declarative knowledge of cognition one the one hand and the ability to use this knowledge appropriately, on the other.

2.4 Brown's Model of Metacognition

Brown (1987) provides the main alternative model to Flavell's in the literature. In her model, which was produced to be used specifically with reference to the educational environment, Brown (1987) proposed that metacognition comprised of two interacting components: knowledge of cognition and regulation of cognition. This is similar to the distinction made by Flavell. Brown proposed that:

> "*metacognition refers to understanding of knowledge, and understanding that can be reflected in either effective use or overt description of the knowledge in question"* (1987 p65).

Brown's model has been developed by other researchers (e.g. Jacobs & Paris 1987, Schraw 1998, Schraw & Moshman 1995). These developments have been introduced on the basis of research in educational environments as opposed to the laboratory settings used by Flavell (1970). The model of metacognition, developed from Brown's model, proposed by Schraw (1998) is shown in figure 2-2.

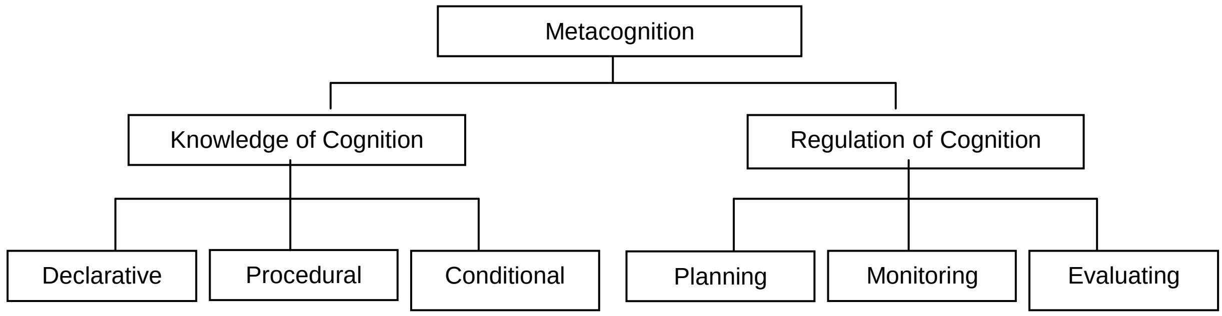


Figure 2- 2 Schraw's Model of Metacognition (redrawn)

According to Schraw, the subcomponents of knowledge of cognition are declarative knowledge, conditional knowledge and procedural knowledge. *Declarative* knowledge is knowledge that individuals hold regarding factors which may affect their performance or in other words, knowing *that*. Research in the area of reading comprehension has shown that successful learners have more declarative knowledge regarding strategies which will help them learn. Such strategies include knowing that re-reading text will aid their understanding; skimming text and finding key words will help locate the text in a specific domain and knowing when they are unable to answer a question they can locate the answer within their text (Garner 1990).

Procedural knowledge includes information regarding the way in which information or procedures should be applied in a given situation, or knowing *how* to do something. In a series of three interview studies Pressley, Van Etten, Yokoi, Freebern and Van Meter (1998) found that students with extensive procedural knowledge were more likely to use a large number of strategies and to vary these strategies appropriately with the demands of the task.

Conditional knowledge is knowledge regarding when a cognitive action is appropriate, or knowing *when* and *why* to use declarative and procedural knowledge (Brown 1987, Schraw 1998). For example in Pressley et al's (1998) study, effective students were able to determine when it was necessary to re-read lecture notes; they knew when it was appropriate to ask questions regarding material and they knew how to relate new learning to prior learning. This type of knowledge allows students to allocate their time and resources efficiently (Reynolds 1992).

Regulation of cognition refers to an individual's ability to control their learning. Three components of regulation of cognition which are encountered in all models of metacognition are planning, monitoring and evaluation (Schraw 1998). *Planning* includes the selection of an appropriate strategy and allocation of cognitive resources to carry out the task. *Monitoring* refers to an individual's on-going awareness of their progress towards a goal. *Evaluating* refers to the ability to make a realistic appraisal of the outcome of the learning experience. Brown (1987) made a critical distinction between knowledge of cognition and regulation of cognition. Whilst knowledge of cognition is consciously accessible, the processes involved in regulation of cognition are not necessarily. Brown writes "*knowing how to do something does not necessarily mean that the activities can be brought to the level of conscious awareness and reported on to others"* (1987 p68). Perhaps this inability of an individual to be fully conscious of their regulatory activities has in some way contributed to contradictory findings in the empirical literature which will be discussed later.

Unlike Flavell's model which was rooted within the area of cognitive psychology and memory, Brown's model, and subsequent developments, have been rooted within education and learning. However, both these models suggest conceptualisations of metacognition. Furthermore, they propose the usefulness of the concept in effective learning.

However, other researchers have chosen to use the concept of metacognition as a subcomponent in models of learning in order to explain its precise role.

2.5 Metacognition and learning

2.5.1 Metacognition as part of developing expertise

According to Sternberg (1998) metacognition is crucial to success within any learning environment due to its role in the development of expertise. Sternberg asserts that research evidence, employing many different methodologies and in many domains, suggests that metacognition converges with other attributes that have been linked to the abilities necessary for school success within "*a construct of developing expertise*" (p132). According to Sternberg, expertise is not an end-state in learning which is identifiable through a set amount of knowledge having being obtained. Rather it is a point on a continuum of development in a domain. The learning which occurs in the classroom is therefore part of this continuum. The passing of an exam does not constitute an end-state of expertise in a domain, although it may constitute being an expert at passing exams (Sternberg 1998).

Sternberg (1998) highlights certain characteristics as being contributory factors for an individual to achieve a level of expertise in a domain. He suggests that individuals must possess the motivation to do well; they must also display a positive affect which will allow them to deal with stressful situations. A third characteristic proposed by Sternberg is that of *metacognitive abilities*. In the development of expertise, he suggests, it is important to be aware of metacognitive strategies available in a given situation. Metacognitive skills such as time management, awareness of difficulties of a problem and monitoring are also important (Sternberg 1998).

Sternberg (1998) asserts that motivation is an important factor in the acquisition of metacognitive awareness. He suggests that if a child is motivated only to the extent of passing a test, then they may attend only to the information necessary to achieve this. Conversely a child who is motivated to understand may pay more attention to the underlying reasons for applying a specific procedure. They may look for similarities and differences between problems. A child who is efficient and motivated in their metacognitive knowledge may be said to show qualitative differences (in terms of the types of strategies) and quantitative differences (in terms of the number of strategies) in their control of metacognitive strategies. According to Sternberg (1998), possessing strategies to solve problems is not enough. Rather an individual must also possess the metacognitive awareness of which strategies may be useful and why.

Motivation may also be linked to epistemological beliefs regarding knowledge. Children may acquire an understanding of knowledge as 'factual, fixed data' which is transmitted from teacher to pupil. Rather, Sternberg (1998) suggests, they should understand knowledge as being fluid and constantly developing. He argues that when learners view knowledge in a static way they are less likely to accept the extra 'thinking' which is required in metacognitive strategies.

According to Sternberg's developing expertise theory, metacognition is one component required to reach a level of expertise in a specific domain. Other factors include motivation and affective components. Motivation can affect the development of metacognitive skills and awareness. When a learner is motivated to understand a topic rather than merely pass an exam, they are more likely to develop domain-specific metacognitive awareness.

2.5.2 Metacognition as part of self-regulated learning and self-efficacy

Similar characteristics can be seen in Schraw et al's (2006) account of metacognition and learning. In adopting a social-cognitive perspective to learning they consider metacognition as a sub-component of *self-regulated learning* (e.g. Zimmerman 1990). Self-regulated learning theory stems from Albert Bandura's social learning theory which posits that learning occurs through the interaction of personal, environmental and behavioural factors. A self-regulated learner is one who is able to "understand and control their learning environment" (Schraw et al 2006 p111).

Self-regulation is affected by three components: cognition, metacognition and motivation. The *cognition* element refers to the cognitive abilities that a learner may employ in the learning task. These are simple strategies, problem solving and critical thinking. *Metacognition* refers to Flavell's (1979) original conception of knowledge of cognition and regulation of cognition. However, Schraw et al (2006) further distinguish between the elements of 'knowledge of cognition' into declarative, procedural and conditional knowledge, which were referred to earlier. These three areas constitute metacognitive activity such as a learner being aware of their working memory capacity, or being able to use mnemonics to aid learning. The motivation element of the theory concerns a learner's self-efficacy and epistemological beliefs. Self-efficacy is the degree to which an individual believes he or she is able to achieve a specific task (Bandura 1977).

Bandura (1977) proposed four sources of efficacy information which might impact self-efficacy: performance accomplishments; vicarious experience; verbal persuasion; and emotional arousal. *Performance accomplishments* refers to experiences during tasks. Repeated failure of tasks may contribute to low self-efficacy, whereas repeated success should contribute to higher self-efficacy. Furthermore, Bandura (1977) asserts that repeated success might act as a barrier to the impact of occasional failure. *Vicarious experience* refers to the experiences of seeing others succeed through difficult situations or experiences. *Verbal persuasion* refers to the persuasion of others that an individual might succeed at a task, despite previous failure. *Emotional arousal* refers to the physiological state which may occur during tasks such as stress, and which may affect an individual's perception of their capabilities.

Therefore, according to Bandura (1977), when an individual is repeatedly successful in a task, experiences the success of others, is exposed to encouragement from others who assert a belief in their ability, and possesses a non-anxious affect, self-efficacy will increase.

Bandura(1977) notes that self-efficacy is not a fixed entity; rather it is open to change and can be domain specific. An individual therefore may feel confident in their ability to carry out a problem in mathematics, yet lack such confidence in their ability to complete a writing task. Schraw et al (2006) suggest that self-efficacy may be improved in two ways. Firstly through the use of peer interaction and modelling and secondly through the use of feedback on performance. Peer interaction and modelling occurs where individuals view others performing tasks and learn from them and with them. Evidence suggests that children who learn from interaction with peers are more likely to change their self-efficacy beliefs than those who do not interact with peers, since they view others with similar ability achieving or performing a task (e.g. Schunk 1996). Similarly, feedback on performance improves self-efficacy as it brings a learner's attention to what they have achieved and how it relates to their goals (Schraw et al 2006).

Schraw et al (2006) suggest that the relationship between cognition, metacognition and motivation is a dependent and inter-connected one and no element is adequate on its own to result in learning. An individual may have all the correct cognitive strategies to solve a problem, yet without the motivation to do so, they are useless. Schraw et al (2006) suggest that metacognition is a mediating force between cognition and motivation. Being metacognitively aware allows an individual access to their cognitive abilities. This, in turn, improves self-efficacy since they believe they have the necessary capabilities to accomplish a task, and if they are lacking a skill, they become aware of that and how to find it.

Theories which give metacognition a role in the learning process therefore view it as an important, but not solitary factor. As both Sternberg (1998) and Schraw et al (2006) note, there is an interplay between motivational, affective and metacognitive factors when learners engage in a task. As well as theoretical accounts of the role of metacognition in learning, empirical research has provided evidence of its efficacy.

2.5.3 Metacognition and learning - Empirical evidence

The previously mentioned research suggests that individuals can and do develop an awareness of their cognitive functioning (e.g. Brown & McNeil 1966, Flavell et al 1970) and are able to regulate it (Lodico et al 1983). Hacker (1998) notes that cognitive and developmental psychology had been the main source of empirical research on metacognition since its inception in the 1960s. However, more recently there has been a change in focus from theory to application. Researchers have become aware of the benefits of metacognition in learning and have turned their attention to the area of education (Hacker 1998).

Research in this area has provided evidence of a relationship between the components of metacognition and successful learning. Garner (1990) suggested that successful learners are aware of *what* they know. Pressley et al (1998) showed that successful learners also have more knowledge regarding *how* to perform tasks, *when* a particular strategy will be appropriate, and *why* it is appropriate. Paris and Winograd (1990) have highlighted the potential benefit of metacognitive research to pupils whilst Borkowski and Muthunkrishna (1992) have also shown the potential of metacognitive research to aid teachers and other educators. Whilst the move into a more ecologically valid setting necessarily restricts the type of studies which can be carried out, it is nonetheless a positive move and in line with Boneau's (1992) assertion that research should tackle problems of the natural world, rather than solely the artificial problems of the laboratory.

Perhaps the most prolific area of research which has produced consistent results is the area of metacognitive interventions and their ability to produce higher educational achievement.

Empirical research has been concerned with metacognitive interventions in areas such as science education (Adey & Shayer 1993, Georghiades 2000, Zohar & David 2008), mathematics (Mevarech & Kramarski 2003, Kramarski 2004, ,Desoete, Roeyers, & De Clercq 2003, Teong 2003, Mevarech & Kramarski 1997, Mevarech & Fridkin 2006), chemical engineering (Case & Gunstone 2006), reading (Michalsky, Mevarech & Haibi 2009, McElvany & Arlelt 2009) and teacher education (Kramarski 2008). These empirical studies have included both quantitative and qualitative research methods. They have also spanned a wide age range and different educational domains. The unit of analysis in such studies may be achievement in the specific domain, metacognition in a specific domain, metacognition and achievement, the development of metacognition or transfer of learning.

In the area of science education, Georghiades (2004) assessed achievement of primary school pupils after an intervention focussing on metacognitive thinking skills. Those who underwent the intervention had higher achievement levels in class tests. However, this advantage was not found when problems were straightforward and required little metacognitive ability. Similarly, Zohar and David (2008) applied a metacognitive intervention with older science pupils aged 13-14. They specifically focussed on a sub-component of metacognition, that of meta-strategic knowledge which they defined as "*general, explicit knowledge about thinking strategies*" (Zohar & David, 2008 p59). Students in the intervention group showed a significantly higher increase in strategic and non-strategic knowledge compared to the control group. Furthermore, students who had been classified as 'low achieving' improved their skills to almost the same level as the high achieving students. Spanning both science and literacy, Michalsky, Mevarech and Haibi (2009) applied a metacognitive intervention to assist children with their understanding of scientific texts. Those students who received the intervention after reading outperformed all other groups.

One set of studies which has provided evidence of the efficacy of metacognitive interventions on learning is the CASE program (Cognitive Acceleration in Science Education, Adey 2002). The CASE program was designed to provide cognitive acceleration through general thinking skills. It is based mainly on Piagetian theory within the framework of Vygotsky's social constructivism. Based initially on Inhelder and Piaget's (1958) stage theory of development, the intervention aimed at accelerating students' thinking skills from concrete to formal operational. During an intervention which lasted 2 years, Adey and Shayer (1993) found that students' learning improved, not only in science education, but across the curriculum. The CASE intervention however did not solely focus on metacognition, but also incorporated *concrete preparation* whereby concepts and terminologies were introduced that would be applicable to problems; *bridging* of thinking strategies which allowed to students to understand how their thinking could be applied elsewhere; and the use of problems specifically designed to produce *cognitive conflict* whereby students were presented with problems which did not fit with their existing schemas which encouraged them to look for new understandings.

It is not only within the classroom that metacognitive interventions can improve achievement. McElvany and Artelt (2009) devised a metacognitive intervention for parents to use with their children at home to supplement the reading instruction they had at school. Parents worked with children for 30 minutes each day during their reading homework. Units of analysis in the study were text comprehension, reading motivation, metacognition, vocabulary and fluency. Results of the study showed that, compared to the control group, those children who participated in the intervention showed significant gains in metacognition and vocabulary.

Research has also shown that metacognitive interventions with teachers can produce increased achievement of their pupils. In a longitudinal study lasting two school terms, Gillies and Khan (2009) gave teachers systematic training in how to promote metacognitive thinking with children. The study found that pupils who were exposed to metacognitive questioning provided more information regarding justifications and reasons for their answers than did those who did not receive the intervention.

The empirical research in the domain of education gives support to the assertion that metacognition is an important component of effective learning. Furthermore, it is a set of skills or abilities that can be taught in order to bring about increased achievement.

As this thesis is primarily concerned with the area of problem solving in mathematics education, the empirical research in this area will now be considered.

2.6 Metacognition and mathematics - Empirical evidence

Metacognitive research within mathematical problem solving has two main directions: attempting to understand how students use metacognition; and the use of metacognitive interventions to improve learning. Metacognitive interventions have been applied in order to improve mathematical understanding. These studies support the idea that metacognitive skills can be taught and are beneficial to students during the problem solving process. Outcome measures are generally individual achievement either in group settings (e.g**.** Mevarech and Kramarski 2003) or during individual working (e.g. Teong 2003, Cardelle-Elawar 1992).

2.6.1 Metacognitive Interventions

Studies which look at the specific 'teaching' of metacognitive abilities have provided results which suggest that they are teachable and doing so produces gains in terms of achievement for individuals. One research paradigm which has been used in a number of empirical studies in mathematics education is the IMPROVE paradigm (Mevarech & Kramarski 1997). The acronym IMPROVE stands for **I**ntroducing new concepts, **M**etacognitive questioning, **P**racticing, **R**eviewing and reducing difficulties, **O**btaining mastery, **V**erification and **E**nrichment.

Derived from theories of social cognition and metacognition, the intervention is designed specifically for teaching mathematics in heterogeneous classrooms. There are three interdependent components to the intervention: metacognitive activities, peer interaction and systematic provision of feedback-corrective-enrichment. The use of peer interaction should, according to Mevarech and Kramarski, produce a situation of varying background knowledge which would be advantageous to all pupils concerned. The metacognitive questions were designed to encourage elaborate explanations regarding the structure of the problem, connections between new and existing knowledge and specific strategies which may be appropriate for solving the problem.

The initial study employed a quasi-experimental design and focused on Israeli children in 7^{th} grade (age 12-13). The study was designed to measure their information processing ability and mathematical reasoning ability. One group underwent the IMPROVE intervention and the control group worked with the same curriculum, individually without the intervention. Results showed that pupils who underwent the intervention achieved higher scores in the post intervention test. However, results were not seen across all measures and low achievers were not consistent with their improvement. Mevarech and Kramarski (1997) concluded that metacognitive instruction is useful when the problem calls for that kind of reasoning. In problems which require a simple application of a procedure or algorithm, there was no advantage to be gained from the metacognitive intervention.

The initial IMPROVE study compared children learning in cooperative groups with an intervention as opposed to those learning individually without an intervention. The results could have been due to the cooperative setting rather than the intervention per se. The study was therefore extended by Mevarech and Kramarski (2003) to ascertain the difference between two groups utilising cooperative learning. One group underwent the intervention and the other did not. Mevarech and Kramarski (2003) found that the group which underwent the intervention performed better than those without the intervention, thus suggesting that the intervention brought a qualitatively different kind of interaction between the group members. However, Mevarech and Kramarski did not investigate the qualitative differences in interactions in an attempt to ascertain *why* achievement improved. Another study compared individuals using IMPROVE to individuals without an intervention. Mevarech and Fridkin (2006) found in this study that the IMPROVE students performed better than those in the control group.

Another programme which aims to increase metacognitive ability and learning, is the *Cognitive Acceleration in Mathematics Education* (CAME, Adhami, Johnson & Shayer 1998). The CAME programme was developed from the previously mentioned CASE programme where cognitive development occurs through thinking processes and group work skills. Based on stage development theory (Inhelder & Piaget 1958), the intervention also incorporated the notion of social construction of knowledge posited by Vygotsky (1978). Initial interventions were designed to encourage the development from Inhelder & Piaget's (1958) *concrete operations stage* to the *formal operations* stage. Although the intervention was based within the area of mathematics, results showed that achievement in other areas such as science and English increased compared to control groups who did not receive the intervention.

In other studies, Cardelle-Elawar (1992) examined the effects of teaching metacognitive skills to students with of mathematics ability. Using Brown's (1987) model of metacognition, the intervention was designed to highlight students' knowledge of cognition and regulation of cognition. Students were taught and encouraged to use strategies for learning and remembering specific terminologies within their mathematics lesson. Students worked individually and received feedback from the teacher regarding their strategy use. Pre-tests showed there was no significant difference between the experimental and control groups. However, after the intervention, the experimental group significantly outperformed the control group on their use of appropriate strategies.

Utilising a computer-based environment, Teong (2003) implemented a CRIME (Careful Reading, Recall possible strategies, Implement strategies, Monitor, Evaluation) intervention with 11 & 12 year old students. Students were encouraged to adopt the CRIME problem solving strategy and go through each stage with each problem. As well as measuring achievement before and after the intervention, Teong also videoed students solving problems. She used a think-aloud protocol during their collaborative problem solving sessions. Results from this study showed that achievement was significantly higher for those students in the CRIME group compared to the control group who underwent no intervention. Results for the video analysis showed that the students who underwent the intervention demonstrated higher levels of metacognitive utterances than those who did not. However as there were no pre-test patterns of metacognitive behaviour it is difficult to assign this difference to the intervention rather than individual differences.

Using a slightly different format to the interventions, Veenman Kok & Blote (2005), gave high school students metacognitive cues during their mathematics problem solving sessions. When students failed to employ metacognitive thinking, they were given cues which reminded them of such thinking, rather than cues to help them solve specific problems. The researchers found that those students who received the cues used more metacognitive thinking and had better learning outcomes than those who did not.

These studies show that in the domain of mathematics education metacognitive interventions generally improve achievement in collaborative or individual settings. However, it is difficult to ascertain the precise *nature* of the metacognitive development. Such a research question would be difficult, if not impossible, to answer. However, some indication of the role of metacognition during problem solving may be found in studies which are concerned with collaborative learning.

2.7 The role of metacognition during collaborative problem solving

In attempting to ascertain the role of metacognition during problem solving, many studies have focussed on collaborative learning situations. This change of focus has been due to both theoretical and methodological issues. From a theoretical perspective, metacognition fits well with the constructivist view of learning (Carr & Biddlecomb 1998). Both Piaget and Vygotsky viewed the child as being the constructor of knowledge. Piaget asserted that children construct knowledge from their own experiences of the world, whereas Vygotsky asserted that children construct knowledge through interactions with their peers and significant others. This latter socio-cultural view suggests that learning occurs through the process of social interaction such as when working in collaborative settings. When children work with their peers to solve a problem, metacognitive awareness may be enhanced through the need for children to explain their reasoning to their peers, or critique a suggestion made by a peer (e.g. Schraw et al 2006). From a methodological perspective, when trying to ascertain the types of interactions children use when solving problems, it may be easier to assess these when they are articulated during the process of problem solving with peers (Veenman Van Hout-Walters & Afflerbach, 2006).

In order to ascertain the role of metacognition during collaborative problem solving, Artz and Armour-Thomas (1999) studied several groups of students during their problem solving class. Utilising protocol analysis, Artz and Armour-Thomas coded utterances as either cognitive or metacognitive. They found that students who successfully solved problems demonstrated higher levels of metacognitive interactions than those who did not.

Goos, Galbraith and Renshaw (2002) developed this research further to try to ascertain the difference that metacognitive awareness may make to the interactions of the group as a whole. Artz and Armour-Thomas (1992) had only coded individual interactions within a collaborative situation. However, Goos et al (2002) argued that it was important to look beyond the individual, particularly as to whether students played any part in their partners' metacognitive development. Goos et al (2002) conducted a 3-year study with year 11 and 12 pupils (aged approximately 15 & 16). The study aimed at understanding the way in which collaborative problem solving could mediate metacognitive activity. They found that during successful collaboration, students questioned their own and others' ideas. That is, they monitored each others' cognitions. Goos et al concluded that:

"collaborative metacognitive activity proceeds through offering one's thoughts to others for inspection and acting as a critic of one's partner's thinking"

(*Goos et al 2007, p 207*)

Such research suggests that metacognition is important for successful collaborative problem solving. However, it does not give an indication of how students with differing levels of metacognitive awareness are likely to interact. Hurme, Palonen and Jarvela (2006) addressed this question in their study which considered the role of metacognition during a networked discussion in mathematics with 13-year-old students. Data were collected from three computer supported collaborative learning lessons during one week. Utilising correspondence analysis, social network analysis and content analysis, they found that those children who showed more advanced patterns of metacognitive processes had greater involvement in discussions and subsequent solutions. This suggests that those students with higher metacognitive awareness are the key players during the problem solving exercise. However, since this study was conducted with data which only spanned one week, it was not possible to tell if those students with lower metacognitive awareness would benefit metacognitively over time through working with those with higher metacognitive awareness.

There is evidence to suggest that this would not be the case. In a study which tracked the collaborative problem solving of two students over twenty months Sfard and Kieran (2001) found that their conversation did not develop in a manner which would be expected had collaborative work been ‘automatically’ conducive to metacognitive development. Sfard and Kieran (2001) recorded collaborative interactions between two 12 year old boys over a period of twenty months whilst solving algebra problems. Although this study did not explicitly study metacognition, the focus was on the interactions of these two students and the way in which they interacted to solve the problem. One boy seemed motivated only to solve the problem himself, rather than interact with the other. He found the problem solving relatively easy and was able to do so without the aid of his partner. The second boy however seemed motivated more towards the social interaction of collaboration than being concerned with the actual problem. This caused problems in terms of how much the boys learned, and also caused interpersonal problems between them, with the first boy seeming quite dominating at times. Despite working together for a period of 20 months, the interactions of the boys did not change much from beginning to end. Sfard and Kieran note that “*if conversation is to be effective and conducive for learning, the art of communication has to be taught”* (2001, p71).

Viewed in the light of the previous research (Artz & Armour-Thomas 1992, Goos et al 2002 and Hurme et al 2006) there is clear evidence that collaborative learning environments do not by default produce higher levels of metacognition. Nonetheless, as previously mentioned, such skills can be taught in order to bring about gains in education.

The research highlighted in this section shows that various issues influence the use of metacognition during collaborative problem solving. Individual levels of metacognitive ability may influence who will be the key players in the discussion and they are more likely to produce the solution. Collaborative work can provide an environment for students to mediate each others' use of metacognition, however it should not be assumed that this is automatic.

Individual levels of metacognition appear to influence the way in which students approach a task. The next section will consider the research evidence regarding the way in which metacognition develops.

2.8 Development of metacognition

Research in the area of the development of metacognition has given a picture of a concept which develops with age and is linked with *theory of mind* (Flavell 2004). However, different components seem to develop at different times and it is not clear what influence each component may have on the development of others (Veenman et al 2006).

Theory of mind refers to a child's understanding that their own mental state is different from that of others, which generally develops around the ages of 3-5 years (e.g. Wimmer & Perner 1983). Children come to realise that others see things in a different way from them and believing that something is true does not actually guarantee that it is. (e.g. Wimmer & Perner 1983). In order to understand that others can view the world in a different way, children must become aware that their own cognitions are representative of the way in which they view the world. Evidence suggests that metacognition is related to theory of mind and as such can be viewed as a developmental attribute which changes with age and experience (e.g. Lockl & Schneider 2006). This developmental trajectory continues throughout childhood and into adulthood. Beyond the initial development of theory of mind, metacognitive awareness is apparent in young children and increases with age (e.g. Larkin 2006, Flavell 1979).

Lockl and Schneider 2006 argued that in order for a child to be able to understand their own cognitions in the form of metacognitive knowledge, they would first need to gain the understanding that mental states are *representational*. In other words, they would have to achieve theory of mind. They hypothesised that theory of mind could predict metacognitive knowledge at a later age. In order to test this hypothesis, Lockl and Schneider (2006) tested the theory of mind ability of children aged on average 4 years and 6 months. One year later they tested the metacognitive knowledge of the children. Theory of mind was assessed through three standard tests of false-belief task, false-belief transfer task and an appearance-reality task. For the metacognitive knowledge component, children were given tasks which related specifically to memorial abilities. These tasks were devised from the Munich Longitudinal Study on the Genesis of Individual Competences (LOGIC, Weinert & Schneider 1999). For example, children were asked which of two strategies would be better in reminding them to perform a task in the morning. To counter guessing, they were also asked to explain why they thought so. This assessment was administered at ages 5, 5½ and 6.

Results of the study showed that those children who achieved theory of mind earlier, displayed greater awareness of factors which determine memorial ability up to 18 months later. This developmental trajectory continues throughout childhood and into adulthood. Beyond the initial development of theory of mind metacognitive awareness is apparent in young children and increases with age (e.g. Larkin 2006, Flavell 1979).

2.9 Issues in research in metacognition

Although there appears to be much evidence in support of the concept of metacognition and its role in learning, there are many issues within the literature which influence the interpretation of such evidence. This section will report on a number of these issues.

2.9.1 Assessment of metacognition

Veenman et al (2006) note that the attempt to measure and assess components of metacognition has resulted in the adoption of a wide variety of methods and designs. These designs might be categorised into prospective, retrospective and on-line designs. *Prospective* designs ask students to say what they would do if presented with a specific problem. *Retrospective* designs ask students what they did do when they completed a task. *On-line* designs capture the explicit thinking of the student as they are solving a problem. Methods used in such designs have included questionnaires, interviews, and think-aloud protocols.

For example, Thomas (2003) devised a prospective questionnaire to measure the metacognitive abilities of science students. Whereas Zimmerman & Martinez-Pons (1990) used interviews with students to ascertain issues which may affect metacognition. Think-aloud protocols, such as that previously mentioned in research by Teong (2003) allowed students to 'talk' through what they were doing so that the researcher could assess their use of metacognition.

The methods mentioned above tend to assess *individual* metacognition rather than the use of metacognition during collaborative problem solving. During collaborative tasks, students naturally verbalise their thinking (although not necessarily all of it). Studies which consider metacognition during collaborative work utilise recording techniques such as audio or video in order to analyse on-line data.

Each of these methods and designs has its drawbacks. For example, studies which show offline analysis, where an individual is asked either before or after completion of a problem solving activity what procedures they are likely to employ, might be subject to memory distortions and tend to not be a true reflection of the actual procedures employed (Braten 1991). However, methods such as questionnaires which are used in off-line designs are quick and relatively easy to administer to large numbers of students, yet Veenman et al (2006) suggest that validation of such items is difficult.

On-line analysis is time-consuming as researchers may spend many hours analysing verbal utterances from smaller numbers of students. However, the results from such analyses give a clearer picture of what the students did in order to solve the problem. Care must be taken in assuming a full picture is given as much cognitive processing can be automatic and proceduralised, therefore not available to verbalisation. Similarly, on-line analysis techniques such as *think-aloud* protocols depend on a student assessing a piece of information to be important enough in the problem solving situation to verbalise. Since students are not aware of what the researcher is looking for, they may subconsciously omit specific information. This may be somewhat countered by designs which include collaborative problem solving whereby students must work together to towards a goal. However, again, it cannot be assumed that all metacognitive or cognitive thought will be verbalised although during collaborative interaction students are expected to and have been shown to make known their thinking to those in their group (e.g. Goos et al 2002).

Perhaps one enduring issue with assessments of metacognition is that, like methods used to ascertain domain specificity, which will be discussed in due course, they have mainly been focussed at students from the age of around 12. However, researchers have recently begun to uncover metacognitive ability in younger children through the use of assessment tools specifically designed for such ages. For example Whitebread, Colston, Pastenack, Sangster, Grau, Bingham, Almegdad, and Demetriou (2009) found evidence of metacognition in children as young as three years old. Whitbread et al (2009) provided a checklist of behaviours under the headings of metacognitive knowledge and metacognitive regulation. During observation of children in their nursery class, the researchers were able to ascertain the extent to which young children are capable of metacognitive interactions.

The assessment of metacognitive ability in young children was also the focus of Larkin's (2006) research with primary school children who received the CASE intervention. Children worked on activities which were focused at aiding cognitive development from pre-operational to concrete stage. These included classification, seriation and causality. Larkin (2006) followed the metacognitive development of two children involved in a collaborative learning environment. She found that over the intervention period of one academic year, the students in the study showed evidence of metacognitive development, specifically in the areas of knowledge of cognition and monitoring thinking.

2.9.2 Domain specificity

Domain specificity is an important aspect when considering metacognition in a learning environment. If metacognition is a domain specific skill, then a different intervention would be required for each domain or subject area. If, on the other hand, metacognition is a domain general skill then it would possible to develop general metacognitive interventions that could be used in many different subject areas (Veenman et al 2006).

Domain specificity is a difficult area to research within metacognition and the literature does not provide an answer to the question. Many research studies have been in specific subject areas and there may be good reason for this. As previously mentioned, Flavell's initial conception of metacognition was based on Piaget's formal operational stage of cognitive development. According to Piaget, students generally achieve this around the age of 12. This coincides with a move to high school and the separation of subject areas.

Kelemen, Frost and Weaver (2000) suggest that metacognition is not a general ability but has domain specific properties. They tested students on various components of metacognition such knowledge of cognition through a 'feeling of knowing' judgement.

Students were tested again one week later. Although the individual differences in memory and confidence levels were stable over the two test periods, the metacognitive accuracy was not. Kelemen et al concluded that had metacognition been a general attribute, levels of individual differences would have remained stable.

Contrary to Kelemen et al's claim, Schraw, Dunkle, Bendixen and Roedel (1995) found evidence to support a general *monitoring* skill. The question of domain specificity may be aided by research on metacognitive interventions. As previously mentioned, if metacognition was a domain specific skill then an intervention in one domain would bring about improvements in other domains. As previously mentioned, both the CASE and CAME studies have produced such findings.

Veenman et al (2006) suggest that whilst some researchers propose that there are aspects of metacognition which are domain general in nature, current evidence favours domain-specific knowledge. However, it is possible that this evidence has been produced as a result of the theoretical history of metacognition. Since interventions show some power in a general sense, the idea of some form of general metacognition cannot be discounted.

2.10 Defining Metacognition

Although there are various conceptualisations of metacognition, researchers generally agree that metacognition may be divided into a knowledge component and a skill component (Larkin 2009). Metacognitive knowledge is based on Flavell's (1979) conception of knowledge and understanding of one's own cognitive processes. The skills component comprises the ability to *regulate* or control this knowledge. However, the field of research in metacognition is constantly evolving, and therefore our understanding of the definition of metacognition is also evolving.

Much research on metacognition has focussed on *individual* metacognition from a cognitive or developmental psychology perspective. However, more recently, researchers in metacognition have adopted a socio-cultural view to understanding the development and use of metacognition (e.g. Larkin 2009, Schraw 1998). A socio-cultural view suggests that learning occurs through the process of social interaction. As previously mentioned, when children work with their peers to solve a problem, metacognitive awareness may be enhanced through the need for children to explain their reasoning to their peers, or critique a suggestion made by a peer (e.g. Schraw et al 2006).

Research grounded in a socio-cultural perspective attempts to understand metacognition within social settings such as collaborative work. In particular it aims to understand how students use metacognition in an interactive way to reach consensus or solve problems. This differs from psychological views of metacognition which aim to understand individual use either in individual settings or collaborative settings.

Findings from studies which adopt such a view suggest that during collaborative work students act as *monitors* of one another's cognitions (Goos et al 2002). Also, those students who have more advanced metacognitive abilities tend to dominate discussions and subsequent solutions (Hurme et al 2006). And finally, the use of metacognition during collaborative sessions is mediated by factors, such as social relationships between students (Larkin 2009).

Such issues are clearly not included in the models of metacognition discussed in this chapter. In the next chapter I will address this and describe the definition of collaborative metacognition which will be adopted in the thesis. In so doing, I will provide an overview of current research in the area of *group* metacognition. I will present a critical analysis of the conceptualisation and operationalisation of both metacognition and collaboration used within these studies. The purpose of so doing is to ascertain if there is a current conceptualisation which is suitable for the purpose of addressing the research questions of this thesis.

2.11 Summary

Although the term metacognition was first used by Flavell (1979), the concepts proposed by him can be found in the writings of learning theorists such as Piaget and Vygotsky. Furthermore, manifestations of metacognition have been researched by cognitive psychologists, in particular, cognitive monitoring and cognitive regulation.

A number of models of metacognition have been proposed. However it is those of Flavell (1979) and Brown (1987 further developed by Schraw 1998) which dominate the literature. As well as researchers proposing different models of metacognition there are also different opinions regarding its role in learning. Metacognition has been researched independently in order to ascertain the relationship between metacognition and effective learning. It has also been researched and conceptualised as sub-component of other skills which are necessary for effective learning.

Empirical research on the efficacy of metacognition in learning has provided evidence that metacognition is ‘teachable’ and during metacognitive interventions, learning has improved. These results have been seen in many educational domains.

Within the area of mathematics learning, empirical research again provides support for the assertion that metacognition is a teachable skill which results in improved educational outcomes. During collaborative problem solving, individual differences in levels of metacognitive ability influence contributions to group discussions. For example, individuals with higher levels may dominate discussion and are more likely to produce the solution. Although studies have shown that collaborative work provides an environment for students to mediate one another’s use of metacognition, this does not necessarily happen automatically.

Researchers in the field of metacognition have used a variety of theoretical definitions of the concept. Furthermore these definitions are operationalised in different ways. This has, I believe, resulted in a research area where findings are difficult to synthesise. It is imperative, therefore, that researchers make clear the model of metacognition they are using in their research in order to provide a more coherent account of the concept of metacognition and its relationship with successful learning. The study reported in this thesis is based on collaborative metacognition. In the next chapter, I will provide a conceptualisation and operationalisation of the term collaborative metacognition adopted in this thesis.

Chapter Three Collaborative Metacognition

3.1 Introduction

In this chapter I will argue that a new definition and operationalisation of the term *collaborative metacognition* is required in the literature in order to understand the relationship between the process of interaction and the use of metacognition during mathematical problem solving. I will also provide evidence of this relationship through the use of data from the studies which are outlined in the methods section. The research question addressed in this chapter is: *How can collaborative metacognition be conceptualised and operationalised in a way that is both conceptually rigorous and empirically tractable?* In order to address this question, this chapter will be written as an individual research paper rather than part of the monograph of the thesis. The reason for doing so is that the information required for the argument posited in the first line requires a mixture of theoretical content; empirical research and new research data from the study reported in the thesis. This will provide a more coherent argument which will act as an introduction to the results chapters which follow. Only methodological details pertaining to this chapter will be included.

I suggest that a new definition and operationalisation of collaborative metacognition are required in the literature in order to bring clarity to the field and to allow consolidation of research findings. As will be made clear in the following sections of this chapter, researchers differ in their understanding of metacognition, their understanding of the term collaboration and the relationship between the two.

Problem-solving in the primary school mathematics curriculum might be understood as the application of previously learned abstract mathematical concepts to *real-life* situations. Alternatively, it might be understood as a method by which students become aware of gaps in their understanding and develop the ability to fill these gaps. Educational researchers have long acknowledged the important role of problem solving in allowing individuals to develop a contextual understanding of mathematics (e.g. Schoenfeld 1992, Verschaffel & De Corte 1997). As mentioned in the introduction, the Scottish Government has embraced this notion and promotes the use of problem solving during mathematics in the primary classroom. Furthermore, in line with *real-life* working situations, group problem solving is promoted in order to develop the necessary skills and abilities to work effectively with others.

Working effectively with others in an attempt to solve a problem requires interaction processes which will result in mutual understanding of the problem, agreement of potential solutions and the ability to evaluate those solutions. Individuals must make known to others their knowledge and thought processes, such as potential procedures which might be appropriate. When an individual does so, others with whom they are communicating must decide if they understand and agree before proceeding. If they do not agree, the communication may develop to include questioning and negotiation. I would argue that the kind of talk which might be termed *metacognitive* as detailed in the literature review, would be influenced by these processes of interaction. Furthermore, the use of metacognitive talk might also influence the process of interaction by encouraging others to engage in an effective manner.

As mentioned in the literature review, current models of metacognition which describe components of the concept have been produced from research which has usually been concerned with individual *spontaneous* metacognition (e.g. Flavell 1979). Furthermore, research studies which have established a link between metacognition and learning have generally been conducted using individual metacognition rather than group metacognition (e.g. Pressley et al 1998) Interventions which have been developed for use by teachers in classrooms with the aim of improving students' use of metacognition, have also mostly been developed from findings on individual metacognition (e.g. Fueurstein 1980).

When students are *taught* metacognitive skills to aid their individual problem solving, these skills might not transfer to a group learning environment where the interactions of other students may impact them. Whilst the current research on individual metacognition is useful, it can only account for part of the educational experiences of students. Often in classrooms, for many different subjects, students are asked to work together on problems. Furthermore, employers seek out individuals who are able to work effectively with others on projects to produce creative and meaningful solutions to problems. It is therefore crucial that researchers turn their attention to understanding the manifestation of metacognition during group situations in authentic classrooms, with a specific focus on the impact of interaction.

Current conceptualisations of metacognition limit researchers who are concerned with group work and the manifestation of metacognition in these situations because they fail to address the potential impact of interactions on the use of metacognition. Furthermore, they do not address the reciprocal impact of metacognition on the interaction process. Researchers have, in recent years, begun to address this issue. Current findings in this area imply that the group environment has some impact on the use of metacognition. For example, individuals who are more metacognitively competent tend to dominate discussion (e.g. Artz & Armour-Thomas), individuals in groups might act as regulators one another's thought processes (Goos et al 2006) and social factors influence success outcomes despite effective use of metacognition (e.g. Larkin 2009).

Whilst the relatively small number of studies which have been carried out in this area provide some insight to the impact of interaction on metacognition, consolidation of results is difficult since conceptualisations of both metacognition and the role and impact of the interaction processes tend to differ between researchers. Due to the diversity of research methods adopted in the field of metacognitive research it is crucial that researchers clearly state which conceptualisations are being adopted in each study (Azevedo 2009). Consolidation is often made more difficult by the design of the studies in this area. Although researchers might claim a naturalistic design, they often include some manipulation of the situation. For example researchers might only include students who are metacognitively sophisticated compared to their peers (e.g. Goos & Galbraith 1996, Goos et al 2002); or only include high achieving students (e.g. Hurme et al 2006, Iiskala et al 2004 & 2010). By excluding students who are less likely to provide a realistic view of learning in most classrooms, findings are often skewed in favour of more competent students. I do not view this as a criticism of the field as it is often through knowing what *successful* students do, that struggling students might be helped. However, research which is conducted in an authentic classroom situation without manipulation, provides a more realistic understanding of the use of metacognition. Some researchers of course do focus on the classroom as they find it. However, the empirical studies which have focussed on metacognition during group work in a naturalistic setting, have either occurred in a different educational domain such as writing (e.g. Larkin 2009), or have focussed on high school students as opposed to primary school students (e.g. Artz & Armour-Thomas (1992).

I propose therefore, that a clear definition and operationalisation of the concept of collaborative metacognition would benefit the research field as it would allow researchers to focus attention on a very specific area of the relationship between interaction and the use of metacognition. Furthermore, by making clear and adopting such a definition, research findings could be consolidated in order to provide a more robust evidence-base for use by educators and policy makers. The production of such a definition, and evidence for its usefulness by using data from a natural classroom setting, will add to its efficacy in the field of metacognitive research in mathematical problem solving.

3.2 The structure of the chapter

In this chapter I will firstly consider the use of the terms collaboration and metacognition within the literature in order to provide a theoretical understanding of the terms used within this thesis. Although group work is a common theme in educational research, the term has a number of pseudonyms, often referring to different types of group work. Such terms might be theoretical in nature or operational, referring to the roles adopted by individuals whilst working in a group. By providing an overview of the theoretical role of social interaction during learning, I will provide justification for the assertion that current individual cognitive models and understanding of the use of metacognition may not transfer well to group situations and therefore group work should be studied using a different approach. I will also outline the theoretical perspective I have adopted in order to understand the term collaboration. In chapter two I provided an in-depth account of current research in the field of metacognition, therefore, only a brief overview together with the definition adopted in this thesis is necessary here. I will then go on to critically examine a number of research studies which focus on metacognition during group work in order to examine the extent to which each study proposes a relationship between individual interactions and metacognition. Through highlighting gaps in the current research area, I will provide a definition of collaborative metacognition which is distinct from current conceptualisations.

Although providing a theoretical definition of collaborative metacognition is an important factor in research design, it is also necessary to be able to *operationalise* the term. It is crucial that such an operationalisation is meaningful in terms of its ability to mirror the theoretical concept. I will therefore provide a methodological account of the way in which the term will be operationalised for the results chapters which follow. In the methods section I will also outline the process of data analysis undertaken in order to ascertain the relationship between metacognition and a specific type of interaction. I will then present data which provides evidence of this relationship. This data will act as a case study to demonstrate the value of the theoretical notion of collaborative metacognition as well as providing support for the analytical approach adopted in the thesis. Finally, I will present a general discussion and conclusion.

3.3 The theoretical understanding of collaboration and metacognition adopted in this thesis

In this section I will provide justification for the assertion that current cognitive models and understandings of metacognition may not transfer well to group situations. Therefore different methods should be adopted which provide an insight to the use and development of metacognition in such situations. Justification for adopting a group work design in the study of metacognition is complex and based mainly on theoretical understandings. Whilst many learning theorists have suggested a relationship between social interaction and learning, the focus of this thesis is on learning *processes* and in particular metacognition. Metacognition might be understood as an innate ability which develops with age. Alternatively metacognition may be viewed as a linguistic tool, learned through social interaction. Learning theories which are often used to understand the use of metacognition during group work (e.g. Vygotsky and Piaget) pre-date the term and therefore they do not give an explicit role to metacognition during learning, nor do they refer to the ontological origins of the concept. However, it is crucial to attempt to understand the concept within these theories in order to ensure that any theory chosen in order to understand the concept is congruent with the conceptualisation of the term metacognition. I will therefore attempt to understand the impact of social interaction on a specific learning process as well as highlighting the theoretical impact of the social situation on learning as contained in each theory. Justification for suggesting that metacognition be studied in collaborative environments must therefore provide a theoretical understanding of the role of social interaction on school learning and also on the development and/or use of metacognition during such learning.

The first part of this section is concerned with term collaboration. I will provide an overview of learning theories which support the notion that social interaction will have some impact on learning, providing an explanation of this role in each. I will also provide my understanding of the role of social interaction on metacognition as contained within such theories. I will then outline the theory which has guided the approach adopted in this thesis. In the next section I will discuss the theoretical concept of metacognition, together with the theoretical understanding adopted in this thesis. The purpose of the literature review was to present an in-depth account of research in the area of metacognition.

Therefore, only a short summary of relevant information will be required here.

3.3 Collaboration - The theoretical role of social interaction during learning

Although it may be beneficial from a practical perspective to study groups (for example the natural verbalisation involved provides rich data of what *actually* occurs as opposed to speculating what might occur), the decision is often based on the theoretical perspective on the nature of learning which has been adopted by the researcher. The notion that learning can be influenced through social interaction has its roots in a number of learning theories. Whilst it is not the purpose of this chapter to describe and critique learning theories, an overview of relevant theories will be given, outlining the relevance of each to the study of metacognition. I will then outline and justify the theoretical perspective which has been adopted in this study.

The area of psychology has provided many models of learning which have come in an out of favour with educators. Models have changed and developed from the early behaviourist approaches where the individual was seen as a tabula rasa ready to be filled with knowledge (e.g. Watson 1924), through cognitive and information processing models which were concerned with specific aspects of learning and memory (e.g. Atkinson & Shifrin, 1968). In recent years educational researchers have begun to recognise the role of social interaction during learning, and have adopted theories which recognise this role in shaping their research. Some theories which advocate a role for social interaction include, but are not limited to, constructivist theories and socio-cultural theories.

3.3.1 Constructivist Theories

Piaget's Cognitive Constructivist Theory

Piaget's (1978) cognitive constructivist view of learning provides a dual-process account of learning. Certain skills and abilities required for formal school learning will develop through biological maturation. Once these skills and abilities have developed, the process of social interaction may aid learning of concepts encountered in the school environment. Piaget suggested that formal school learning occurred through the continuous processes of assimilation and accommodation to reach *equilibrium*. Existing knowledge structures are modified through *assimilation* of experiential evidence. When information does not fit with existing understandings the process of *accommodation* allows this new information to be incorporated in order to achieve a state of equilibrium. Learning could occur through interactions with objects or people. It is theorised that in formal school learning, situations which result in cognitive conflict, e.g. when students critique one another's thinking, will influence these processes of assimilation and accommodation (Smith et al 2003). These processes may be triggered through students disagreeing with one another's arguments or judgements (Mugny & Doise 1978). Piaget, therefore focussed on the role of *conflict* in producing learning outcomes when students interact.

Although Piaget viewed social interaction as critical for development of learning, the learning occurred on an individual basis. As mentioned in the literature review, Flavell's model of metacognition was based on Piaget's formal operational stage, where children became able to

> *"mentally execute possible actions on [objects] and reflect these operations in the absence of the objects which are replaced by pure propositions. Concrete thinking is the representation of all possible actions and formal thinking is the representation of a representation of a possible action"*
>
> (Piaget 1964, -1968 p 63).

In other words, children became able to think about their thinking. Although Piaget's theory acknowledged the role of interaction on the learning process, his theory was primarily concerned with the *developmental stages* which occurred through biological maturation (Tudge & Winterhoff 1993). The ability to use metacognition effectively would, according to Piaget's theory, require biological maturation rather than social interaction. However, as mentioned in the literature review, evidence suggests that even very young pre-school children have displayed the ability to use metacognition (e.g. Whitebread et al 2009). Piaget's theory therefore does provide a role for social interaction and learning, however this is dependent on biological stage of maturation of the brain. Furthermore, Piaget focussed extensively on the individual as the unit of analysis and sought to understand development and learning from the individual perspective rather than by considering the role of others in these processes (Tudge & Winterhoff 1993).

However, when individuals are placed in groups and asked to *jointly* solve a problem, there is a process of interaction which must occur in order for them to achieve this state of collaboration. For example they must regulate the learning of the whole group in order to monitor progress and achieve consensus (Howe, Tolmie, Thurston, Topping, Christie, Livingtson, Jessiman & Donaldson 2007). Such processes would imply that an individual's understanding of a problem and its solution might be influenced by others in the group. This notion is addressed in Vygotsky's (1978) socio-constructivist view of learning. I will now consider the extent to which Vygotksy's theory might explain the role of the social situation on the use of metacognition.

Vygotsky's Socio-Constructivist Theory

Vygotsky's (1986) socio-constructivist theory was developed through his concern with the development of language in relation to thought. Vygotsky proposed that language and thought had separate ontologies. Only through social interaction could the two develop in a way which produced interaction between them. Vygotsky suggested that the psychological tools required for learning are acquired and then used through social interactions. Language was Vygotsky's prime example. The predisposition of humans to communicate through speech he termed a 'natural function', so too was the predisposition for internal thought and reflection. However, it is only through social interaction that these two functions may interact to produce 'higher order functions' such as speech, or language and thought. Vygotsky suggested that children internalise psychological tools such as language and gestures and then use them to develop higher order skills such as problem-solving. These internalised tools are then used creatively in order to achieve goals. In his theory, Vygotsky was keen to move from the notion that individual's actions are *re*-actions to the situation in which they find themselves. Rather, individuals are active in creating their own environments in order to improve their abilities and understanding.

Unlike Piaget's stage approach to development and learning, Vygotsky suggested that social interaction was the key to development of skills which would then impact on learning. Braten (1991) suggested that in Vygotsky's theory, metacognition might be viewed as an internalised skill or tool which allows an individual to gain access to and control over internal representations of concepts. Vygotsky (1986) makes reference to such a skill where children are aware of their knowledge and when it should be applied: "*the conscious use of concepts simultaneously implies that concepts can be controlled voluntarily*" p 174. This is a useful way of understanding of metacognition as it suggests that metacognition is a tool which might *develop* through social interaction.

Vygotsky used the theoretical notion of the *zone of proximal development* to explain the relationship between social interaction and the development of conceptual learning and the development of tools - :

> "*we propose that an essential feature of learning is that it creates the zone of proximal development; that is, learning awakens a variety of developmental processes that are able to operate only when the child is interacting with people in his environment and in collaboration with his peers"*
>
> (Vygostky, 1978 p90).

Whilst learners may be at one specific level in their ability, they also have a potential level of ability which may be reached through interaction and guidance with a more knowledgeable other or peers. This potential level is known as the zone of proximal development (ZPD). Although Vygotsky's notion of ZPD has often been used to describe the level of learning a child can achieve with help from a teacher, Vygotsky also considered the ZPD in terms of equal status partnerships and proposed that during play with peers, children were able to regulate their own and others' behaviour (Minick 1987). In Vygotsky's theory, the learning potential of a group of students working together is not equal to the learning potential of each individual student working alone. Learning occurs through verbal interactions and an attempt to reach a consensus. Slavin (1989) notes "*under the right motivational conditions, peers can and, more important, will provide explanations in one another's proximal zones of development."* (p1166). It is through this interaction, that students are able to regulate and mediate learning.

Both the Piagetian and Vygotskian perspectives provide an insight to the role of social interaction during learning and both have been used simultaneously as the basis for empirical studies (e.g. Adey & Shayer, 1993). However, the conceptual understanding of metacognition in each theory differs. Metacognition from a Piagetian perspective might be viewed as a skill which develops through biological maturation rather than social interaction. In such a theory, studying the impact of the social situation on the way in which students use metacognition might not be an appropriate concept to study. From a Vygotskian perspective metacognition might be understood in terms of a skill or tool which develops through social interaction. This tool might be used to aid learning with others in a collaborative environment. The use of metacognition during group work would therefore, be an appropriate concept in such a theory. However, Vygotsky's ideas, like Piaget's assumed a learning environment where students were motivated and ready to learn. As I noted in the previous section, empirical studies often manipulate classroom settings to include only those who are more skilled academically. This does not provide a complete account of formal learning in schools. Furthermore, Vygotsky also suggested that tools and skills were simply internalised by individuals to be reproduced at a later time. This might suggest that although the general use of metacognition might be influenced by the social and cultural setting, once students have learned how to use metacognition this will simply be replicated by students within each situation which calls for it.

Learning theorists, who support a socio-cultural perspective have adapted and developed Vygotsky's original ideas. In particular proponents of socio-cultural theory have rejected his idea of internalisation as being too constraining to the development of understanding. I will now give an overview of such theories in order to ascertain if any is able to provide a suitable alternative or complement to these aforementioned theories.

3.3.2 Socio-cultural Theory

As previously mentioned, Vygotsky's notion of internalisation has been criticised by proponents of socio-cultural theory as suggesting that individuals merely accept cultural norms and ways of interacting without adding to them or changing them. In particular Leont'ev's expansion of Vygotsky's ideas were criticised as being overly focused on internalisation at the expense of the more creative externalisation where the process of interaction and mutual understanding might result in a *change* to cultural norms (Lektorsky 1999). Rather than social interaction resulting in the replication of common understandings and processes, sociocultural theorists propose that understandings and norms are influenced and changed through the specific cultural and historical period within which they exist. By adopting such a perspective, researchers can explain developments in knowledge and understanding as well as changes in norms such as teaching and learning. Although there are several theories which might be termed sociocultural, they each have a slightly different focus on the relationship between social interaction and learning.

Sociocultural theories of learning might view the social practice of learning as *socially shared cognition* (Resnick, Levine & Teasley 1993), participating in a *community of practice* (Lave & Wenger 1991) or participating in an *activity* (Engestrom 1999).

Socially-shared cognition

The theoretical notion of socially shared cognition (Resnick et al, 1993) suggests that thinking and cognition are a *social* practice, rather than being something isolated to the individual. As such, learning should not be studied through the individual practices of students. Students *learn* through social interactions with their peers (Resnick, et al 1993). The focus of such studies in group learning would be the role of the group as whole and the way in which the group members interact to produce a learning outcome or shared understanding. Metacognition therefore may be viewed as the way in which group members regulate or monitor the use of cognition.

Communities of Practice

Communities of practice is a term suggested by Lave and Wenger (1991) to understand the socio cultural dimensions of learning. Learners participate in a social and cultural practice, where they move from being a novice in a new situation to an expert in that situation. Furthermore, learners may appear at different points on a scale of expertise depending on what they are learning (Lave 1996). Studies adopting such an approach might focus on the exchange of existing understandings and methods of working from experts to novices in the progression by the novices to expert status. However, perhaps more importantly, they also focus on the production of *new* understandings and methods which might occur as a result of the interaction process. However, these new or developing understandings are bound by *legitimate peripheral participation* (Lave & Wenger 1991). This concept describes the progress of a novice to expert status which must be legitimised by those already viewed as experts and which must be achieved through collaboration (Wenger 1998). The communities of practice theory was developed initially in relation to work-based learning and informal learning although it has more recently been used in classroom-based practice. However, some have questioned the extent to which the theory would translate well to school-based learning such as the problem solving in this study, as the mathematics taught in school often differs to the type of mathematics practiced by mathematicians (Boylan 2005).

Furthermore, the concept of learning within the theory adopts the traditional unidirectional approach whereby learning occurs by the progressive adoption of new skills and abilities (Engestrom 2001). However, Engestrom (2001) suggests that learning is not necessarily linear, and can also occur through a *sideways* move where participants in an activity might change their way of working without increasing their knowledge or skill set.

Activity Theory

Participation in an *activity* is another way of understanding the learning situation. Proponents of Cultural Historical Activity Theory agree with Vygotsky’s suggestion that individual thoughts and actions are mediated by tools and artefacts which can be psychological or physical. Furthermore, according to Engestrom's (1999) model, a subject (i.e. individual or group) uses mediating artefacts during a learning activity, towards the outcome (known as the object). This outcome may be enhanced or constrained by mediating artefacts, rules, the wider community and division of labour. Activity Theory might be used as a lens through which to understand an existing situation or it may be used as a development tool where existing practices may be understood and developed to more effective practices (Repkin 2003). By adopting an Activity Theory perspective, a multidimensional understanding of a situation or concept might be achieved through examining the role of one or more of the aforementioned mediating artefacts, rules, the wider community and division of labour. Activity Theory allows for the integration of both the individual and the social level of interactions during learning (Kuutti 1996).

Engestrom's (1999) idea of activity was developed from Vygotsky's writings. In particular, Engestrom addressed the previously mentioned critique of Vygotsky's notion of *internalisation.* Engestrom (1999) suggested that the process of *externalisation* is one which will appear *after* the internalisation of cultural norms and rules. In order for a child to become creative and externalise their knowledge, they must first *know* what it is. Therefore, during the process of group work during problem solving in mathematics, metacognition might be viewed as a tool which students use in order to make known their knowledge and use it effectively. In order for an effective practice to be developed (e.g. group problem solving), members of the community must first be at a level of being able to externalise their understanding. Engestrom (1999) notes that

> '*the expansive cycle of an activity system begins with an almost exclusive emphasis on internalisation, on socialising and training the novices to become competent members of the activity as it is routinely carried out*" (p33).

Once individuals become competent members of the activity and the activity becomes more demanding, externalisation will occur through critical self-reflection and a search for new ways of working. Engestrom (1999) relates this to Vygotsky's zone of proximal development. Whereas Vygotsky was referring to the individual, Engestrom refers to the Activity. Therefore when individuals learn collaboratively, their activity will cause them to internalise new ways of interaction. As they practice these interactions they pull each other through the zone of proximal development to produce effective collaboration.

However, one important factor in being able to do this is the explicit awareness of goals where students are working towards the same outcome. The complexity of the classroom environment is such that interactions, and goals, might be guided by issues outwith the problem solving environment. Furthermore, the goal of the teacher might not always be the same as the goal of the students. For example, the teacher may be interested to ascertain how close the students are to the problem solution, rather than how well they are collaborating. The adoption of an Activity Theory approach allows researchers to understand situations in terms of these different goals that students may be focussing on at given points.

3.4 Summary and adoption of theoretical understanding

Sociocultural and constructivist theories therefore both support the idea of social interaction as shaping learning. However, the role of social interaction differs between them. Through studying the use of metacognition during group problem solving it is necessary to understand not only the impact of the social situation on learning in general, but also the impact of the social situation on the use of metacognition specifically. I would suggest that these two issues are separate because each individual in that group situation may use metacognition *on an individual basis* to solve the problem on their own without interaction with others. However, when students are asked to interact in such a way that makes their thought processes evident to those in the group, other factors might impact their ability or willingness to do so.

The previously mentioned complex nature of research in this area is acknowledged in this thesis and has guided the choice of theoretical frameworks used to understand learning environment. I would argue that the Vygotskian notion of Zone of Proximal Development is relevant in understanding the impact of other students and teachers on the way in which students interact to use metacognition. It also provides justification for grouping students during learning, whereby students might contribute to the scaffolding often displayed by more knowledgeable others. However, the classroom situation is a complex one with many other issues impacting the process. For example, although a teacher might ask students to work collaboratively towards solving a problem, some members of the group may not be concerned with the collaborative aspect, or indeed with solving the problem. Furthermore, when the teacher interacts with the group, the goal of that interaction may be to support the group interactions, or it may be to decipher how well the group has grasped the nature of the problem. In order to provide a more detailed understanding of the collaborative situation and the use of metacognition during group work, an Activity Theory perspective will be adopted as an *explanation* of the situation rather than a *developmental* tool. The design, analysis and understanding of the empirical data in this study will therefore be guided by Vygotsky's notion of zone of proximal development within a framework of Activity Theory.

Collaboration within this framework can be theoretically understood as the points in which the students appear to be united in their goal, or activity, of working together to solve the problem. The awareness of working together is an important factor in the group problem solving situation, however it is wrong to assume that just because students are talking in a group that they are working together. Collaboration is therefore reserved for the points when the talk of the students is consistent with the notion that they are working together and interacting verbally towards the goal of solving the problem. Further details of the operationalisation of this will be presented in the methods section.

3.4.1 Relevance of this approach to mathematical learning

The theoretical understanding of learning adopted within this study necessarily has implications regarding the theoretical understanding of mathematics learning specifically. Cobb (1994) suggests that the two major trends in mathematics education research have been constructivist and socio-cultural. However, researchers have adhered to one or the other with, as Cobb suggests, an epistemological belief that the two cannot be integrated. The adoption of a theoretical understanding of mathematical learning implies a specific understanding of what mathematics learning is.

Learning mathematics might be viewed on the one hand as learning facts, procedures and relationships (Schoenfeld 1992). Students, in such cases, might construct their understanding of facts and procedures through interaction with other students, their teacher, or objects which they encounter through everyday life. However, Schoenfeld (1992) suggests that learning mathematics might also be viewed as a *social* activity, whereby students interact dialogically with others. According to Schoenfeld (1992), students must learn to seek out solutions rather than memorising procedures and they must learn to think through their answers and listen and respond to ideas posited by others.

The social dimension of learning mathematics is also proposed by Sfard(2001) who suggests that conversation is important for mathematical learning. Sfard suggests that this social dimension of learning is so important that communication should be at the heart of mathematics education. However, just as an understanding of mathematical procedures and facts does not develop naturally, neither do the communicative processes which allow students to apply their knowledge. Rather, Sfard and Keiran (2001) suggest that such skills should be the focus of teaching.

However, the adoption of the social dimension to learning mathematics, does not necessarily require the rejection of the constructivist view, which Cobb aligns with an acquisitional view of learning. Rather, Cobb suggests, in the spirit of pragmatism, that the theoretical approach adopted should be congruent with the specific aspect of mathematics being studied.

Mathematics education does require learning facts, procedures and relationships. However, learning mathematics also requires an understanding of the way in which these facts, procedures and relationships relate to mathematical practices of a particular society. In other words, learning mathematics requires students to be able to *apply* their knowledge in appropriate ways.

Within the area of collaborative problem solving, students are required to apply their existing knowledge and understanding through the process of communication with other students. This communication is the *social* aspect of mathematical learning and is crucial in order to develop mathematical understanding (e.g. Sfard 2001). However, rather than suggesting that different *types* of mathematics should be researched independently, I would propose hat an Activity Theory perspective allows an interactive perspective to be adopted in order to more fully understand mathematical learning during collaborative problem solving.

In the following section I will outline my theoretical understanding of the term metacognition as used in this thesis.

3.5 General overview of research on metacognition and adoption of model

The purpose of the literature review was primarily to provide a critical overview of the current research and understanding of the role of metacognition within educational settings. One main finding in that review was that a precise definition of metacognition is lacking in the literature. This may be due to a number of factors such as measurement tools and research design. However, if researchers are to better understand the role of metacognition during problem solving in group settings, it is imperative that those involved in research make clear the model of metacognition they are using and also any particular aspect of metacognition to which their study refers. This is crucially important if studies are to be consolidated in order to provide stronger evidence in the field.

Flavell's (1976) initial description of metacognition was '*knowledge concerning one's own cognitive processes and products of anything related to them'* (p232). Perhaps a more concise development of this definition is Schraw's (1998) division of three types of metacognitive knowledge:

> *'Declarative knowledge refers to knowing* 'about' *things. Procedural knowledge refers to knowing 'how' to* do things. *Conditional knowledge refers to knowing the 'why' and 'when' aspects of cognition'*
>
> (Schraw, 1998 p114).

Another distinction made in the literature is that between *declarative* and *procedural* metacognition. Brown (1987) proposed that:

> "*metacognition refers to understanding of knowledge, and understanding that can be reflected in either effective use or overt description of the knowledge in question"*
>
> (Brown, 1987 p65).

This *effective use* was termed *procedural knowledge.* Brown (1987) suggested that declarative knowledge is that which can be stated about a problem – or *knowledge of cognition*. Procedural knowledge comprises the skills necessary to utilise declarative knowledge in pursuit of a goal. These *regulating* processes include *planning* of the strategy, *monitoring* progress and *evaluation* of the final result. As mentioned in the previous chapter, most researchers agree on a distinction of knowledge of cognition and control or regulation of cognition (Larkin 2009, Schneider & Artelt 2010). Furthermore, many researchers adhere to such a definition, or some amended form of it.

Although these two distinctions are generally agreed in the literature, many researchers choose to only focus on one aspect of metacognition, such as regulation (e.g. Iiskala et al 2004). Whilst this may provide a deeper understanding of that aspect, the process of making known one's knowledge to others is a key aspect of problem solving in groups. Although understanding the process of regulation is an important one, it is also crucial to understand the impact of social interaction on students' '*overt description of knowledge in question'* (Brown 1987 p65). In a group problem solving endeavour each member must be able to verbalise their thoughts and ideas so that they and others may engage in a process of regulation. For this reason, I believe it is important to include in this study of metacognition both aspects of knowledge of cognition and regulation of cognition. In line, therefore, with many other research papers, both on group and individual metacognition, the model of metacognition adopted in this thesis will be one which provides a distinction between knowledge of cognition and regulation of cognition as set out in the literature review.

Whilst I acknowledge that research has not provided a definition of metacognition which is used by all researchers, a pragmatic view suggests that adopting a model which many researchers agree on will allow better consolidation of findings. This is crucially important in the field of education where policy makers and practitioners rely on research findings to shape practice in the classroom. When researchers work with different conceptualisations it is difficult to provide a coherent overview of the research field. However, this does not negate the need to continue to study and improve current conceptualisations of individual or group metacognition. The adoption of an existing conceptualisation of metacognition is also relevant in this research as the main argument contained within this chapter is that the process of interaction impacts the way in which individuals might use or develop metacognition. I am not arguing that components of metacognition might different, but that the way in which they are used might be impacted by the social situation.

As previously mentioned, researchers have begun to consider the impact of group work on the use or development of metacognition. In the next section I will consider the extent to which current empirical research provides evidence for a relationship between social interaction and the use of metacognition. Following on from that section I will outline the theoretical understanding of collaborative metacognition adopted in this thesis.

3.6 Empirical evidence for a relationship between social interaction and the use of metacognition

As previously mentioned, I believe that justification for the theoretical notion of collaborative metacognition must be provided from two distinct perspectives. Firstly, there must be grounds for a relationship between social interaction and learning in order to justify such learning designs. There must also be a theoretical justification for the impact of the social situation on the use of metacognition. In this section I will provide a critical overview of research which considers the role of metacognition during group work, specifically focussing on the extent to which the research studies have proposed and provide evidence for such a relationship. The purpose of this review is not primarily to critique the conceptualisations or operationalisations proposed by other researchers. Rather, I would like to highlight the diversity of understanding within the literature as justification for bringing clarity and unity to the research field. However, a certain level of critical analysis is required in order to justify my own choice of terms. To do this, I will firstly outline the criteria that I used for selecting studies to review. In the following section I will consider each study individually. For each study I will give a brief outline of what the researchers did and what their aims were. I will look at the theoretical understandings adopted by the researchers with relation to metacognition and the role of social interaction. Through a critical analysis of both methods and theoretical perspective, I will consider the extent to which each study furthers our understanding of the role of social interaction and the use of metacognition.

3.7 Criteria for selecting studies

A number of researchers have considered the impact of social interactions on the use of metacognition. However the relatively small number of studies combined with different theoretical perspectives, research domains, research methods and educational stages have led to a situation where consolidation of findings is difficult. The studies which are contained within this section do not represent the full extent of the existing literature on metacognition in group work. However, they have been chosen for a number of reasons: Firstly, for their relevance to the research presented in this thesis. The studies are either based within the area of mathematical problem solving, or they relate to primary aged children. Secondly, the aims of the studies are united, again in line with those in this thesis. Although all of the studies utilised different conceptualisations and operationalisations of metacognition and collaboration, they all seek to understand metacognition during group work. Thirdly, in line with Azevedo's (2009) suggestion, the studies provide clarity of theoretical positioning regarding their design on the use of metacognition during group work. Fourthly, the studies focussed on the use of metacognition by students in natural classroom settings and there was no reported use of interventions or scaffolding of metacognitive processes (although some studies did manipulate the type of students chosen for their study). Finally, studies were chosen in order to highlight the diversity of conceptualisations used in the area. Each study presented used either a different theoretical model of learning, or a different conceptualisation or operationalisation of both metacognition and the role of social interaction in learning. This overview of the literature highlights the diversity of research in the area of metacognition and emphasises the need for researchers to make clear their theoretical understanding of metacognition and group work, together with their operationalisation of these terms.

This review covers seven research papers which have sought to understand the use of metacognition by students during a group work design. In the next section I will consider the conceptualisation and operationalisation of metacognition used in the studies and the extent to which each study furthers our understanding of the impact of interaction on the use of metacognition.

3.8 Review of Current Research

Researchers who have studied the use of metacognition in group situations have differed in terms of their theoretical understanding of the relationship between group work and learning; the operationalisation of this relationship; their conceptual understanding of the term metacognition and the operationalisation of this. This has led to the current situation where the empirical evidence in this area cannot be consolidated to provide an understanding of metacognition in group learning. In this section I will expose these differences in justification of my assertion that a new conceptualisation of collaborative metacognition is required which will allow researchers to focus on a very specific aspect of student metacognition. For each paper I will briefly describe the aims and the methods used. I will also highlight the theoretical understandings which have informed the research and finally assess the extent to which they further our understanding in this area.

Artz and Armour-Thomas (1992) Development of a Cognitive-Metacognitive Framework for Protocol Analysis of Mathematical Problem Solving in Small Groups

The study by Artz and Armour-Thomas was conducted in the area of mathematical problem solving. The aim of the study was to provide a framework for conducting protocol analysis in small group work during problem solving. The authors based their use of group work on the theoretical understanding of information processing models of learning. Artz and Armour-Thomas (1992) drew on the notion that during the process of problem solving, individual cognitive resources are stretched beyond capacity and as a result the process of regulation and monitoring become difficult. By placing students in groups they suggested that the cognitive load might be reduced since other students would monitor inputs and progress (e.g. Garofalo & Lester 1985; Schoenfeld 1987).

The students in the study were approx 12 years of age and worked in groups of four mixed ability students. Artz and Armour-Thomas (1992) were interested in identifying learning processes during the problem solving sessions, with a specific focus on the use of cognitive and metacognitive talk. Two groups of students were videotaped during their problem solving sessions and their verbal interactions were used as data. In developing their coding scheme, the authors chose to focus on the distinction between cognition and metacognition. The researchers based their understanding on both Flavell's (1981) previously mentioned distinction and that used by Garofalo and Lester (1985, p164) - *"cognition is involved in doing, whereas metacognition is involved in choosing and planning what to do and monitoring what is being done"*. Artz and Armour-Thomas (1992) focussed on Schoenfeld's (1985) framework for problem solving. Student utterances were separated using Schoenfeld's (1985) framework for problem solving, highlighting instances of reading; planning and analysing. Each utterance was then coded as metacognitive or cognitive based on the aforementioned differentiation. The metacognitive categories adopted by Artz and Armour-Thomas (1992) were those cited by Flavell (1981) in his model of metacognition.

Artz and Armour-Thomas (1992) found that those groups which were successful in their problem solving attempts displayed higher quantities of metacognitive talk than those who did not succeed. Although the research was primarily concerned with individuals working within a group setting, the researchers did highlight the different levels of individual interaction which were displayed within each group. For example, in one group, an individual seemed to dominate discussion and make important decisions regarding the way in which the problem solving should progress, with little regard to others. In another group, all members appeared to interact towards the problem solution. However, it is not clear if the authors deduced this from watching the videos or if they were able in some way to operationalise the interactions.

This study provides an understanding of the term metacognition which might fit the conceptualisation adopted in this thesis which was outlined in the previous section. It also provides information regarding the efficacy of higher levels of metacognition during successful problem solving. However, it does not represent research which might be understood as considering *collaborative* metacognition since only the individual contributions of students were recorded. There was no attempt to consider a relationship between these contributions and the type of talk which was displayed either before or after.

Goos and Galbraith (1996) Do it this way! Metacognitive strategies in collaborative mathematical problem solving

The aim of the study by Goos and Galbraith was to understand the way in which students monitored progress during mathematical problem solving whilst working collaboratively. Two high school students were videotaped during their problem solving sessions and the resultant verbal data were used for the analysis.

Although Goos and Galbraith adopted the same theoretical understanding of learning as Artz and Armour-Thomas (1992), that of the information processing model, they cited different reasons for their use of a group work design. Their adoption of such an approach was a methodological one in response to criticisms of previously used think-aloud protocols. By grouping students, verbalisation would become a more natural occurrence and was more likely to reflect typical thinking processes (Schoenfeld 1985). However, the authors also acknowledged that the process of working with another might in itself encourage metacognition through the requirement to defend and elaborate on suggestions. Again, as with the previously mentioned study, Goos and Galbraith (1996) based their understanding of metacognition on Flavell's (1981) model and also the distinction previously mentioned by Garofalo and Lester (1985). Their coding scheme was adapted from Schoenfeld's (1985) episode analysis. However, their operationalisation of metacognition was in the form of metacognitive *acts*. These acts were defined as *new ideas* and *assessments*. *New ideas* were coded when useful information was suggested which might progress the problem solving activity, or a new approach may be suggested. *Assessments* related to the students' assessment of a procedure, a result, their own knowledge or task difficulty.

Through attributing these metacognitive acts to each student, the authors produced metacognitive characteristics of each student. For example, whilst one student was able to produce lots of ideas, these were constantly monitored by his partner for their usefulness. This resulted in failure of a task due to the insistence of the *monitoring* student that the pair adopt his strategy.

This study by Goos and Galbraith (1996) has highlighted the potentially negative impact of collaborative interaction when students do not fully consider the usefulness of strategies. It seems that it was through unhelpful social interactions that progress in the problem solving activity suffered. However, it is difficult to assess the impact of the interactions of each student on their use of metacognition since there is no clear operationalisation of the term collaboration in the paper. Rather it would appear the authors have made a judgement as to whether or not the students were working together at various points which has been based on the video data.

There was one exception to this and it was at points when a student proposed a new idea. The response of the partner was coded as being ignored, rejected or accepted. This is the only point when any clear connection was made between metacognitive acts and the partner. Whilst it might be clear when a student verbally rejects an idea, the use of the term *ignored* is difficult to justify. When students are working together we cannot assume that when one speaks the other will *hear* and then choose to ignore. Therefore, I would suggest that information regarding the collaborative nature of the discussion was flawed. Although this study provides potentially useful information regarding the impact of a partner on the use of metacognition, the relationship is not entirely clear since the concept of collaboration has not been clearly defined.

Goos, Galbraith and Renshaw (2002) Socially mediated metacognition: Creating collaborative zones of proximal development in small group problem solving

The design adopted by Goos and Galbraith (1996) was developed by Goos et al (2002) for a study which sought to understand the way in which collaborative interaction might mediate the use of metacognition by students. The authors studied secondary school students over a three year period during their timetabled mathematics problem solving classes. Students who showed a preference for working with others and who also displayed higher levels of metacognitive sophistication than others, were chosen to be videotaped. The verbal data were coded for analysis. Data from three transcripts (each constituted two students working together during one session) were analysed to provide an account of successful problem solving sessions. Data from another three transcripts were used to provide an account of unsuccessful problem solving sessions.

Unlike the previous study, this study was informed by Vygotsky's zone of proximal development in understanding the role of social interaction on learning. However, the conceptualisation of metacognition and the coding scheme were the same as those adopted in the previous study which coded metacognitive acts as *new ideas* or *assessments*. *New ideas* were when potentially useful information was given, or an alternative approach suggested. This might be viewed in terms of *knowledge of* cognition. One limitation of the study is that Goos et al (2002) only included *'potentially useful information or an alternative approach (p199)'* when coding data as metacognitive. Therefore, if a student presented a strategy or approach which was inappropriate for solving the problem, it was not coded as metacognition. As mentioned in the literature review, metacognitive knowledge might consist of declarative, conditional and procedural knowledge. An important factor noted by Flavell (1979) was that metacognitive knowledge may be incorrect and incomplete. Within a problem solving situation, it is important to recognise when metacognitive knowledge is incorrect. For example, if a group of students was working toward a solution with an incorrect understanding of some aspect, it is crucial that this be corrected in order to progress. By excluding specific types of metacognitive knowledge, it is not possible to gain a full understanding of the role of metacognition in the group situation, or the role of the group on the use of metacognition.

Assessments were viewed in terms of *regulation of cognition*. As mentioned in the previous chapter, regulation of cognition consists of planning, monitoring and evaluating. *Assessments* could be an assessment of the appropriateness of a strategy (planning), the accuracy of a result (evaluating) or an assessment of a student's own understanding (monitoring).

The important development from the previous study was that the researchers operationalised the term collaboration. Goos et al (2002) highlighted one distinguishing feature of collaboration as *mutuality*. Mutuality is a process whereby each student explores their own and others' ideas in order to construct a shared understanding of the problem at hand. If students are to produce solutions which are agreeable to all, they must propose and justify ways forward toward solving the problem. As such, Goos et al operationalised collaboration as *'a coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of the problem'* (Teasley & Roschelle, 1993 p 235). Students' interactions were therefore viewed as contributing to the shared understanding and solution of the problem. These type of interactions were termed *transactive* (Teasley & Roschelle, 1993). Data were coded in terms of their metacognitive content (i.e. new ideas and assessments) and also in terms of their transactive (or collaborative) nature.

Goos et al (2002) made specific reference to the term collaborative metacognitive activity and defined it as utterances which were simultaneously metacognitive and transactive in nature. Although the researchers highlighted the reciprocal nature of collaborative metacognitive activity, their operationalisation allowed for an utterance to be coded as such when only one person was involved in the process. For example a student might say 'what am I doing wrong – can someone tell me?'. This would be classed as collaborative metacognition even when no one replied. It is difficult in such cases to argue that the requirement for feedback, or indeed the metacognitive knowledge that the adopted process is not correct, would not have been displayed if the student was working alone. In their analysis Goos et al found that around half of all *collaborative metacognitive* utterances were self-oriented such as this one where students questioned their own thinking in the group situation and invited others to question it. However, the *interactive* nature of the metacognitive questioning was not explored to ascertain if a response was produced.

Goos et al (2002) did examine the interaction between metacognitive utterances and transactive utterances by considering the proportions of metacognitive utterances which were either followed by or preceded by a transactive utterance and these were termed nodes. They found that in successful problem solving sessions, there were about twice as many *nodes* than during unsuccessful sessions. This suggests that the interaction between students is an important factor in successful sessions. However, Goos et al (2002) did not consider further the relationship between transactive, metacognitive and other types of interactions such as cognitive or social. Whilst the study provided detailed information regarding the relationship between transactive talk and metacognitive talk, it is not clear how useful this is compared to other types of talk. For example, a similar relationship might be found between cognitive and transactive talk.

Goos et al (2002) have therefore provided a useful but limited understanding of the term collaborative metacognition. The term was confined to the utterances of one student during the course of interactions. However, I would argue that it is these interactions which are vital in understanding the impact of other students on the use of metacognition. Whilst Goos et al (2002) did consider these interactions in their use of nodes, they did not probe this further and specifically in relationship to other types of talk.

Hurme, Palonen and Jarvela (2006) Metacognition in joint discussions: an analysis of the patterns of interaction and the metacognitive content of the networked discussions in mathematics

Utilising a computer supported collaborative learning design, Hurme et al (2006) studied the interactive and metacognitive nature of computer posts between students. Sixteen 13-year old students, worked in pairs to send and receive computer notes during a mathematical problem solving task. The aim of the study was to further the understanding of the role of metacognition during computer supported collaborative learning tasks. The computer notes from each student pair were coded in terms of their metacognitive content. Multi dimensional scaling was also used to highlight patterns of interaction between students. This allowed the researchers to make inferences regarding the level of interaction of students and their use of metacognition.

Hurme et al (2006) chose to adopt a conceptualisation of metacognition which was based on Flavell’s distinction between metacognitive knowledge and metacognitive skills. Their operationalisation was defined by a coding scheme which was based on Flavell’s *person, task* and *strategy* variables referred to in the literature review. Metacognitive skills were defined after Brown’s (1987) and Schraw and Dennison’s (1994) categories of *planning, monitoring* and *evaluating.* Hurme et al further classified a metacognitive act as something which ‘*referred to the ongoing discussion or provided reasons for arguments’* (p187). However, this statement is ambiguous and possibly constitutes a limitation on the type of act coded as metacognition. The statement could be interpreted such that metacognition can only be *on-task*. Alternatively it could be that metacognition can only be defined as such if it contributes to the part of the problem to which the students are attending at the precise moment. Such a definition may limit the understanding of metacognition during the collaborative problem solving process. For example, students may be working on a particular aspect of the problem but information from that part may trigger some aspect of another part of the problem. As mentioned in the previous chapter, Flavell suggested that items of metacognitive knowledge, which might be seemingly unconnected to the current situation, may become available during problem solving situations. For example, an individual may suddenly remember a previous problem, or part of a problem and use this towards solution of the goal. Therefore, when considering metacognition during collaborative tasks, it would seem prudent to include *all* acts of metacognition when attempting to understand its role in the problem solving situation.

Collaboration was defined as an instance when one pair of students posted a comment and another pair replied to that post. However, it is not clear from the study if *any* type of reply constituted collaboration, or if all replies were included. For example, one pair may have made a suggestion regarding the problem and another pair may have replied with a completely different suggestion as opposed to providing their thoughts on the initial suggestion. This reply may have made no reference to the original suggestion yet may be termed as a collaborative response. Furthermore, there is no indication of the social nature of replies. Students may have interacted on a social level with one another during the course of the study. However, the researchers make no reference to this, specifically whether or not these interactions were included.

Despite this, the researchers did highlight the reciprocal nature of metacognition in a collaborative situation. To operationalise this reciprocity, the researchers coded the purpose of the metacognition displayed. The purpose could have been either to aid the thinking processes of the pair producing the note or the purpose was to help the pair receiving the note. As such, collaborative metacognition might be understood as an act of metacognition which was proposed as regulation or monitoring of a pair's own thinking or that of another pair.

One of the main aims of the Hurme et al (2006) study was to ascertain if there was a relationship between interaction (i.e. those posting higher quantities of notes) and the metacognitive quality of the notes. Although students appeared to create networks where there seemed to be a preferential level of interaction, there was no relationship between this and the use of metacognition. However, students who had higher levels of reciprocal interactions with other student pairs did also display higher levels of metacognitive notes. This suggests, and supports the findings of Goos et al (2002) that the process of collaboration may contribute towards mediating the use of metacognition.

Whilst this study provides helpful information regarding the operationalisation of collaboration and a possible method for probing the relationship between collaboration and the use of metacognition, there are several drawbacks. Pairs of students worked together to produce a note to other pairs of students. As such, Hurme et al (2006) were studying the collaborative metacognitive activity of students in a framework of collaborative metacognitive activity across many pairs of students. As Hurme et al (2006) acknowledge, it is probable that students would have negotiated the content of the note before posting it and therefore may have already engaged in collaborative metacognitive activities. Furthermore, in studying only replies, Hurme et al (2006) fail to understand the relationship of initial suggestions in soliciting metacognitive replies. This is important since the essence of collaboration is to share and critique each other's and one's own ideas in order to achieve shared understanding. By including only replies, we fail to understand the kind of interactions which might encourage this collaboration.

Larkin (2009) Socially mediated metacognition and learning to write

Larkin studied the metacognition and collaborative interactions of 5-7 year old students during their writing lessons in school. The aim of the study was to better understand the way in which metacognition was socially constructed and mediated by young children as they learned to write. Students were observed over a two-year period. Data for the analysis were taken from 36 children to provide a mix of low, middle and high-achieving pairs. The students were videotaped and their verbal interactions were analysed. Further data which informed the analysis were field notes, researcher observations and reflections and teacher reflections.

The understanding of metacognition adopted in the study was based on a distinction between knowledge of cognition and regulation of cognition, drawing on the works of Flavell (1976), Schraw (1998) and Brown (1987). Metacognition was defined as:

> *'observable shifts in cognition from a focus on the task or social interaction at a cognitive level to a focus on an aspect of cognition itself or emotion or a focus on regulation and control of thinking'*
>
> (Larkin, 2009 p152).

The operationalisation chosen by Larkin (2009) consisted of definitions of metacognition which were derived from the data rather than through a coding scheme. Types of metacognition which were highlighted in the study were grouped as being metacognitive knowledge or monitoring. The *type* of act was then recorded as being unique to that particular situation.

Larkin's (2009) approach undoubtedly allows researchers to gain a deeper insight to the types of interactions which influence positive problem solving. Furthermore, Larkin

(2009) focussed on very young children. The type of talk displayed by such young children is less sophisticated than older children. As Larkin notes, due to the nature of talk in such young children, it is often very difficult to determine where one episode of metacognition might begin and end. Whilst adoption of such an approach creates difficulties in terms of consolidation of findings, it does provide an insight to the metacognitive abilities of very young children.

Larkin (2009) referred to Vygotsky's Zone of Proximal Development and Piaget's cognitive conflict to understand the role of others in the learning process. In order to highlight this role, she operationalised collaboration as part of a wider *social* behaviour category. As with the metacognitive behaviours, collaborative behaviours were derived from the data rather than being pre-specified. Such behaviours included students helping one another by suggesting ideas; helping with spellings etc. They also included behaviours such as discussing ideas before writing. Within the paper, it is not clear how metacognition and collaboration interacted. By producing a definition of metacognition and a separate understanding of collaboration the researcher gave a picture of *amount* and *type* of each which were displayed by groups. However, this was a static picture which did not highlight the *interactive* nature of the two concepts. The definition of metacognitive acts as *'those which were acknowledged by the partnership and influenced the collaborative task*' (p152) does imply a certain level of recipocracy which would be found in collaboration. However, interpretation of such broad definitions is difficult. The meaning of *influence* on the collaborative task is not clear, nor is *acknowledged by the partnership*. For example, acknowledgement might simply be a word to suggest to one member that the other has heard what they have said. The acknowledgement might have been negative or positive in nature. Also, it is not always possible to assume that when an individual acknowledges in some way that another has spoken, that they have listened and understood. Potentially one child may have made a suggestion and the other may have acknowledged by saying 'yes' and the task was then influenced by that acknowledgement.

Whilst this acknowledgement of another's input might appear to indicate collaboration, it is vitally important that researchers make clear the impact of that acknowledgement. Bearing this in mind it is important to understand the nature of Larkin's (2009) study. She was concerned with the way in which very young children interact and use metacognition during writing tasks. The verbal interaction skills and metacognitive ability of such young children are often less well developed than their older counterparts and therefore different approaches may be required to understand the nature of their interactions. This sentiment is echoed by Whitebread et al (2009) who have developed tools for understanding and measuring metacognition in very young children. The study of group metacognition in very young children is illuminating in terms of the types of metacognition and collaborative behaviours that they might display. However, I would suggest that such studies require a different approach from those used by older children. The findings of such a study therefore cannot be consolidated with studies which involve, for example, secondary school children, due to specific methodological requirements.

Iiskala, Vauras and Lehtinen (2004) Socially-shared metacognition in peer learning? & Iiskala, Vauras, Lehtinen and Salonen (2010) Socially shared metacognition of dyads of pupils in collaborative mathematical problem-solving processes

In a series of two studies Iiskala et al sought to understand if and how metacognition was displayed in social interaction during collaborative problem solving. The first study, Iiskala et al (2004) analysed the talk of four 10-year old high achieving students working collaboratively in pairs during their mathematical problem solving sessions. Data were in the form of videotaped discussions of the pairs and interviews. The verbal interactions were coded and the non-verbal communication was also included in the analysis, e.g. eye contact, pointing etc.

By focussing on group level activity, Iiskala, et al (2004) viewed learning, not as an individual process which may be enhanced by social interaction, but as a group process which was shaped by social and cultural understandings. This group level focus had implications for the definition of metacognition that was used. Since the researchers were interested in group level metacognition, the definitions of metacognition and collaboration were intertwined. The authors defined group metacognition in two ways: Firstly group metacognition was recorded where *'the students acted taking into consideration each* other' (p 155). This referred to instances where one student may have looked at another whilst making an alternative proposal the problem solution. Group metacognition could also be recorded when '*the student was aware of and attempted to monitor or regulate the pair's cognitive working process'* (p155). This may occur for example if one student decided to stop the problem solving process and consider alternative ways of progressing.

It is clear from these two definitions that metacognition is seen as a *regulating* factor in a group's activity. Whilst this gives a picture of the way in which groups regulate cognition in order to arrive at a goal, it fails to highlight the complexity of the individual in a group situation. The theoretical notion of group cognition may best help us to understand the way in which groups work, however, it is important to also acknowledge individual level issues which may impact on the group regulation. Furthermore, the second description of what constituted metacognition is quite vague. Simply by looking at another who is sitting beside them whilst making an alternative suggestion, the action is regarded as metacognitive. However, it is entirely possible that a student may make a suggestion based on their own understanding of the problem with little regard for what has been said previously.

This study was extended by Iiskala, Vauras, Lehtinen and Salonen (2010) with a larger number of students. Again, working in dyads, students were aged approximately 10 years old. The aim of the study was to contribute to evidence for the social nature of metacognitive *regulation*.

From a theoretical perspective, Iiskala et al (2010) viewed the group again as a social system, distinctly different from a group of individuals working side by side. The researchers suggested that when students work independently, self-regulation may be the process by which they monitor and evaluate progress. However, when a group works together, regulation will occur *inter*-individually. Therefore, Iiskala et al (2010) suggested that:

> "*socially shared metacognition* is the *'consensual monitoring and regulation of joint cognitive processes in demanding collaborative problem-solving situations"*
> (Iiskala et al 2010 p1).

As previously mentioned, the role of knowledge of cognition is also an important in the problem solving process since it is crucial that it is correct knowledge for the specific problem. Regulation processes may highlight a change of direction or evaluation of a solution. However, focussing purely on processes rather than also on the content of knowledge of cognition which is displayed, gives only part of the picture of the group problem solving situation.

Metacognition in the studies by Iiskala et al (2004) and Iiskala et al (2010) is viewed as *regulatory* and *monitoring* processes during group problem solving. The social interaction from collaboration is paramount to the learning process where *shared cognition* may result. However, the individual in the situation is not taken into account. By disregarding the individual, the researchers fail to highlight the importance of individual issues which may have a bearing on social interactions. Furthermore, the interpretation of what is metacognition may be viewed as being ambiguous.

Sfard and Kieran (2001) highlight the complexity of social interaction and the importance of caution when interpreting verbal data:

> *"Interpersonal communication is an extremely complex phenomenon, in that at any given moment each participant is simultaneously involved in a number of object-level and meta-level activities: in trying to understand the explicit contents of previous utterances and to produce new ones, in monitoring the interaction, in presenting herself to others the way she would like to be seen, in engineering her position within the group, and so on"*
>
> (Sfard & Kieran, 2001 p192).

Caution is therefore required when interpreting meaning of individual actions, such as assuming that when a student looks at another whilst talking, they are intending their interactions to be collaborative. Rather, I would argue, it is important to be able to operationalise clearly actual instances where an individual has, beyond reasonable doubt, responded to the utterance of another.

3.9 Summary of Review of Empirical Evidence

In this section I have highlighted the different conceptualisations and operationalisations of metacognition which exist in research papers which attempt to understand the use of metacognition during group learning. The purpose of so doing is to highlight the difficulty of consolidation of findings. Although each study provides a glimpse of the role of social interaction on the use of metacognition, limitations exist in the operationalisation of the term metacognition, the theoretical understanding on the nature of learning and also on the methods and designs adopted by researchers.

Whilst all of the aforementioned researchers have acknowledged that metacognition can be conceptualised as something distinct from cognition and that metacognition consists of an element of knowledge of cognition and the ability to regulate cognition, operationalisation of this concept varies greatly between researchers. Coding schemes which are the result of operationalisation might have a direct link to the theoretical concept (e.g. Hurme et al 2006), they may be produced using an approach akin to grounded theory (e.g. Larkin 2009) or they may be produced through the incorporation of other theoretical understandings, such as problem solving strategies (e.g. Goos & Galbraith 1996). In order to further our understanding of metacognition during group work, I believe it is necessary to be able to conceptualise and operationalise metacognition consistently in order to allow consolidation of results. The previously mentioned research studies have gone some way to further our understanding. However, they leave gaps since none fully integrate current models of metacognition, although Hurme et al (2006) go some way to do this, their additional operationalisation of metacognition is a limitation as it is ambiguous and difficult to interpret.

I would therefore propose that the first limitation of the research on metacognition in group settings reviewed here, is that consolidation of findings is not possible due to the diversity of conceptualisations and operationalisations of metacognition. It is clear that even when researchers conceptualise metacognition in a similar way, they may choose to operationalise it in different ways. There may of course be many reasons for this. However, in order to provide a deeper understanding of the way in which students use metacognition during collaborative problem solving, it is important to provide a clear and useable conceptualisation and operationalisation of the term collaborative metacognition.

A second limitation to our understanding is the use of different theoretical perspectives by researchers. For example, the aim of the studies by Artz and Armour-Thomas and Goos and Galbraith (1996) was to understand the use of metacognition during group work. However, very little attention was paid to the impact of interactions on the use of metacognition. Rather, due to the adoption of an information processing model of learning, the researchers focussed solely on the individual. The studies by Iiskala et al (2004, 2010) take the opposite approach where the group is taken as the unit of analysis rather than the individual. Iiskala et al adopted a socio-cultural understanding of learning, where individuals work together towards a shared understanding of a problem. Metacognition was viewed as a group process rather than an individual one. As such collaboration and metacognition were intertwined. However, by failing to acknowledge the role of the individual during the process, the researchers failed to consider issues which each individual may bring to the group. These studies provide evidence of the impact of theoretical perspectives on our understanding of metacognition during group work.

A final factor which has limited our understanding of metacognition during group work is the adoption of specific methods or the design of studies. For example, through studying very young children, Larkin (2009) was faced with issue of metacognitive and social interactions skills which were still at a very early level of development. In such cases, it is perhaps more difficult to apply knowledge gained from older students. Although the methods adopted to understand the use of metacognition provide rich information in a specific situation, it is difficult to compare or consolidate the data with other findings. The design of the study was also a limitation in the Hurme et al (2006) study where student pairs sent notes to other student pairs. Although the researchers were able to operationalise metacognition and collaboration, student pairs would probably have collaborated prior to writing the notes which were sent to other pairs. Although the authors did consider the relationship between participation in the discussion and levels of metacognition, they did not explore the reciprocal relationship between collaboration and metacognition.

Goos et al (2002) proposed a promising operationalisation of the term collaborative metacognition which highlighted the *transactive* nature of talk between students. However, they failed to make the distinction between individual metacognition which may have occurred regardless of the presence of others and collaborative metacognition which occurred through the process of interaction. Although an individual may ask for feedback during their talk, there was no attempt to clarify if this actually occurred. Furthermore, although the researchers established that successful problem solving contained groups, or nodes, of collaborative metacognition, there was no attempt to establish a relationship between metacognitive talk and transactive talk in relation to other types of talk.

The aim of this section was to ascertain the extent to which the research studies which have been reviewed have proposed and provided evidence for a relationship between collaboration and metacognition. Although all of these studies have considered metacognition during group work, I have shown that our understanding is still limited due to the theoretical understandings and operationalisations adopted by researchers as well as the methods and designs chosen for the studies.

Conceptualisations of learning, metacognition and collaboration, influence and potentially limit, the results produced in research which aims to understand metacognition in a group situation. For example, when only certain aspects of metacognition are studied as in the Iiskala et al (2004) and Goos et al (2002), a limited understanding of the role of metacognition in group work is produced. Similarly, when the role of group work is not clearly defined, or is given less importance as in the Artz and Armour-Thomas (1992) and Larkin (2009) studies, it is difficult to appreciate the *interactive* influence of peers on the use of metacognition. Finally, through producing *situated* definitions of metacognitive acts, it is difficult to consolidate research in the area.

Despite apparent shortcomings in the aforementioned studies, they give some indication that the group situation will impact on the use of metacognition by students. However, the evidence presented highlights the need for a clear definition of collaborative metacognition which can be used in research studies which aim to understand the relationship between talk which has an interactive nature and the use of metacognition. Furthermore, the definition must have ecological validity and reflect actual classroom learning. For many of the aforementioned studies, data was gathered from only high achieving students (Goos et al 2002, Iiskala 2004 & 2010, Hurme et al 2006) who showed a preference for group learning (e.g. Goos et al 2002), or higher aptitude for social interaction (e.g. Iiskala 2004). In some cases data was collected outwith the normal classroom environment (Iiskala et al 2004 & 2010) and often involved only student dyads (e.g. Goos and Galbraith 1996, Goos et al 2002, Iiskala et al 2004 & 2010). Problem solving sessions in primary schools often involve groups of more than two of mixed ability students. Furthermore, problem solving situations throughout life, especially in employment situations, require interaction with more than one other person. It is vital therefore that information be gathered which highlights the impact of such a collaborative situation on the use of metacognition.

In the following section I will present the theoretical model of collaborative metacognition which I have adopted in this thesis. I will then go on to describe the study which forms the basis of the following results chapters, together with evidence of the relationship between the two concepts.

3.10 Adoption of theoretical model of collaborative metacognition

As previously mentioned, the theoretical understanding of metacognition adopted in this thesis refers to previous models with a distinction between knowledge of cognition and regulation of cognition. Collaboration is understood in terms of students being explicitly involved in the process of working together on the activity of the problem to be solved.

Learning in a group can be viewed as an *activity* which involves an attempt by members to reach a shared understanding through the use of various tools, rules and divisions of labour. This is similar to Teasley and Roschelle's (1993) description of collaboration as:

> "*a coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of the problem"*
>
> (Teasley & Roschelle, 1993 p8).

The notion of *continued attempt* suggests a reciprocal relationship between students where the process of sharing one's ideas might act as a catalyst for others to enter the conversation. Collaborative metacognition therefore might be separated to show two distinct components which highlight the reciprocity of the concept: Metacognition which contributes to participation in the activity and metacognition as a result of participation in the activity. The term collaborative metacognition which will be adopted in this thesis can therefore be conceptualised as the following:

> "Collaborative metacognition is metacognition which can be identified as having contributed to, or arisen as a result of, participation in the group activity."

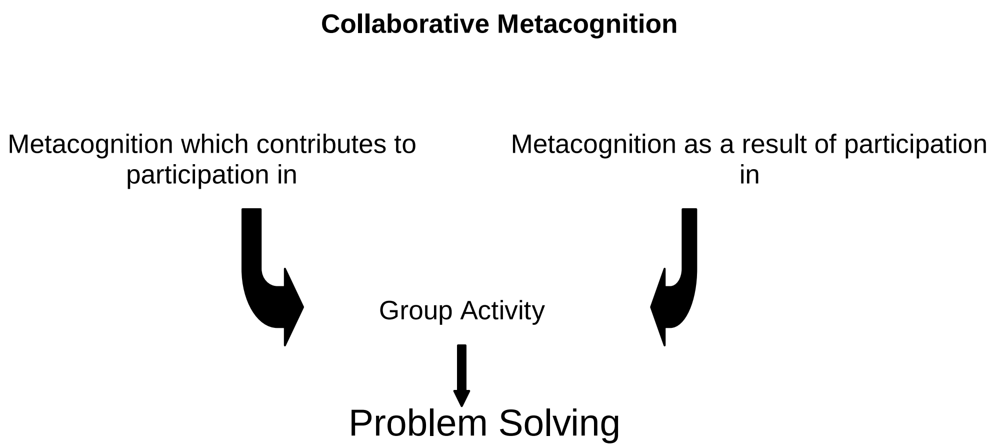


Figure 3- 1 Proposed conceptualisation of collaborative metacognition

This conceptualisation of collaborative metacognition has been influenced to a great extent by the work of Goos et al (2002). As mentioned in the previous section they provided a very useful but limited definition of collaborative metacognition based on the notion of transactive discussion. I propose to develop this definition and provide evidence of its usefulness through a study which aims to highlight the relationship between transactive talk and the use of metacognition. My definition allows for individual metacognition to be displayed in a group setting, but this metacognition has a particular value which appears to encourage or be a result of participation. In order to ascertain the usefulness of such a conceptualisation, the term was operationalised and used in the research study contained in this thesis. The sub-research question addressed was:

Is there a relationship between collaborative talk and metacognitive talk?

3.11 The Study

The data reported in this study were from a wider investigation into the use of collaborative metacognition during problem solving in primary aged children. Twelve students were observed during their collaborative problem solving sessions in mathematics. Students in a primary 5 classroom (aged 9-10) were asked to work together in groups of four each week for one full school term lasting 15 weeks.

Research suggests that it is difficult to isolate specific issues which may influence group dynamics on a global basis (Dillenbourg, Baker, Blaye & O'Malley 1995). Issues such as the most effective group size, number of girls versus boys and levels of knowledge will all impact on collaboration to some extent. However, that extent is different for each task and indeed may be different from day to day. It is therefore important to acknowledge that such issues exist but are not issues which can be eradicated in a normal classroom setting. In light of this, and as one of the main purposes of the study was to understand metacognition in a natural group setting in a classroom, it was left to the teacher to choose how to group students based on what would normally occur.

Students were grouped in four with two boys and two girls in each and the groups reflected the mixed ability of the class. Those students not participating in the study were grouped and worked in the same way as those in the study.

The problem solving sessions lasted approximately 90 minutes. The lessons began with a short whole class discussion led by the teacher, the primary purpose of which was to provide an overview of the task at hand and remind students that they were to work together to jointly solve the problem. Students were then asked to join their groups and work on the problem. During the problem solving sessions, the teacher and researcher joined the groups at various points to monitor progress. Occasionally, if the teacher felt that *all* groups were struggling with some aspect of the problem, she would call them together for a whole-class discussion on that particular aspect.

This design differs to the existing research which considers metacognition in group work. Previous research has focussed on students who are high-achieving (Goos et al 2002, Iiskala 2004 & 2010, Hurme et al 2006) show a preference for group work (e.g. Goos et al 2002) and students working in dyads (e.g. Iiskala 2010). To my knowledge there are no published studies which consider collaborative metacognition during mathematical problem solving within a completely natural classroom setting which has not been modified in order to accommodate potential findings.

Students worked together each week and were videotaped over three sessions. One session near the beginning of the study, one in the middle and one near the end of the study. Further information and justification for the design of the study can be found in the methods section.

3.11.1 Data and Coding

Data were in the form of verbal utterances. Data were taken from three groups of students over the three sessions, providing a total of 9 videotaped sessions. In order to understand the extent to which students displayed both metacognition and transactive talk, two coding schemes were developed. The first was to understand the learning processes and type of talk that students displayed, specifically focussing on metacognition. The second coding scheme was required to understand the collaborative nature of the interactions. Further details of the development of the coding schemes can be found in the methods chapter and the coding schemes can be found in Appendix A.

3.11.2 Data Analysis

Utterances were coded according to the coding schemes, firstly to understand the types of talk displayed. The transactive coding was then applied to understand the extent to which students interacted with one another. This double coding of the data meant that a metacognitive statement could also be coded as transactive and a transactive statement could also be metacognitive. Totals were provided for each type of talk. In order to investigate the relationship between transactive (collaborative) talk and other types of talk, it was necessary to understand the interactive nature of the analysis. Totals of each type of talk provided a static account of the quantities of talk displayed. However, I was interested in how often a transactive statement would lead to a metacognitive one and how often a metacognitive statement would lead to a transactive one. This interaction provided the operationalisation of collaborative metacognition.

Once the coding schemes had been applied, analysis was performed to produce an understanding of the type of statements which followed from each. Figures were produced for the amount of transactive statements which led to other statement types and also for the amounts of each statement type which led to a transactive statement. However, these figures did not provide a realistic account of the data since there were far more social statements than cognitive and metacognitive. A more appropriate method was to use proportions of each statement type which were preceded by a transactive statement and also which led to a transactive statement. It is these figures which are reported on in the results section.

As previously mentioned, the notion of collaboration is a theoretical one and the operationalisation of this term is through the use of transactive coding schemes. The research question has therefore been divided into two distinct questions which reflect the operationalisation of the term:

Is there a relationship between the transactive quality of a statement and the type of statement which followed it?

Is there a relationship between the type of statement made and the transactive quality of the statement which followed it?

3.11.3 Results

Is there a relationship between the transactive quality of a statement and the type of statement which followed it?

What proportion of each utterance type was preceded by a transactive utterance?

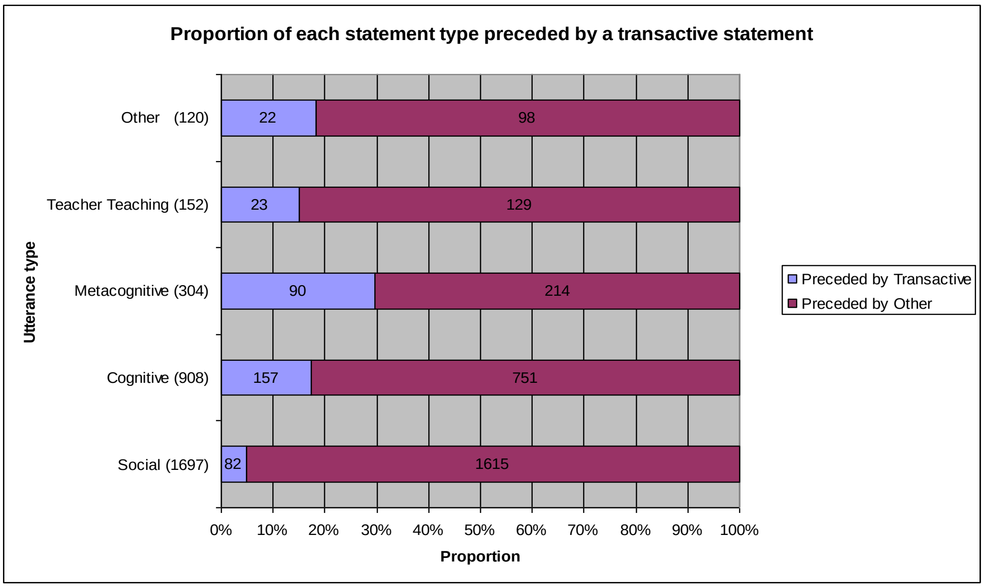


Figure 3- 2 Proportion of each statement type preceded by a transactive statement

Is there a relationship between the type of statement made and the transactive quality of the statement which follows it?

What proportion of each utterance type was followed by a transactive utterance?

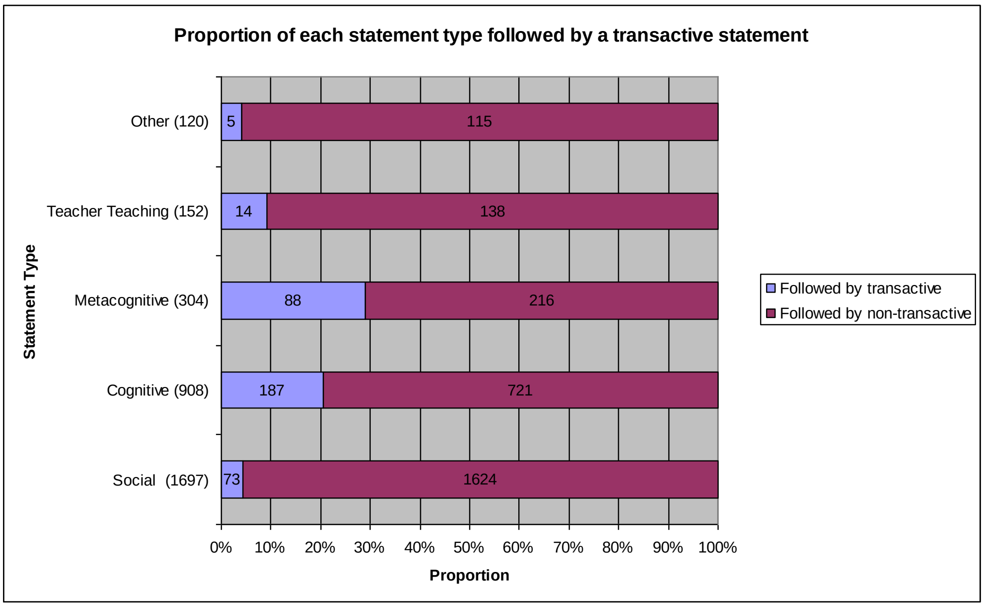


Figure 3- 3 Proportion of each statement type followed by a transactive statement

Figures (3-2) and (3-3) suggest a relationship between transactive statements and metacognitive statements. Although there were higher *quantities* of cognitive statements which both led to and were followed by a transactive statement, a higher *proportion* of metacognitive statements fell into this category. Overall, a higher proportion of metacognitive statements were followed by a transactive statement than were other statement types. Similarly when a metacognitive statement was made, a higher proportion of these were preceded by a transactive statement, than all other statement types.

Chi square tests of association were performed to ascertain if the differences were statistically significant. Test were performed for metacognitive and cognitive statements preceded by a transactive statement and also for the difference between metacognitive and cognitive followed by a transactive statement as these represented the largest proportions.

The purpose of a chi square test is explained differently by researchers. Coolican (2004) suggests a chi square is used to search for an association between data. Cohen, Manion and Morrison (2007) on the other hand describe a chi square test as a test for difference. The different descriptions can be better classified as what the research question wants to ascertain versus what the statistical analysis does. The chi square tests for a difference between expected frequencies and actual observed frequencies. In determining the difference between expected and observed frequencies, inferences can be made regarding the presence of an association between the categories.

The type of data appropriate for use with this test are categorical data where each item must appear in only one of the cells. Furthermore, some statisticians (e.g. Cochran 1954) suggest that no more than 20% of the cells should contain less than 5 counts. If such a case arises, a Fischer's Exact test is more appropriate than the Pearson's (Cochran 1954).

The data from this study were categorical and each utterance could only be coded as one type (e.g. metacognitive). Therefore a chi square was an appropriate test for ascertaining if there was difference between the observed and expected frequencies of each utterance type.

Utterances preceded by a transactive statement

Around 30% of all metacognitive utterances were preceded by a transactive statement compared to around 17% of all cognitive utterances. A χ^2 analysis of the difference was significant, (1, N = 1212), $\chi^2 = 21.28$, $p<0$.

Utterances followed by a transactive statement

Around 29% of all metacognitive utterances were then followed by a transactive statement compared to around 21% of all cognitive utterances. A χ^2 analysis of the difference was significant, (1, N = 1212), $\chi^2 = 9.05$, p=0.003.

Therefore, there was a significant difference between the proportion of metacognitive utterances which were preceded by a transactive utterance compared to cognitive utterances preceded by a transactive utterance. Similarly, there was a significant difference between the proportion of metacognitive utterances which were followed by a transactive utterance compared to the proportion of cognitive utterances followed by a transactive utterance.

3.12 Discussion and conclusion

In this chapter I have argued that a new definition and operationalisation of collaborative metacognition is required in the literature. This is based on the theoretical understanding that social interaction has an impact both on the use of metacognition and on learning. Current conceptualisations of metacognition, together with understandings concerning the role of metacognition in learning have been based mainly on research with individuals in individual learning environments. However, much of school learning, and indeed work-related activities, involve collaboration with others. It is necessary therefore to understand the use of metacognition and its relationship to learning in such situations. Researchers have begun to consider this. However, theoretical understandings of collaboration and metacognition, together with operationalisations of these terms differ between researchers. This has resulted in the current situation where consolidation of findings is not possible.

In reviewing current research in the area, a picture emerges of the impact of the social situation on the use of metacognition. However none of the research studies reviewed, was able to provide a clear account of the impact of reciprocal interaction on the use of metacognition. In order to provide a more coherent evidence base for theorists, educators and policy makers, I propose that a new theoretical understanding of the term collaborative metacognition be adopted. This term has been influenced by Vygotsky's notion of zone of proximal development and also by Activity Theory, which is a development of Vygotsky's theory. The theoretical notion of collaborative metacognition has two distinct strands: metacognition which contributes to participation in the activity and metacognition which is a result of participation in the activity. These two strands are fundamentally important in our understanding of the reciprocal nature of collaboration. When a student makes a metacognitive statement to the rest of the group in a problem solving situation it is difficult to assume that the student wants it to be acknowledged, or indeed commented on. However, regardless of the initial motivation for making the comment, if another student is then drawn into a discussion which questions, critiques or adds to that comment then this might be viewed as *contributing* to participation in the activity. The metacognitive statement appears then to have drawn in other group members. Similarly, when a student appears to question, critique or extend the argument or statement of another during the problem solving activity, metacognition which appears to be as a result of this might be viewed as collaborative metacognition.

The operationalisation of the term has been influenced greatly by the Goos et al (2002) study where the researchers based their notion of collaborative metacognition on Teasley and Roschelle's (1993) concept of transactive discussion.

The usefulness of the term collaborative metacognition was assessed through a study of primary school children. Results showed a higher proportion of metacognitive statements led to a transactive statement than did cognitive statements. Similarly, a higher proportion of transactive statements led to a metacognitive statement. Chi square tests of association showed these differences to be statistically significant. Transactive statements therefore appear to act as a catalyst for students to make their thinking processes available to others. Similarly, when a student makes a metacognitive statement, the processes of making their thinking known appears to draw others into the discussion.

This relates well to the theoretical understanding of the concept which was highlighted previously and as such provides a potential tool to assist researchers in their understanding of the role of metacognition during collaborative problem solving in mathematics.

Further investigation of this role will be reported in the results chapters. These chapters will address the relationship between collaborative metacognition and successful problem solving as well as the impact of the teacher on collaborative metacognition.

In the next chapter I will provide an overview of the methodologies which guided the research study.

Chapter Four Methodologies

4.1 Introduction

The purpose of this chapter is to explain the methodology which has been adopted in this research. Stahl (2004) notes that methodologies are often shaped by ontological assumptions regarding the nature of reality. Guba & Lincoln (1994) suggest that such assumptions are philosophical positions and are not themselves open to testing in any respect. However, different ontological assumptions have produced much debate within the area of educational research.

Gage (2009) claims that within educational research there has been what he terms paradigm wars. He notes that historically, apparently conflicting paradigms have been used to guide research in the field - the main two being interpretivist and positivist. According to Gage (2009), a consequence of adopting one or other paradigm has been that particular methods have to a certain extent been associated with each paradigm. Gage (2009) suggests that whilst there may be differences in the way in which researchers who adopt one paradigm over another approach and interpret their research, these differences should relate more to the types of issues which are under investigation rather than representing an attempt to promote one particular paradigm as the only possibility within the research field.

Pring (2000) suggests that whilst the reality is not quite as simple as a dichotomous split, the concept of two different views provides a useful way to understand the important connections between philosophical understandings of the nature of knowledge, theoretical frameworks and subsequent methodologies. Whereas Grix (2002) claims that the ontological position adopted by a researcher is representative of the way in which they view the world and the nature of reality. Grix (2002) suggests that this will then influence the type of research questions which are asked, together with the theoretical frameworks which are used to understand the research situation.

In this chapter I will firstly give a brief overview of the two main ontological views within the field of educational research, positivism and interpretivism. I will then provide an overview of a third paradigm that of critical realism, which I believe is in line with the ontological and epistemological assumptions made in the research contained within this thesis. Following this I will outline the theoretical framework which has informed my research. Finally, I will provide details of, and justification for, my choice of case study as the methodology used to address the research questions.

4.2 Ontological Assumptions

4.2.1 Positivism

The positivist view was borne out of a desire by philosophers, amongst them Auguste Comte, to study phenomena which were real and concrete. Pring (2000) notes that this was in contrast to more abstract phenomena which he suggested are not observable such as the truth status of religious beliefs. Pring (2000) suggests that the ontological belief associated with positivism is that there is a reality which exists independently of the researcher. However, he notes that within the post-positivist view this reality may not be fully obtainable. Rather, a critical look at evidence produced will provide the closest possible state towards certainty of reality without actually reaching it (Guba & Lincoln 1994). As Weber (2004) notes, the positivist tradition suggests that the researcher is able to observe and consider reality outwith their own subjectiveness.

By defining reality in a specific way, certain constraints are then put on the way we can come to *know* reality. The process of *knowing* is known as epistemology (Cohen, Mannion & Morrison 2007). Guba and Lincoln (2004) suggest that methodologies tend to reflect the view of reality which is adopted by the researcher. Gage (2009) notes that traditionally, those researchers adopting a positivist paradigm employ methods such as experimentation, or quasi-experimentation as well as non-experimental methods such as questionnaires, surveys or use of existing data.

Cohen et al (2007) suggest that in utilising such methodologies researchers hope that it is possible to arrive at general views regarding the studied phenomenon, which may then be applied to similar situations. Furthermore, the scientific and rigorous nature of the research design allows other researchers to employ the same techniques and replicate the studies. Pring (2000) suggests the importance of such research is that the type of data derived from such methodologies may allow practitioners to modify their pedagogy or it may help guide policy decisions at government or local authority level. Questionnaire and surveys may also be very useful in obtaining the views of many people in a short space of time.

However, such methodologies are not without their drawbacks. Gorard, Rushforth and Taylor (2004) noted that within educational research there may be a lack of good quality quantitative research. They have suggested that high-arching claims based on weak research design can be very damaging to the reputation of educational research.

Other criticisms of the positivist view go beyond the methodology employed and are concerned with the ontological and epistemological assumptions of the paradigm. Stahl (2007) suggested there is a danger when employing the positivist view that human beings may be viewed as 'objects' rather than people. Cohen et al (2007) note, similarly, that the positivist method has been criticised because it may reduce human experiencing to entities that are measurable, while disregarding the individual experiences of people.

4.2.2 Interpretivism

The main alternative discussed in the educational literature to positivism is that of interpretivism. Gage (2009) notes that this view proposed that the individual cannot be separated from reality and therefore it is not possible to engage in such objective research. Rather, the individual creates their own reality which is bound by the social, cultural and historical situation within which they find themselves. Pring (2000) suggested that a logical conclusion of this is that there are as many realities as there are people.

The main aim of interpretivist research is to understand situations rather than measure behaviours. Since the individual negotiates their own meaning of an event or situation it is necessary, when trying to understand the situation, to take account of these different meanings and their interactions (Pring 2000). However, this is not to say that each individual is unique in their understanding and that no generalisation may be found in the interpretivist paradigm.

Pring (2000) suggested that although many different complex situations interact to produce behaviours and beliefs of each individual, such beliefs and behaviours are also shaped by common and generalised concepts. Language for example is one such generalised concept. In order for individuals to function and communicate it is necessary to for them to be able to create a shared understanding of a situation. However, the path to this shared understanding starts from different points for different individuals. Pring (2000) suggests it is the role of the interpretivist to understand these different points and their continuing influence on the construction of shared meaning. Therefore generalisation is possible to a certain extent insofar as certain issues which occur in human nature are generalisable (Pring 2000).

Pring (2000) notes that whilst researchers who adopt an interpretivist view will generally employ qualitative methods, quantitative methods can be used as valid tools for generating knowledge. Naturalistic enquiry bears the characteristics of the interpretative paradigm. Naturalistic enquiry can take many forms including case study, comparative study, retrospective studies, longitudinal studies, ethnography, grounded theory and biography.

The interpretivist view draws criticism on one of the main aspects which differentiates it from the positivist view – subjectivity. Fay (1996) suggests that the subjectivity of the researcher is often criticised as being mistaken or based on superficial information. This not only applies to the researcher, but also those participating in research and whose thoughts and experiences are sought. However, in order to reduce the impact of subjectivity, triangulation of methods can be employed. In such a case, evidence from different perspectives can be drawn together in support of an argument.

However, Weber (2004) suggests that the criticism of subjectivity need not necessarily be dwelt upon. He notes that within the research process, both positivist and interpretivist views bring with them a certain amount of subjectivity which may bias results. However, the difference is that those in the interpretivist tradition make clear their subjectiveness, whereas positivists are less inclined so to do.

4.2.3 Critical Realism

According to Sayer (1992), critical realism is a paradigm which suggests that there is a reality which exists independently of our knowledge of it. Scott (2005) notes however that an important proposition of critical realism is that researchers may adopt the ontological position that reality does exist whilst at the same time holding the epistemological view that this reality may not be fully known. In other words, although a reality may exist outwith human consciousness, our attempts to understand this reality will never be able to result in absolute truth of what is real.

Scott (2005) notes that the way in which we order our world, the categories we use and the relationships we propose will always be replaceable by other categories or other relationships. This is not to say that these categories or relationships or findings from research studies are incorrect. Rather, Scott (2005) suggests that they are fallible. His use of the term refers to his proposition that each individual is only able to view the world from a fixed position. This position is bound by time, place and beliefs, etc. As such no individual has access to complete knowledge regarding the world and can only work within the information they have at that time. When new, or different, information becomes available, then new understanding and descriptions of the world are developed.

Sayer (1992) also acknowledges the impact of the social situation on knowledge production:

> *"Knowledge is also largely – though not exclusively – linguistic, and the nature of language and the way we communicate are not incidental to what is known and communicated. Awareness of these relationships is vital in evaluating knowledge"*
>
> Sayer (1992 p5)

It is due to this very social nature of knowledge construction that Scott (2005) argues there can be no fixed stable understanding of reality. Rather, what is real is constantly evolving and what we can come to know must be known and understood within the context of the fixed position from which they are viewed. Easton (2010) argues that a critical realist approach is concerned with understanding why things are the way they are.

Critical realism represents, as do interpretivism and positivism, a philosophical view of the nature of the world. Gage (2009) notes that the adoption of particular ontological or epistemological positions may be influenced by experiences that an individual encounters in life, or may be associated with their personality, or a mixture of both. Regardless of how we come to hold such beliefs, I believe it is important for educational researchers to acknowledge their own beliefs as well as acknowledging the impact that these beliefs might have on the methods employed in a research programme. Both Pring (2000) and Scott (2005) assert the need for philosophical views to be addressed prior to addressing methodological ones.

My own personal ontological and epistemological beliefs are more closely aligned with those posited by critical realism. I do believe that there is a world which exists outwith my knowledge. I also believe that there are many factors which might impact our ability to know and understand this world. This understanding of why things are as they are is, I believe, a crucial concept. Rather than simply producing a description of what is, I believe educational research should attempt to understand why it is.

The way in which we can address the why is, I believe, through interaction with those who are connected with the object of our research. It is my belief that, although a reality exists, each individual has an understanding of that reality which may be different to those around them. This is not to say that the reality is different, rather, through each individual's construction of meaning which has been influenced by their own life experiences, they potentially develop a different understanding of that reality. Sayer addresses these multiple perspectives and the need to address the why questions within social science research:

> *"Critical realism acknowledges that social phenomena are intrinsically meaningful, and hence that meaning is not only externally descriptive of them but constitutive of them (though of course there are usually material constituents too). Meaning has to be understood, it cannot be measured or counted, and hence there is always an interpretative or hermeneutic element in social science"*
>
> Sayer (2000 p 17)

I have therefore adopted a research design which aims to understand a particular learning environment. This design has been informed by my aforementioned ontological and epistemological beliefs. Another important factor which has informed my choice of theoretical framework and research design is my understanding of the term learning within the context of this study.

Hodkinson and Macleod (2010) suggest that the term learning is a social and linguistic construct which has been developed as a label. This label is used in different ways in different countries in order to refer to and begin to understand complex processes. We might say that learning occurs when we repeat a new nursery rhyme over and over to the point where we can say it without reference to text. We might also suggest that learning occurs when we burn ourselves on a hot object and learn not to touch it again. The term learning might equally be applied when, having attempted several crosswords by the same author, we begin to see patterns in the way in which they compile clues. All of these scenarios represent a learning experience. However, they represent different types of learning experiences. Hodkinson and Macleod (2010) assert that, not only do they represent different activities associated with learning, they also represent different conceptualisations of learning.

If I were asked to research the learning which occurred in each of these cases, I would design different studies and use different methods. Hodkinson and Macleod (2010) suggest that the particular understanding of learning which is adopted will in turn impact the kind of research which might be conducted.

Sfard (1998) has suggested that understandings of the term learning within the educational literature might be categorised using acquisition and participation metaphors. According to Sfard’s (1998) categorisations, an acquisitional view of learning suggests that knowledge exists outwith the mind and the purpose of learning is to somehow put that knowledge into the mind. Sfard suggests that the acquisitional view proposes that knowledge is then stored in the brain in the form of cognitive structures. Through the addition of further learning, these structures may become modified.

The participation view of learning suggests that knowledge is created through participation in a learning endeavour. As such, there is no knowledge which exists outwith a particular learning situation. Learning is situated in the environment within which it is created. The participation metaphor views the learner as a full participant in a specific context. Knowledge cannot be decontextualised or objectified. Knowledge is only relevant in the context that the individual is doing or being. Within this metaphor there is no knowledge that can be learned in one arena and then transferred to another arena. Learning is viewed as becoming proficient at communicating in the language of that situation (Sfard 1998). However, if this is the case, there would be very little to gain from previous knowledge and a lot of what we learn would then become ‘redundant’. As Sfard notes, there is no theory of learning which discounts completely the role of previous experience. If we are to view learning in the context of being able to assist individuals in other areas outwith the context of the learning experience, any theories must take into account the ability to acquire and retain knowledge which is then accessible across situations.

These views seem to represent extreme positions which cannot be complementary. However, Sfard (1998) warns against adopting one at the expense of the other. Whilst participationist views may go some way to explain learning, it is difficult to completely discount the role of prior learning in any theory. Such is the complexity of human learning, that it is not appropriate to make claims for the universality of one theory over another. Rather, Sfard (1998) suggests, it is more important to understand the purpose of the learning endeavour and match that with a suitable theoretical understanding.

Hodkinson and Macleod (2010) echo Sfard's assertion and suggest that rather than attempting to show empirically that one conceptualisation is correct at the expense of the other, research should instead be concerned with aligning appropriate conceptualisations with methods. Hodkinson and Macleod (2010) also suggest that Sfard's proposal of two metaphors for learning is too limiting and many other metaphors for learning may occur.

This issue is addressed by Paavola, Lipponen and Hakkarainen (2004), who propose a third metaphor for learning – the knowledge-creation metaphor. Through the analysis of three models of learning: Activity Theory's Expansive learning (Engestrom 1999), Nonaka and Takeuchi's (1995) model of knowledge-creation and Bereiter's (2002) model of knowledge creation, Paavola et al (2004) propose an understanding of learning which results in new knowledge creation. Learning therefore is not acquisitional in terms of knowledge being transferred from teacher student. Nor is learning merely participation in an existing social practice. Paavola et al (2004) propose that learning might be understood as *"a collaborative effort directed toward developing some mediated artefacts, broadly defined as including knowledge, ideas, practices, and material or conceptual artefacts"*. (p569). It is through individuals participating in an activity that different and innovative ways of practicing might be created.

The metaphor proposed by Paavola et al (2004) suggests that learning might be viewed as constructivist in the sense that individuals might work together to construct new knowledge and understanding. However, they emphasise the importance of the *processes* of that construction within the collaborative situation. These processes are influenced by mediating artefacts such as rules, division of labour and tools (e.g. Engestrom 1999).

Paavola et al's (2004) proposal is useful in understanding the innovation which might occur through participation in an activity such as collaborative problem solving. As I outlined in chapter three, this research has been informed by socio-cultural theory and Activity Theory. I have used these theories as I believe that when students are engaging in collaborative problem solving during their mathematics lesson, they are participating in an activity. I also believe that during this activity, students are able to use existing knowledge, particularly linguistic tools such as the use of metacognition, and apply them to the learning situation. As I mentioned in chapter three, the concept of scaffolding is also important in my conceptualisation of learning. It is through interaction with more knowledgeable others, that students can learn new patterns of behaviour. However, this learning may be influenced by social, cultural or historical issues. Therefore my understanding of learning, as contained within this research, does not sit comfortably in either of Sfard's (1998) metaphors. However, it does propose a view of learning where the individual is active in the learning process, where the individual utilises existing knowledge and is then able to construct new meaning through interaction with others. This interaction is influenced by many factors which should be taken into account when attempting to understand the learning situation.

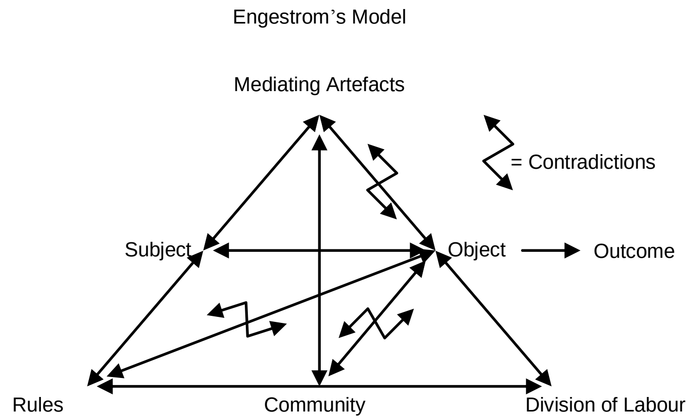
4.3 Theoretical Framework

As mentioned previously, the theoretical framework should be congruent with the adopted ontological view. The two theories which have informed this research are Vygotsky's socio-cultural theory (Vygotsky, 1986) and Activity Theory (Engestrom 2009). In the chapter on collaborative metacognition, I provided justification for my choice of theoretical framework in relation to the research questions. I provided possible alternatives together with justification for rejection of such theories. As well as these theories being justifiable in terms of the research questions, they are also congruent with the adoption of a critical realist ontology. Both of these theories propose that knowledge is acquired within specific cultural, historical and social settings.

I will now provide a more detailed critical overview of Activity Theory and its development from socio-cultural theory. Within this overview is reference to the concept of *contradictions*. Briefly, contradictions represent tensions within the activity system which become the motivation for development of the system. This concept has formed the basis of my analysis of portions of the qualitative data.

4.3.1 Activity Theory

Activity Theory has been described as a framework for understanding situations, rather than a predictive theory, and is often more useful for identifying problems within activities (e.g. Nardi 1996). Activity Theory provides a '*unified account of Vygotsky's proposals on the nature and development of human behaviour'* (Lantoff, 2006 p8). A central concept of Activity theory is that the development of human abilities occurs through object-oriented *activity* (Lazarev, 2004). Furthermore, the purpose of Activity Theory is to understand individuals and the *social entities they compose* in everyday settings (Engestrom & Nardi, 2006). Engestrom (2009) suggests that participation in an *activity* occurs when human action is *object-driven*. These objects, which Engestrom (2009) also refers to as *concerns,* are *"generators of foci, attention, motivation, effort and meaning"* (Engestrom p304). In other words, when attention, motivation, effort or meaning are oriented towards a particular object (or goal), the individuals involved are participating in *activity.*



Object – generator of foci of attention, motivation, effort and meaning, the goal
Subject – individual or group at the focus of the study
Mediating Artefacts - instruments, tools and signs used in the activity
Division of Labour – division of tasks amongst subjects during the activity
Rules – norms and rules which influence actions and interactions
Community – those participating towards the object of the activity
Contradictions – the motive for change within the activity system

Figure 4- 1 Engestrom's (1999) Model of Activity

Engestrom's Model of Activity

Activity Theory is an evolving theory, currently in the *third generation* (2009). Engestrom's (1999) second generation model of Activity Theory is shown in figure 4-1. Third generation Activity Theory develops this model to include *multiple* Activity Systems orientating toward a potentially shared goal, shown in figure 4-2. In Engestrom's model the *subject* refers to the individual or group at the focus of the study. The *object "refers to the 'raw material' or 'problem space' at which the activity is directed and which is moulded or transformed into outcomes with the help of physical and symbolic, external and internal tools*" (Engestrom, 1993, p67). According to Engestrom these *tools* are used to guide or influence the object of the activity. These tools can be internal (e.g., language) or external, such as textbooks or instruments. However, not all Activity theorists agree that internal tools such as language can exist. For example, Nardi (2005) notes that the object of Activity Theory is to understand the link between *consciousness* and activity. She continues that consciousness is *located in everyday practice and not in the brain*, therefore there are no internal representations of knowledge which can be accessed outwith the context. However, I would agree with Engestrom's (1990) assertion that "*mediating artefacts include tools and signs, both external implements and internal representations such as mental models*" p381.

Within Engestrom's model, *community* refers simply to those who are participating with the activity towards the same object. *Division of labour* refers to the division of tasks amongst the subjects during the activity. Finally, *rules* can be norms which influence actions and interactions within the system (Engestrom, 1993, Kuutti 1996).

Development of Activity Theory

The concept of *activity* was first seen in the writings of German philosophers such as Hegel and Kant (Repkin 2003). Around the time that they were writing, the predominant view of humanity was that of 'reactors' to their situation. Life was viewed as being pre-determined either by a creator or by the influence of environmental factors. Therefore, individuals could not be held fully accountable for their own life course. The philosophers suggested a different way of conceiving of humanity. Rather than being passive, they suggested that individuals were instead active creators of their environment and life. Responsibility was therefore placed with the individual for their own life course. The idea that individuals were active in creating their life experiences caused attention to turn to the nature of development of competencies and individual's potential in life. Marx adopted this philosophical position which was in turn adopted by Vygotsky in the 1920s when he developed his socio-cultural theory of development. Whilst many theorists have provided input to the forming of Activity Theory, for example Leonti'ev and Luria, the writings of Vygotsky have remained one of the prominent influences in its development (Repkin 2003).

Activity Theory rests on the premise introduced by Vygotsky that individual thoughts and actions are mediated by tools and artefacts which can be psychological or physical.

Engestrom (1990) suggests that in order to understand the actions carried out during an activity it is necessary to understand the components which comprise the system. As mentioned in the chapter on collaborative metacognition, the *activity* studied within this thesis is that of collaborative problem solving. In doing so, I have particularly focussed on the relationship between the use of a linguistic tool, that of metacognition, and participation in the *activity*. However, as previously mentioned, the third generation of Activity Theory proposes *multiple* activity systems, as depicted in figure (4-2).

Engestrom (2009) proposed that multiple activity systems interact and focus on a shared object. For example, within the context of the research contained within this thesis, it is possible to highlight multiple activity systems. One system might be the student group. The object of the activity is solution of the problem. However, teachers may also represent an activity system whose object might be the development of metacognitive skills in students. Part of that object will overlap with the student activity system since metacognitive skills are required for solution of the problem. At another level, government departments might represent an activity system whose object is to ensure students are engaged in appropriate learning experiences, such as collaborative group work. All of these activity systems can be focussed on the shared object of the problem solving. As such, each system might influence the object in different ways.

Engestrom (2009) has proposed that a potential outcome of multiple activity systems is the concept of *runaway objects*. Objects in an activity system are constantly changed through the multiple activities. *Runaway* objects have the potential to expand between multiple activity systems. They may begin as small objects or goals, yet develop, often without prediction, to these larger runaway objects. Engestrom (2009) asserts that whilst *runaway* objects will generate opposition, they are not necessarily a negative phenomenon. Rather, *runaway* objects may be emancipatory in nature.

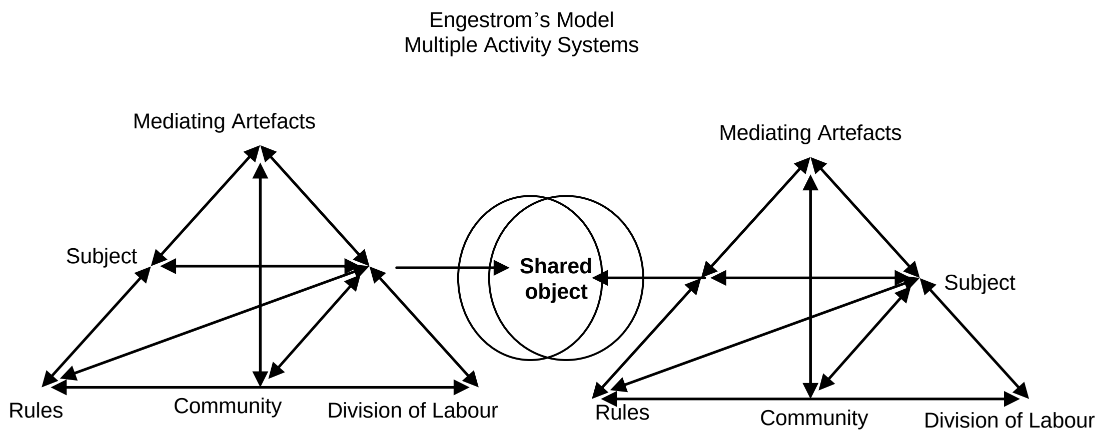


Figure 4- 2 Engestrom's (2009) Third Generation Model of Activity

Five principles of activity theory

Engestrom (2001) refers to five *principles* of Activity Theory which guide research in this area which are outlined below.

Unit of Analysis

The first principle of activity theory states that the main unit of analysis is the *activity system*. Individuals act towards the goal, or object, of the activity. However, these individual actions cannot be understood independently of the activity system. Rather, they must be *"interpreted against the background of the entire activity system"* (Engestrom 2001 p136). In the study reported on in this thesis, the primary activity system was the groups of students who were working together during their problem solving tasks.

Multi-Voicedness

The second principle is *Multi-voicedness*. This refers to the different perspectives and histories the members of an activity system bring to the activity. These different perspectives might impact the system either positively or negatively (Engestrom 2001). Data from student recall interviews and teacher focus groups contributed towards the understanding of multi-voicedness within the activity system.

Historicity

Historicity is the third principle and draws attention to the historical development of the activity system. The study of the history of an activity system allows a deeper understanding, both of the problems of the system and the potential development of the system. The data from the teacher focus groups also addresses the principle of historicity.

Contradictions

The fourth principle is that of contradictions. *Contradictions* within the activity system can produce transformation and change, but can also have a negative impact on the activity. Contradictions represent the *motive* for change or development within activity systems. The impact of contradictions might be positive or negative. Engestrom (2001) notes that contradictions are not simply conflicts or disagreements, rather they have a deeper social, cultural or historical meaning. Contradictions *"generate disturbances and conflicts, but also innovative attempts to change the activity"* (p137). It is through the analysis of the activity system *as a whole*, that underlying contradictions, which give rise to both failures and innovations, might be identified (Engestrom 2007).

Contradictions might be identified as *"deviations in the observable flow of interaction"* (Engestrom, Brown, Christopher & Gregory, 1991 p 91). They can represent *'problems or breakdowns'* within the system (Kuutti 1996, p34), and are often the result of an individual receiving conflicting messages or demands (Engestrom 2001).

Crucially, contradictions are not always identifiable by those working within the activity system. When they are identifiable, they may not, for different reasons, be *discussible* at the point of the activity. It is because such contradictions go unacknowledged that they have the potential to be so damaging to the activity (Capper & Williams, 2004).

Since contradictions are not always explicit within the activity system at the time of the activity, it is necessary to employ the previous three principles in the research design. The data from the student recall interviews and the teacher focus group both provided evidence of contradictions both within and between activity systems.

Expansive Learning

The fifth principle of activity theory is *expansive learning*. This refers to the development of the activity. Once individuals become competent members of the activity and the activity becomes more demanding, externalisation will occur through critical self-reflection and a search for new solutions. Engestrom (2001) refers to expansive learning as the collective *zone of proximal development* of the system:

> *"It is the distance between the present everyday actions of the individuals and the historically new form of the societal activity that can be collectively generated as a solution to the double bind potentially embedded in the everyday actions."*
>
> (Engestrom, 1987, p. 174)

According to activity theory, development and learning occur through the process of expansive learning. However, Daniels (2004) notes that activity theory encourages a *pedagogic imagination* in teaching and learning. Engestrom (2001) suggests that many traditional theories of learning make certain assumptions about the learning process, for example, that knowledge is static and fixed and can be transferred from a knowledgeable teacher to a student. Even when students have all of the knowledge they require at their disposal to solve a problem, there is no guarantee that they will do that. Rather, other issues, especially when working collaboratively might impact the situation. A *pedagogic imagination* allows educators to develop new ways of working and engaging students which take into account such issues. Engestrom (2001) notes that expansive learning need not necessarily be a move *upwards* in understanding, but can also represent a sideways shift in the way in which learning occurs.

According to Engestrom (2001) expansive learning produces culturally new *patterns* of learning. These new patterns do not occur simply through individuals becoming more expert in a particular area, such as becoming expert at mathematics. Rather, the use of an activity theory framework might highlight potential explanations for this lack of occurrence, through the concept of contradictions. In doing so, these issues can then be addressed within the system in order for expansive learning and development to occur. As previously mentioned, *contradictions* impact positively or negatively on the process of expansive learning. It is these contradictions which are the motive force of change in the system (Engestrom & Miettinen 2007).

Critique of Activity Theory

Whilst the use of activity theory in research projects has increased over the last three decades (Engestrom 2009), it has attracted criticisms in a number of areas.

The Problem of Compulsory Education as an Activity

Repkin (2003) suggests that learning activity is a special form of human activity and refers to development education as the means by which to study it. The questions with which learning activity is concerned are those such as 'how do we learn?' 'what mechanisms underlie learning?' and 'are there hidden resources available to us?'.

According to Repkin (2003), not all activity is produced by internal needs or motivations as is posited by other Activity theorists. Rather, individuals may find themselves participating in activities involuntarily – such as education. A child is 'sent' to school. An important aspect of this is that the goal of the activity is not set by the individual, yet pertains *to* the individual. *Activity* itself in terms of the theoretical interpretation, is one in which the individual is actively and freely involved. Therefore a child learns because they want to rather than because they are told. The difference here is motivation towards the goal. This provides a difficulty in terms of researching activity within the learning environment – or indeed in any environment – children can perform a task but not be involved in *activity*.

However, Repkin's view is perhaps too negative in terms of the motivational influences in children. In looking at a classroom full of children who appear to be thoroughly engaged with their learning it is difficult to suggest that they are not taking part in an activity. The same argument that Repkin uses could indeed be applied to any individual taking part in an activity that is not the result of a pure biological need. If a number of adults were asked their motivation for going to work in the morning I would be surprised to find that their main one was for self-fulfilment or because it was what they longed to do. Rather, many people go to work, primarily because it is expected of them in order to pay the bills, if nothing else. Likewise, children go to school because they have been socialised into going to school – it is just what children do. We can therefore assume that children are motivated to take part in the learning activity. However, motivations may be different between children. Also, this motivation may be influenced by other factors within the activity system.

Whilst the problem of motivation is one that can be overcome within the compulsory education setting, it is nonetheless one of the weaknesses of Activity Theory. Kaptelinin and Nardi (2006) suggest that *meaningful activity* should be the unit of analysis. This description does represent a potential difficulty within a class problem solving activity. However, it is also addressed to a certain extent by Engestrom's (2009) proposal of multiple activity systems. Whilst students are in the classroom setting, their motivation and attention may be on an *activity*, however it may not be the learning activity.

Ratner (1997) suggests that activity theory fails to fully explain negative or destructive activities by individuals within the system. However, this criticism can be answered, to a great extent by the previously mentioned concept of contradictions. Whilst negative behaviours, do not in themselves constitute contradictions, they may nonetheless be observable forms of underlying contradictions. However, such explanations can clearly not be applied to all negative behaviours and it is a criticism worth bearing in mind.

Despite these criticisms of Activity Theory it remains, nonetheless, a useful framework for understanding the use of collaborative metacognition during group work in mathematics. Activity theory takes account of multiple perspectives as well as the historical context of mathematics in the classroom. Furthermore, it allows the voice of the individual to be heard within the context of group work.

Activity theory has been associated with many different methodologies (Kaptelinin 2013). The chosen methodology for this study is case study which will be addressed in the next section.

4.4 Case Study Methodology

Case study research is, as the name suggests, concerned with a very specific instance of a phenomenon. It may be described as "*a specific instance that is frequently designed to illustrate a more general principle"* (Nisbet & Watt 1984, p72). A *case* within educational research may be a child, a group, a class, a school or a community. Within this research, the case is a class within a Scottish primary school.

A case study is particularly relevant when working with a primary school class. Hitchcock and Hughes (1995) note that case studies are of particular value when the research is taking place in a naturalistic environment over which the researcher has little control. Robson (2002) suggests that case studies involve looking at a real life situation with the aim of providing a rich description of the situation through the use of different types of data. The use of different instruments to gather data allows the case study to combine both subjective and objective descriptions (Dyer 1995). Cohen, et al (2007) note that the case study should, as much as is possible, be a reflection of the actual research situation. I understand this within the context of the critical realist paradigm, to mean that the case study will endeavour to uncover as much as can be known within the confines of both my own understanding and those involved in the research study.

Researchers have classified case studies into different types. For example Yin (2003) classifies case studies in terms of their *outcomes* which may be exploratory, descriptive or explanatory. Exploratory case studies may serve as a pilot to generate hypotheses which may then be tested by larger surveys or experiments. Descriptive case studies provide a narrative account, or story of the situation. Explanatory case studies may be used to test theories.

Merriam (1988) describes three types of case study using similar distinctions to those of Yin (1984). Descriptive case studies give a narrative account of the situation. Interpretative case studies are used to develop concepts which may be used to confirm hypotheses. Evaluative case studies aim to explain situations. Furthermore, these three types of case study may be classified as ethnographic, psychological, sociological or historical (Merriam 1988).

Stake (1994) categorises case studies as intrinsic, instrumental or collective. Intrinsic case studies are concerned with understanding the particular case that is being studied. Instrumental case studies use a particular case to provide a richer insight into theory. Collective case studies are groups of individual case studies which combine to provide a more complete understanding of a situation.

Rather than categorising the case study in this thesis as only one of those previously mentioned, I have used the case study in different ways which relate to the type of claims I am making.

Overall within the context of the thesis, the case study has been used in a *descriptive* way to provide a story of the situation being researched. I have also used the case study in an *explanatory* way, where I have sought to understand if there is a relationship between collaborative metacognition and the outcome of the problem solving sessions. The use of critical recall interviews may be categorised as an *exploratory* study with the aim of trying to generate potential hypotheses about why collaborative metacognition did not occur. The case study has also been used in an instrumental way in order to provide richer insight into metacognition in collaborative situations. Finally, the case study is evaluative as I have attempted to *explain* a situation.

The use of a case study also fits well with an activity theory framework since it represents a naturalistic account of the activity. Furthermore, case studies might utilise many different methods in order provide a rich understanding of the situation. This allows multiple perspectives to be taken into account, contributing to triangulation of evidence.

Such an approach might be considered *a mixed methods* approach (Bryman 2004) whereby qualitative and quantitative data are combined during a research study. Bryman (2004) notes that the use of such an approach can vary between research studies. For example, researchers may choose to employ qualitative data as a complement to quantitative findings. Within this study, the quantitative data and qualitative data have been combined to provide triangulation of evidence. Through this triangulation, qualitative data provide explanations for particular patterns of quantitative data.

This type of research design is not only applicable within an educational setting such as collaborative problem solving in mathematics. Through the unique application of methods, communicative patterns and issues which impact these might be better understood in different domains. For example, within the context of management and organisational behaviour, collaborative decision-making might be better understood through the application of the design reported in this study. In particular, the quantitative analysis of *actual* talk combined with the qualitative perspectives of those involved, would bring a rich understanding of issues which may impact such decision-making.

Although a case study methodology provides a rich insight to a naturally occurring situation there are also weaknesses. The weaknesses centre on the interpretation of the data. Since the researcher is so closely involved in the research situation, observer bias is an issue whereby the researcher might interpret data to fit their view of the situation. However, this might be overcome to an extent by triangulation of evidence.

Selectiveness of data might also be an issue where only data which *fit* the research outcomes are used. However, again, the use of multiple data sources might address this shortcoming. Finally, generalisation of results might be limited. When a case study is carried out in a very specific situation it is difficult to produce generalisations to a larger population.

In the case of the research reported in this thesis, the *case* was a primary school class. Both quantitative and qualitative data were generated. Whilst the results will only refer to the specific research situation, a certain amount of generalisation to similar situations will be possible. This will be addressed in the discussion.

Despite potential weaknesses of the methodology, case studies provide a rich level of data which is required to understand the processes involved during collaborative group work. The case study takes account of the individual within a specific situation, whilst also taking account of the situation. The use of a case study in this research has provided a real life account of the way in which students work together in their classroom, with the interruptions of daily life. In the following chapter I will provide details of the methods used in the case study.

Chapter Five: Methods

5.1 Introduction

In the previous chapter I outlined the theoretical framework which was adopted in order to understand the data collected in this research. I also provided justification for my choice of case study methodology as fitting with the theoretical framework and ontological assumptions. The purpose of this chapter is to provide details of the design of the research, to provide information on the methods which were used in order to collect data and also to give an account of the analysis of the data.

Data were collected from three different sources: verbal utterances of students; critical recall interviews with students and teacher focus group data. I will firstly provide an overview of the study and the role of the researcher. I will also provide details on all participants at this point, together with sampling information. I will then separate the data sources into three sections. Within each section I will provide details of the type of data collected and the method of analysis adopted. Some information regarding this study has been explained in chapter three and so will not be repeated here.

5.2 Overview of the study and role of the researcher

The purpose of the study was to understand the use of collaborative metacognition during problem solving. Data collection took place in a primary school in Scotland, where a primary school was chosen as most studies which have considered group metacognition have either occurred in high school or pre-school/infant school. There is relatively little information regarding metacognition during group work in mathematics at primary school level. Three data sets were generated during the study : content analysis of student interactions; transcripts from critical recall interviews; and transcripts from teacher focus groups.

Students were videotaped during their weekly problem solving sessions in their normal classroom. The sessions lasted approximately ninety minutes during which times students were in groups of four. The teacher grouped the students based on her assessment of the likelihood of them working well together. She also grouped them in terms of their ability in mathematics as measured by the standard assessments used by the teacher. Each group had a mixture of students whom the teacher knew to find mathematics relatively easy and those who found it more challenging. Equal numbers of boys and girls were participating in the study and so two boys and two girls were in each group.

The problems on which the groups worked were mathematical problems which did not necessarily fit with the area of mathematics which was being covered in the curriculum at that time. The problems were chosen by the class teacher, who followed three criteria which I will now outline. The problems were ones which required metacognitive thinking. Previous research suggests that not all problems require such an approach and therefore might result in no metacognitive interactions (e.g. Georghiades 2004). Secondly, the problems, although potentially difficult for all class members, were not beyond their capabilities. Again, research has shown that when students work with more difficult problems, metacognitive thinking is more likely to result (e.g. Georghiades, 2004). The final criterion was that the problems were ones which would lend themselves to group interaction. The teacher used existing school resources to identify such problems. Students were filmed during three sessions and during each session they worked on a different problem. The first problem was about measurement, the second one about area and the final one about sequential patterning. The problems can be found in Appendix B.

The duration of the study was 15 weeks, the students were videotaped at three points: Once at the beginning of the study, once in the middle and once at the end. This approach was adopted because it was congruent with an Activity Theory perspective which suggests that researchers should spend enough time in the research situation in order to gain an understanding of that situation. The data from these videotapes were then transcribed and content analysis was performed in order to understand the use of collaborative metacognition. More detailed information regarding this can be found in the section below entitled *content analysis*.

As previously mentioned, in order to gain a richer understanding of the use of metacognition, I employed an Activity Theory perspective. Within Activity Theory, the principle of contradictions allows researchers to uncover potential issues which might impact the activity. In order to understand these issues I employed a critical recall method. Students were shown a point in their problem solving session which was important to the outcome of the session. The students were asked to talk about that point in the session in order to highlight any potential contradictions. The students who participated in these interviews were the same students as those who were videotaped. Further details are presented in the section *critical recall interviews.*

The final data set came from teacher focus groups. In order to further understand the impact of the presence of the teacher on collaborative metacognition I conducted a focus group. I chose to interview a number of teachers rather than only the class teacher. This was for two reasons. Firstly, by the time students reach primary five they have had a number of class teachers. Although students have one specific teacher for the year, classes are often taken by other teachers as cover for absence, training, etc. Therefore many teachers had an impact on each learner's experience of collaborative problem solving during mathematics. In order to understand the historical perspective of teacher influence in this area, it was necessary to understand multiple perspectives. Secondly, interpretation of findings is more valid if a number of teachers report similar experiences, rather than only one teacher. Further details of the focus group are contained within the section *focus group.*

5.2.1 Ethical Considerations

This research was subject to the rigorous ethical procedures employed by the University of Glasgow. The research study was reviewed and approved by the School of Education's Ethics Committee. In line with the guidelines provided by the University of Glasgow, informed consent was sought from all those who participated in the study. Participants were provided with an overview of the aims of the study, together with details regarding the procedures and the type of data which would be collected. All participants were informed that they would be able to withdraw from the study at any point during data collection. They were also informed that once the data collection phase was complete, they could ask for their data to be withdrawn, without the need to provide any reason for this. For the students in the study, parental consent of the same nature was also obtained.

Throughout the study I ensured that students continued to be happy to be filmed and that none were feeling uncomfortable with the video cameras. Furthermore the teacher also ensured that students were able to communicate directly with her regarding any issues which may have arisen due to the research study

Confidentiality and security of data is paramount in a research study with human data, but even more so when dealing with children. All videotapes were kept in a securely locked cabinet, along with consent forms. In order to protect the identity of those involved, pseudonyms have been used throughout this thesis. Further ethical considerations are addressed in the following sections, where appropriate.

5.2.2 Sampling

Access to primary school classrooms poses certain ethical considerations. Due to these it is neither easy nor guaranteed. Non-probability sampling (Cohen et al 2007) was the appropriate method to adopt since I was looking for a specific age group of children. However, there were many other factors which I had to take into consideration. Firstly, the methods which I had chosen for my study required that I would be in the classroom during the course of the study. Furthermore, I would be required to transport and use a lot of recording equipment. I therefore adopted a convenience sampling approach in order to ascertain if there were any schools in the local area willing to participate. A number of negative responses led me to widen my search and engage teachers whom I knew personally to ascertain if it would be possible to gain access to their schools. Only one positive response was given and so I chose to go to that school.

There are drawbacks to such an approach. Generalisation to the wider population might not be possible (Cohen et al 2007). However, as I noted in the previous chapter, generalisation is problematic within case studies. The focus, rather then being on generalisation is to provide a rich detailed account of a situation.

Sampling is an important consideration in research concerning children within their school environment. The process by which we are able to learn more about *real* classroom learning is research. However, there is no compulsion to allow such research and access will only occur if it is accepted at school and local authority level. The growth of methodologies such as *action research,* where the teacher is also the researcher addresses this issue to a certain extent. However, teachers are afforded a maximum of thirty five hours per year for continued professional development (CPD). This CPD should consist of:

> *"an appropriate balance of personal professional development, attendance at nationally accredited courses, small scale school based activities or other CPD activity"*
>
> (Donaldson, 2011)

The thirty five hours per year afforded to teachers is not sufficient to be engaged in projects of the size contained within this thesis and would require teachers to be removed from the classroom for long periods of time.

This issue of sampling is not an easy one to overcome. However, when interpreting findings, it is worth bearing in mind the overall purpose of the study which is to understand a very specific situation from the perspective of those who are involved in that situation.

5.2.3 The impact and role of the researcher

Engestrom (2009) suggests that the researcher should participate in the activity which is being studied. As such, my role was as participant observer. I *participated* on a level similar to that of the teacher. The students regarded me in the same way they would regard another adult helper in the classroom, such as a classroom assistant. However, this raised an important issue of reactivity effects (e.g. Cohen et al 2007) where behaviour was potentially changed due to my presence. For example, students may have been less attentive, or they may not have accepted me as a teacher figure. Students might also have felt that if they were being observed that they should work hard. The teacher might also be influenced by the presence of another adult. For example, she may have spent more time on lesson preparation or paid more attention to particular aspects of classroom management. All of these issues might have in turn influenced the use of collaborative metacognition.

In order to reduce the reactivity effect as much as possible, I worked with the teacher and the students in the classroom for some time before the commencement of the study. I contacted the teacher during the school year prior to the one in which the study was conducted. At that time, the teacher was working with a primary five class (age 8-9). Each week for one hour, the students engaged in collaborative problem solving in mathematics. The problem solving sessions took place in the morning and I spent each morning with the class during their sessions. I worked with the teacher for three months during that school year prior to the one from which the data were collected. Although there were different students during this time it was important to understand the approach that the teacher took during her problem solving sessions. It was also important to understand general classroom and school rules regarding behaviour.

Although the data collection for the study took place over two school terms, I worked with the class for the whole of the school year. This meant that the students were introduced to me at the same time as their new class teacher. It also meant that the problem solving sessions were always the same, with both the class teacher and I present. By working closely with the teacher and students for a significant period of time prior to the study, I was able to assess what was "normal" classroom behaviour as compared to classroom behaviour which was influenced by the presence of others.

Students often encounter other adults in their classroom such as classroom assistants, pre-service teachers and parent helpers. All of these might impact behaviour. It is reasonable to assume that the regular presence of another adult over the course of the entire school year would not influence behaviour greatly. However, the possibility of this occurring should not be ignored and so remained a potential issue.

One other element of the study which had the potential to influence behaviour was the presence of the video recording equipment. The presence of the cameras produced a lot of interest from all of the students in class, even those who were not being filmed. In order to reduce the impact, the recording equipment was taken into the class on a number of occasions prior to the collection of data. By the time the data collection started, the students were used to being recorded. However, it was evident that they were still aware of the cameras, particularly at the beginning of sessions. Often, students would make faces into the camera, or say something silly. However, this generally occurred at the beginning of sessions and behaviour settled during the session.

It is difficult to assess the impact of the cameras on the work of the students and specifically their impact on the measured variables. However, the large proportion of social interactions recorded suggest that the cameras did not encourage students to be more focussed on the task than they would normally be. As with the presence of the researcher, it is an issue which should be borne in mind when interpreting the data.

5.3 Content Analysis

In this section I will outline the method of content analysis and provide an overview of the way in which I analysed the verbal data from the video sessions. The research questions which were addressed in the content analysis were:

- To what extent do students use collaborative metacognition during problem solving?
- What proportions of talk that could be categorised as collaborative metacognition are displayed during successful versus unsuccessful problem solving?
- What proportions of talk that could be categorised as collaborative metacognition are displayed when the teacher is present compared to not present?

The data collected for the content analysis was the same as that previously reported in the chapter on collaborative metacognition.

The method of content analysis is primarily concerned with the reduction and quantification of qualitative data through the use (generally, although not exclusively) of a pre-defined coding scheme. This data may take the form of written text, verbal interactions, video data or indeed any other data which may be broken into units for analysis (Neuendorf 2002). It is a research method that uses systematic procedures to make valid inferences about a text (Weber 1990).

The design of a content analysis is not straightforward and a number of issues must be resolved prior to data collection. Since the method involves systematic procedures, it is necessary for researchers to state explicitly which choices they have made in the process of compiling the coding scheme. However, Strijbos, Martens, Prins & Jochems (2006) note that such explanations and justifications are very rarely found within the literature. As well as this problem, there is also the problem of ambiguity surrounding the categorisation of different types of content analysis. Such categorisations include quantitative versus qualitative, emic versus etic and manifest versus latent. Before embarking on the production of a coding scheme it is necessary to determine the type of content analysis which will take place.

Quantitative versus Qualitative Content Analysis

Some researchers suggest a distinction between qualitative and quantitative content analysis, whilst others suggest that content analysis by nature can only be quantitative. Neuendorf (2002) refers to content analysis as being primarily concerned with producing *counts* and *frequencies* of categories and measurements and suggests therefore that a qualitative analysis is not possible. However, Hurme, et al (2006) refer to the use of a ‘qualitative content analysis’. In their study, Hurme et al (2006) coded data produced by students during networked discussions. Predefined categories were used and frequencies of the categories were produced as data. Clearly, this is a quantification of qualitative material. Strijbos et al (2006) also categorise content analysis as qualitative and quantitative. Quantitative analysis occurs where the data are coded and summarised to produce frequencies and percentages which may be used for statistical testing. Qualitative analysis still utilises codings but does not then subject them to statistical testing.

When quantitative or prospective analysis occurs, a hypothesis which has been derived from theory is used. An example may be that students will display more metacognitive utterances after a metacognitive intervention than before. In order to test this, metacognitive utterances may be coded and counted prior to the intervention and after the intervention. A statistical analysis may then be performed to calculate if there is a significant difference between the two conditions.

Qualitative or retrospect analysis occurs when no such hypothesis is present and no statistical testing is required. Strijbos et al (2006) suggest the purpose of such analyses is understanding a situation or phenomenon. For example, DeLaat and Lally (2003) used content analysis to understand collaborative knowledge construction during networked learning. However, as with Hurme et al (2006), they coded and counted messages and presented this quantification as data. However, no statistical testing was carried out. Rather the data were used to understand learning situations in relation to theory. The quantitative/qualitative classification in the literature seems to be ambiguous since all content analysis results in *counts* of data, however further analysis of the data may or may not include statistical testing (Krippendorff 2004). Despite this ambiguity it is important to ascertain which kind of analysis is required.

Within this thesis I have understood content analysis as being *quantitative* since it represents counts of utterances, some of which have been subject to statistical analysis. However, no predefined hypotheses were tested and the analysis was used to understand data in light of previous findings.

Emic versus Etic Categorisation

When preparing text for content analysis a decision must be taken on the unit of analysis. Neuendorf (2002) highlights the use of etic versus emic units. *Etic* units exist prior to the analysis of the text. For example, it may be decided that the researcher will divide the text into five minute samples, or a unit may represent one message in on-line collaboration. With *emic* units, no such predefined units are used. Rather, the text is read in order to find out where natural units occur. Such an approach raises issues of reliability since the detection of units is entirely subjective (Neuendorf 2002).

Within this research an etic approach was taken to unitisation and the unit of analysis was determined prior to coding. Further details of this will be given in the section *defining the unit of analysis.*

Manifest versus Latent Categorisation

In designing a content analysis it is necessary to decide if the researcher will use the manifest or latent content. Manifest utterances are the specific words or actions being observed. Latent content includes inferences made by the researcher (Bos & Tarnai 1999). Inference may be appropriate if, for example, the research aim was to infer learning through changes in utterances (Chi 1997). The use of latent content has implications for coding schemes and reliability since those who are carrying out the coding will have to be able to detect the correct variables. However, equally, when coding actual words, interpretation can also be flawed.

Some researchers suggest that the dichotomy of manifest versus latent is not a particularly helpful one since the boundaries between the two are not always clear. Also, manifest content is always required in the coding since latent content is only detectible using manifest content (Neuendorf 2002). Whilst Potter and Levine-Donnerstein (1999) argue that a distinction is helpful, they suggest that the two should be viewed as a continuum from manifest to latent, rather than purely one or another. Moreover, they suggest a distinction be made between two types of latent content into *pattern* and *projective*. When *pattern* content is used there is an assumption that there is an objective pattern which may be detectible by coders who will be able to detect specific *patterns* in the data. Such an approach was adopted by Hurme et al (2006) when they looked for specific patterns of speech which represented different metacognitive behaviours. *Projective* content relies more on the judgements of the coders.

Potter and Levine-Donnerstein (1999) suggest that when considering the type of latent content that will be used, two issues are important. Firstly, the degree to which the researcher is willing to allow for subjective interpretations of the data. When codings are compiled and tested, it is often the case that reliability can be difficult to achieve (Strijbos et al 2006). This may, in part, be due to the unit of analysis, but may also be due to the difficulty in verbalising subjective interpretations. For example there may be a high degree of consistency when asking people simply to detect disruptive behaviour in a classroom. However, once a coding rule is *written* for such behaviour, the consistency in detection may change. This is because each individual may verbalise or describe disruptive behaviour slightly differently.

The second issue concerns the extent to which the researcher is willing to consider the interpretations of those for whom the report is intended. For example, a study might be commissioned to assess the level of disruptive behaviour in a classroom following 'wet-breaks' where children do not get out to play as compared with normal breaks. A researcher with predefined descriptions of disruptive behaviour may conclude that there is no difference between wet-breaks and outside breaks. However, the perception of the teacher, and indeed pupils, may be different because they perceive certain types of behaviour as being more disruptive than others. Therefore in such instances, research findings might be enhanced through the inclusion of perceptions of those outwith the research team.

Such issues are clearly important when considering the reliability and validity of a study. Reliability may be compromised because coding schemes must use a generic verbal description of behaviours or utterances, which may not make sense to all coders. This is also a validity issue, since, as I have mentioned previously, researchers may code according to different interpretations of coding labels. Validity may also be compromised because the behaviours or utterances being measured may not actually be the ones of importance to those who may benefit from the research.

Potter and Levine-Donnerstein (1999) note that there is continuum which moves from manifest to pattern to projective content, with overlapping as in the figure 5-1 below:

Manifest Content → ← Projective Content

← Pattern Content →

Figure 5- 1 Three types of content (Potter & Levine-Donnerstein 1999)

Within the continuum there is an increase from left to right in the degree to which coders are likely to utilise their own understanding of categories, thus possibly reducing reliability. When moving from right to left, there is an increased confidence in the use of codings as being valid indicators of the specific behaviour.

This research study used *manifest* content. The text was coded according to the *actual* words which were used. However, since the data were unitised into turns, there was a strong element of *pattern* content, since I was looking for indicators which were suggestive of, for example, metacognitive talk. However, as the coding scheme also utilised codes such as *social talk*, there was small element of *projective* content. The full coding scheme can be found in Appendix A.

Defining the unit of analysis

Defining the unit of analysis is a difficult but crucial task in the development of content analysis process. It is one which requires careful attention to issues of reliability but one which also requires a pragmatic approach. Neuendorf (2002) notes that within content analysis, the unit of analysis must always be some form of communication. The unit of analysis is a message or part of a message which *'serves as the basis for reporting analyses'* (p71). The size of the unit may vary depending on the type of data and the research questions being answered.

The definition of units of analysis allows the researcher to divide the text and propose units which are identifiable by a particular word or description. Units therefore should have boundaries which are distinct from other units (Krippendorff 2004).

Rourke, Anderson, Garrison and Archer (2001) suggest there are five types of units; *the whole message; paragraphs; unit of meaning; sentence or syntactical unit* and *illocution*. Krippendorff (2004) also suggests five possible ways to define units of analysis: physical, syntactical, categorical, propositional and thematic. A *physical* unit of analysis may include dividing the text into time samples. This would have no bearing on the meaning of the text but would merely define a unit as, for example, every one minute of speech, as with Rourke et al's (2001) *whole message*. *Syntactical* units are identifiable by their grammatical boundaries. For example, text may be divided into sentences, paragraphs or words. *Categorical* distinctions divide the text into references to particular categories. An example may be each utterance which refers to 'how difficult mathematics is' is a unit. *Propositions* might be sentences, claims or assertions which may be put together to produce meaning. This unit of meaning is one of the most frequently used (Strijbos et al 2006). *Thematic* units of analysis require a careful interrogation of the text in order to highlight specific themes which may be addressed. Strijbos et al (2006) suggest that these themes may be referred to in different ways by different people and as such tend to cause reliability problems for coders.

The purpose of this study is to establish the levels of metacognitive used by individuals during problem solving sessions. As such, it is face-to-face communication which serves as the data to be unitised. When problem solving in groups students may start out on one train of thought and then quickly change to something completely different. Furthermore, especially with younger children who may be less adept at social interaction, there are a lot of interruptions of thought processes from other children. This can result in rather messy data. If time sampling is used, it could be the case that there is no real meaning in any of the units. Syntactical units may seem a reasonable alternative since it may be helpful to use sentences or paragraphs. However, for the same reason as stated previously, these may be rather messy and hold no real meaning when they are separated from the rest of the text.

A pragmatic approach when dealing with young children is that a unit of analysis should be a *unit of meaning*. However, defining and segmenting such a unit is not straightforward. A unit of meaning is described by Krippendorff (2004) as a propositional unit which includes sentences or utterances which may be put together to provide meaning, while Muukkonen, Lakkal and Hakkarainen (2001) define the proposition unit as *'representing a single idea'* (p462). Chi (1997) suggests a unit of meaning can be a '*proposition, an argument chain or an idea'* (p284). Both Chi (1997) and Krippendorff (2004) allow for the compilation of more than one utterance in achieving meaning.

The segmenting of such units of meaning may require a novel approach since the boundaries are not clear. Chi (1997) refers to the use of *non-content* and *activity* features when segmenting text. Non-content features are those physical features such as a sentence, a word, a paragraph, a time lag. Activity features are features relevant to the activity such as turn-taking or change of activity. When attempting to segment a unit of meaning during face-to-face dialogue turn-taking seems a reasonable boundary.

Therefore the *unit* was defined as turn-taking – or the *conversational turn* of the student. This was the unit used in the study by Goos et al (2002), detailed in the chapter on collaborative metacognition. Since this current research utilised and extended the coding scheme adopted by Goos et al, it was appropriate to unitise the data in a similar way.

5.3.1 Development of the Coding schemes

Two coding schemes were developed in order to understand verbal interactions. The first coding scheme provided an understanding of the metacognitive content of the interactions whilst the second one was used to code the transactive quality of the interactions.

When constructing a coding scheme for use in a content analysis, two different methods may be appropriate. As previously noted, predefined codings schemes are generally used. However, codes which are derived from the text might also be employed. Larkin (2009) in her study on metacognition and writing, compiled codes directly from the text. Although the study was shaped by research on metacognition, the particular codes were grounded in the data to reflect the behaviours which were being displayed. These behaviours were then categorised under broader headings such as *monitoring, control* or *theory of mind*. The alternative approach to coding is to use pre-defined codes. These codes may be ones which have been derived specifically for the current research project, or they may be ones which have been used in previous research. The advantage of using previously published coding schemes is that comparisons may be made between studies. However, codes which are derived for a particular study, or indeed *from* a particular study have the advantage of providing codes which have contextual relevance.

In order to provide some continuity and allow comparison between studies, this study drew on previously published coding schemes. The empirical studies which were reviewed in the chapter on collaborative metacognition provided a starting point from which to find suitable coding schemes. In the following section I will provide details of the coding schemes used in order to fully understand the verbal data, starting with transactive and moving on to the metacognitive scheme.

Transactive Reasoning Coding Scheme

The coding scheme used to operationalise collaboration was taken from the Goos et al (2002) study which focussed on the transactive nature of interaction as an operationalisation of collaboration. This scheme was chosen because it had been published previously in a similar study and also because the theoretical conceptualisation of collaboration was similar to that in this study.

Transactive reasoning

The notion of *transactive* interaction was first described by Berkowitz and Gibbs (1983) who studied the reasoning abilities of children. They suggested that *transactive discussion* might be understood as '*reasoning that operates on the reasoning of another'* (Berkowitz & Gibbs 1983, p402). This type of interaction might be thought of as a form of argumentation and as such could be positive or negative in nature. This notion was further developed by Kruger and Tomasello (1986) who proposed three types of transacts: *transactive statements*, *transactive questions* and *transactive responses*. *Transactive statements* were defined as statements which represented a critique, refinement or extension of an idea. *Transactive questions* were defined as requests for clarification, justification, or elaboration of the partner's ideas. Both transactive questions and statements were defined as being spontaneously produced. *Transactive responses*, however, were defined as responses which occurred following a transactive question where an individual would give justification for their ideas or proposals (Berkowitz & Gibbs 1983, p683). Furthermore, these transacts could be self-oriented or other-oriented. Self-orientation refers to a statement, question or response made by an individual about his or her own utterance. Whereas other-oriented represents a statement, question or response made about an utterance of another.

Research in this area was initially conducted from a Piagetian perspective and sought to understand the relationship between transactive discussion and learning through the notion of cognitive conflict (e.g. Kruger 1993). However, a parallel field of research has been conducted from a Vygotskian perspective in order to understand social learning processes (e.g. Teasley 1997). Although these theoretical perspectives have differed, the concept of transactive discussion has remained constant. Teasley's (1997) conceptualisation of transactive discussion was similar to that proposed by Berkowitz & Gibbs (1983) where a child would use their conversational turn to operate on the reasoning of others or themselves. Nucci (2006) refers to the attempt of the *speaker* to extend the logic of or critique the prior speaker's argument. Finally, Wahlstedt & Lindkvist (2007) suggested *"a turn is considered transactive if it extends, paraphrases, refines, completes, critiques an other's reasoning or the speaker's own reasoning"* (p1078). Wahlstedt & Lindkvist (2007) proposed a development in the understanding of the role of transactive discussion. When individuals work collaboratively towards a goal, they suggest that it is important that they are able to "*support and use each other in a way that contributes to goal fulfilment"* (p1078). They suggest that within the collaborative environment there is a *social obligation* to engage in such a way that encourages collaboration.

This understanding of transactive discussion in a collaborative environment is congruent with the understanding of collaboration as being part of the *activity* of problem solving. By viewing transactive discussion in such a way we can understand the importance of the interactive nature of collaboration.

As previously mentioned, the coding scheme for the transactive contribution of talk was taken from the Goos et al (2002). This coding scheme is representative of the *transacts* which were suggested by Kruger and Tomasello (1986) which are *statements, questions and responses*. The coding scheme can be found in Appendix A.

Metacognition Coding Scheme

The coding scheme for metacognition proved to be more difficult to produce. The previously mentioned studies have operationalised metacognition in different ways and the operationalisation of metacognition was often more of a qualitative judgement rather than based on the use of a coding scheme. Three papers did provide some direction in the coding scheme: Artz and Armour-Thomas (1992), Goos et al (2002) and Hurme et al (2005) all provided clear operationalisations of metacognition. However, the purpose of those papers was to highlight instances of metacognition, although Artz and Armour-Thomas were also concerned with highlighting cognitive talk. Whilst one aim of the research in this thesis was to identify instances of metacognition, it was also important to understand the other types of talk in which the students and teacher engaged, particularly, in relation to being able to distinguish between cognitive and metacognitive and also on-task statements versus off-task statements. It was therefore necessary to employ additional codes.

Since the teacher joined the groups at various points, it was also necessary to differentiate the types of talk displayed at that time. The coding scheme for points when the teacher was present in the group was taken from a previously published scheme which had been developed specifically to understand the types of interactions by made teachers whilst working with groups (Lally & DeLaat, 2002, based on Anderson et al 2001). This coding scheme referred to the types of interactions that the teacher might make such as facilitating discourse, giving instructions or encouraging student contributions.

In order to understand the nature of student talk, codes were developed through the amalgamation of coding schemes used by Artz & Armour-Thomas, Goos et al (2002) and Hurme et al (2006) and the addition of a previously published coding scheme used to understand the types of talk displayed by students during collaborative problem solving (Lally & DeLaat, 2002 adapted from Veldhuis-Dermainse & Beimans 2000). A full breakdown of the coding scheme is provided in Appendix A, together with examples of each type of utterance and reference to the research paper from which it was derived. Data were categorised under the main headings of *cognitive*, *metacognitive*, *social*, *teacher teaching* and *other*. However, these were broken down further to provide more detailed analysis of the talk. In doing so, it was hoped that the reliability might be strengthened (discussed more fully in the *reliability/validity section*) as a more detailed analysis provided less opportunity for ambiguity of coding.

Furthermore, a distinction was required to aid coding of metacognitive statements in relation to cognitive statements. This distinction is not often clear and a statement taken out of context might be seen as either cognitive or metacognitive. Therefore, in order to try and avoid the arbitrary use of inferences being made regarding what the student meant or how a student understood a situation, a distinction was used to refer to during the coding process. Although some of the previously mentioned studies provided a distinction between cognition and metacognition, Teong (2003) has provided a clearer distinction which was adopted:

> "*metacognitive behaviours could be exhibited by statements made about the problem or about the problem solving process while cognitive behaviours could be exhibited by verbal actions that indicated actual processing of information"*
>
> (Teong 2003 p141).

5.3.2 Pilot Study

A pilot study was conducted in order to highlight any potential problems which might occur with the recording equipment and also with the coding schemes. The pilot was conducted in the term prior to the actual study commencing. Two issues became apparent in the pilot study. One was with the recording equipment and the other was with the coding schemes.

Firstly, the built-in microphones in the video cameras were not sensitive enough to capture the student interactions. This was because the classroom was full of students talking simultaneously. The options to remedy this were either to remove those who were being recorded from the classroom, or use a more sensitive recorder to record the audio separately from the video. Since one aim of the study was to understand the use of collaborative metacognition within a natural setting, the latter option was chosen. The result of this was that once the recording had taken place, the video and audio files had to be synchronised into one file before transcription could occur.

The second issue was highlighted when coding began on the data. There was an unexpectedly high amount of social interaction which was not related to the task the students were working on. Secondly, students sometimes made silly noises, or spoke in a nonsensical manner which could not be interpreted. Two further codes therefore had to be added to the coding schemes to take account of these. The two categories were *social* (separating negative and positive social interactions) and *unclassified*. By adding these new codes, all utterances were able to fit within the coding scheme.

5.3.3 Further issues with data collection

Whilst the pilot study highlighted a number of issues which were dealt with prior to collection of the data, there were a number of other issues which impacted data collection during the study. These issues are reflective of everyday life within the school environment and were issues over which no one had any real control. However, they did impact the study and should be borne in mind when interpreting the data.

Firstly, the whole study was postponed for four weeks because the school had to close due adverse weather. Although the school was not closed for this entire time, once the students and teachers were settled in the school there were many other curricular issues to which the teacher had to attend before having time to deal with the research study.

The first week that recording was due to commence, the class teacher was off sick. This meant that another teacher had to take the class. Whilst this teacher was happy to be involved in the study, I thought it was not appropriate to video on this occasion. As previously mentioned, I had spent a lot of time working with the class teacher and getting to know the way in which she worked. Working with another teacher would have compromised the validity of the study.

Another issue which arose was regarding the problems which were given to the students. Although I had agreed with the class teacher prior to commencement of the study which problems would be given to the students, the order of these was changed unexpectedly. Therefore, the problem which the students were working on was not suitable for videoing. The problem which had been set, required students to sit back-to-back for one particular part. This meant that the recording equipment could not be placed in the middle of the students and so no recording was made.

On another occasion when filming was due to occur, two students were off sick from one of the groups. The teacher had decided to move another two students (who had given consent to participate in the study) into that group in order to maintain a group of four. However, this was not an appropriate change since I was interested in understanding group level processes. If the group changed, such an analysis would not be possible.

5.3.4 Analysis

The data were first coded using the *metacognitive* coding scheme. This provided an account of the types of talk that were being displayed. The data were then coded for their *transactive* quality. Each utterance therefore had two codes.

Data for all of the groups and all of the sessions were combined in order to provide totals of each type of utterance. Although the groups may have displayed differences in their interactions, the combination of data allowed for patterns to be detected. It was also hoped that by so doing, differences between groups might be cancelled out and the patterns which emerged were more reflective of the groups as a whole.

During the analysis it became apparent that there were very high quantities of social talk and very low quantities (relative to social) of both metacognitive and transactive talk. In order to provide meaningful data, the social utterances were classified as *off-task*. For the majority of analyses, only on-task data were used.

In order to address the issue of low quantities of metacognitive and transactive talk, *proportions* of utterances were used rather than counts. This also addressed another issue which became evident – students had different opportunities to speak and spoke for different lengths of time. Furthermore, the presence of the teacher in the groups was not consistent. Students in one group might have worked on their own for a large proportion of time whereas another group may have had an additional member for some time (the teacher). Therefore, counts of utterances did not do justice to the actual quality of talk produced in the sessions. A similar approach was also adopted by Goos et al (2002).

In order to answer the specific research questions, data were further separated to show periods when the teacher was present in the groups. Sessions were also separated into periods where students had successfully completed the problem set and periods where they had failed to complete all or part of the problem. Further details of the segregation of the data are found in the appropriate results chapters.

Proportions of the each type of utterance were calculated in relation to the total number of utterances displayed. These will be presented in the results chapters to follow.

5.3.5 Reliability and Validity

Reliability

Reliability concerns the extent to which the measurement instrument will produce the same results in repeated trials. Within content analysis, reliability is important in the coding process. The codes being used should be sufficiently defined as to allow more than one coder to produce similar findings (Neuendorf 2002). Inter-coder reliability raises three specific problems: the definition of each unit of meaning; the question of whether all disagreements should be resolved; and if not, which ones should be (Krippendorff 2004, Chi 1997).

Chi (1997) suggests that if two coders disagree on which code to assign to a particular piece of text because it is ambiguous, it may be more appropriate to leave that particular piece of text out of the analysis. Once the entire text has been coded, a percentage may be computed of data which has been left out. The final analysis may report that (for example) only 80% of the data were used in the coding. This is the approach adopted by Larkin (2009) when coding for metacognition during classroom discussions.

Krippendorff (2004) suggests reliability may be tackled by having 3 independent coders reaching consensus. Such a task will only be accomplished through the use of rules during the coding procedures. For example, during the unitising process, coders must agree on what constitutes a ‘unit of meaning’. A rule for dealing with disagreement may be that the majority decision is followed, or if no consensus is reached on a particular unit, that may be left out of the data.

Within this study it was not possible to conduct inter-coder reliability. This was due to guidelines regarding the nature of the research, since the data collection and analysis had to be completed individually by the researcher. It is therefore an issue when interpreting the findings. However, as mentioned previously, the coding scheme was developed to allow fine-grained analysis of the talk. As such, the opportunity for coding talk incorrectly was hopefully reduced and therefore contributed to some extent to the reliability of the coding.

It is important to interpret the weighting of such an issue in the context of the thesis as a whole. If PhD students are confined to the use of only certain measurement instruments then it places constraints on the educational research domain as a whole.

Validity

Validity is the extent to which the instrument is measuring what it claims to be measuring (Neuendorf 2003). Within content analysis this refers to the appropriateness of the unitisation and coding. Furthermore, the interpretation of the coding scheme might be flawed which would affect validity. To try and address this issue, multiple readings of the text were performed to ensure that coded utterances seemed consistent throughout the texts.

Referring to computer-mediated communication, Enriquez (2009) notes that, in order to produce valid findings, content analysis must take into account issues outwith the specific situation within which the communication is occurring. It must take account of historical, social and cultural factors which combine to produce the communication. This issue is also raised by Chi (1997) who suggests that validity may be improved through the use of other converging evidence. The use of critical recall analysis and focus group data was used in this study in order to provide converging evidence.

5.4 Critical Event Recall

The method referred to within this thesis as critical event recall (e.g. Lally 2002) appears in the literature under a number of synonyms such as *critical incident technique* (Flanagan 1954), *interpersonal process recall (Kagan 1984)*, and *stimulated recall* (Lyle 2003). Although different terms are used to describe the method, generally, the aim of research using these approaches is to understand interactive processes from the perspective of the individual or individuals involved. Kain (2004) suggests that

> *"the critical incident technique provides a systematic means for gathering the significances others attach to events, analyzing the emerging patterns, and laying out tentative conclusions for the reader's consideration"*.

Kain (2004 p85)

Critical event recall is congruent with an Activity Theory perspective as it provides an understanding of the activity from the perspective of those involved in the activity. Furthermore, in utilising such an approach, an understanding of behaviour and interactions within a naturalistic setting may be produced. However, there is some variation in the processes of critical event recall. The technique generally consists of showing an individual, or group of individuals, a portion of video where they have been involved in an activity. Criteria for selection of the video portion varies between studies, depending on the issue being researched. Some studies choose to focus on a specific or *critical* incident (e.g. Fullick 2005) whereas in others time-sampling approaches might also be employed. Furthermore, the incidents chosen for analysis might be identified by participants (e.g. Lyle 2003) or by the researcher (e.g. Lally 2002).

Once the portion of video has been identified, individuals are prompted by the researcher to describe their thinking processes at the time of the incident. The interview may consist of pre-defined questions or it can be less structured (Lyle 2003). The use of critical event recall can provide a deeper understanding of the processes involved in group problem solving compared to content analysis alone (Lally 2002). When a number of individuals converge in a collaborative endeavour, they each bring with them a unique set of thoughts, ideas and experiences. It is therefore important to try and understand the way in which these might influence interactions and subsequent outcomes of the sessions.

One of the main areas of research within which the method is employed is that of teacher education and training. The technique is used to develop teachers' skills within the naturalistic setting of the classroom. For example, Stough (2001) successfully utilised the technique to train student teachers. In such studies, expert teachers are asked to comment on their own performance in order to uncover the decision making processes which occur. This information can then be applied by student teachers. Such an approach has been adopted in many similar situations (e.g. Reitano, 2004). As well as in teacher education, the method has also been used to develop positive interactions in the area of counselling and nursing education (Lyle 2003).

5.4.1 Critical event recall with children

Whilst most research utilising this method has involved adults, it has been employed more recently with young children. Morgan (2007) employed a video recall technique with students aged between 3 and 7. Students were videotaped in their normal classroom environment during lessons with their class teacher. The researchers focussed on establishing the student's perceptions of the learning process and the interactions with their teacher. The study concluded that these young students found it easier to recall emotions as opposed to learning. However, a possible explanation for this is under developed metacognitive skills which might allow the students to verbalise their cognitive processes. Nonetheless, the findings show that students can recognise and recall their feelings when shown video recordings.

Cheesemen and Clarke (2007) used video recall with 53 children aged 5 to 7 years old in order to understand their assessment of learning during their mathematics lesson. They found that after being shown a video of the lesson, students were able to accurately report back about the lesson, their interactions with the teacher and their learning experiences. However, there were considerable differences between individuals, with two not recalling the lesson at all.

In another study, DeWitt and Osborne (2010) employed a similar method in order to probe cognitive engagement and meaning-making of students during a visit to a science centre. Students aged between 9 and 11 were videotaped and photographed during their visit to a science centre. On their return to the classroom, the students were shown portions of video and photographs. The study sought to understand cognitive understanding of the science centre exhibitions. However, as with the previous study, it was the emotional responses of students which were most salient and easily accessed.

Theobald (2012) used a similar technique with 4 to 6 year old children during playground interactions. The aim of the study was to understand the way in which young children account for their interactions with others. Theobold (2012) found that young children were able to provide explanations for their behaviour which were based on their perceptions of their own social worlds. Such explanations were not necessarily congruent with the way in which an adult might interpret the situation.

The use of video recall is therefore a useful tool in understanding participation in an activity from the perspective of the individual..

5.4.2 Participants

The participants for the study were those students who had previously been videoed during their problem solving sessions.

5.4.3 Selection of video

Selection of appropriate video segments of critical events took place after several viewings of all the video data. When developing criteria for selection, the principle of *contradictions* was referred to. There were a number of criteria which were applied. Firstly, all three groups were to be represented in the recall interview. This was in order to allow as diverse an account as possible of the potential *contradictions.* Secondly, the incidents had to appear to influence the eventual outcome of the session. Finally, the incidents could be positive or negative in nature, in line with the principle of *contradictions* as producing development within an activity or hindering the activity. Three portions of video were highlighted for the critical event recall.

5.4.4 Procedure

The interviews took place in an area in the school outwith the normal classroom setting as it would have been disruptive to the rest of the class if the interviews took place within a normal class lesson. It might also have been embarrassing for others in the class to see the video of students interacting which in turn might have impacted on their responses. Furthermore, the presence of the teacher during the interviews might also have had an impact on responses. Since the interviews themselves might be described as being contrived and not representing a real life situation, it was not necessary for them to occur in a specific setting.

The interviews were conducted as soon as possible after the event in order to minimise any potential impact passage of time might have on memory of the events (Lyle 2003). The time between filming and the interviews varied between two and four weeks. The delay occurred due to the length of time it took to transcribe data and identify a suitable point in the session for use in the interviews. Furthermore, school holidays and changes to timetables also impacted access and delayed interviews.

Previous research has suggested that when confronted with themselves on video, individuals might become self-conscious or distracted by their own image. In order to overcome this Pirie (1996 p3) suggested incorporating a "*giggle time"* into the design. Therefore, the students in the study were first shown the appropriate portion of video. As expected, they did giggle and spent some time imitating themselves and others. The students were allowed time to compose themselves and become familiar with the concept of seeing themselves on video prior to the discussion. Once the students were calm, they were shown the video again.

The interview questions were of a non-structured nature. Whilst I was looking at a very specific point in the problem solving procedure, I was interested to ascertain what the students proposed as being salient issues at that time. It was therefore important not to guide their thoughts too much in one specific direction but to allow them time to reflect upon the situation and their thoughts and feelings at that time.

Each group was interviewed as a whole. This approach was adopted for three reasons. The first reason was purely practical. Time was very limited and the interviews required the students to be away from their normal learning activities. Since I had received permission to be in the school for a specific number of hours each week it would not have been possible to conduct 12 recall interviews. Secondly, there is some evidence to suggest that children, in particular, feel more at ease in a group interview rather than an individual one (Eder & Fingerson 2003). Furthermore, interviewing the children as a group allowed an interaction *between* the students and not simply researcher to student. This type of interaction can add to the validity of the interviews since each student is corroborating what the others have remembered.

The interviews took around one hour to complete. The interviews were recorded and were then transcribed verbatim.

5.4.5 Issues during group recordings

During the first group interview, the recording equipment failed to operate initially. Due to time constraints I had to continue with the interview and so transcribed the responses by hand. Very soon after the interview began, the equipment started to work again.

The last group interview took place on the second last day of term. Due to the many curricular constraints towards the end of term, this was the only day that access could be gained. At the time of the interview, the students and staff from the school were performing an end of term musical concert. The students in the recall group were keen to attend this concert, which was evident from their interactions. Furthermore from an ethical perspective, it was difficult to justify keeping four students from the school away from their end of term concert, where they had friends who would be leaving the school that year performing. The interview was therefore cut short to around 40 minutes. As a result it did not provide as much rich information as the previous two interviews had done. Nonetheless it was fruitful and did provide some insight to the contradictions which might have impacted interactions.

5.4.6 Analysis

The purpose of the recall interviews was to highlight potential *contradictions* within the activity system, as referred to in the previous chapter. In order to highlight the contradictions, the transcribed recordings of the interviews were read in conjunction with the video taped portion of the problem solving session. This allowed me to understand the responses of the students in relation to the actual interactions which occurred.

The interview data were analysed in terms of the components of the activity system referred to in the previous chapter. The headings for contradictions were rules; mediating artefacts; division of labour and community. Although the interviews lasted approximately one hour, they contained relatively small proportions of talk regarding potential contradictions. However, these small proportions were interpreted in the context of the whole interview rather than simply 'removing' them and analysing them separately.

For example, I considered if students might have been referring to rules of interaction or use of tools. When a potential contradiction was referred to by a student, I then looked for further evidence from the interactions of the other students. One important aspect of this analysis was to ensure that the contradictions were not merely disagreements between students. Rather, the contradictions had to represent deeper issues which were not always explicit in the original interactions.

5.4.7 Critique of critical event recall

The use of video recall has attracted criticism from a methodological perspective in terms of validity and reliability. Moreover, the use of the method with children has attracted criticism from those questioning the ability of young children to reflect on their interactions.

Validity

Gass and Mackey (2000) suggested that validity might be compromised due to the subjectivity of the researcher during analysis. Validity might also be compromised due to the accuracy (or lack) of recall by participants (e.g. Kain 2004).

Whilst this critique is a perfectly valid one, it was evident from the students that they were able to recall the events apparently accurately. For example, one group, when they were shown the portion of video were able to recall almost *verbatim* what was said in the next section of the video. All groups remembered very well the incidents they were shown and could recall information both prior to and after the event they were shown. The students were also able to recall information from other weeks which had been videotaped. This suggested that their recall and understanding of the situation was good. Furthermore, following Lally (2002), I ensured at various points that the students understood that I was interested to know how they felt *at the time of the incident* as opposed to how they felt looking at it afterwards.

Another potential threat to validity is one highlighted by Theobold (2012). She suggested that when children are viewed in a negative way, e.g. during an argument, they may change their explanation of their behaviour in order to be able to deflect attention from themselves onto another group member. Caution should therefore be taken when interpreting interviews which involve sensitive interactions which might reflect negatively on one individual in the group. However this can be overcome to a certain extent by reassuring students that their behaviour is not being judged. Rather, the researcher is seeking to understand what might guide behaviour.

In this particular study, the responses of the students indicated that they were not attempting to divert attention from negative behaviours. They responded in a manner which suggested that they were aware of their behaviours and understood them to be negative, or positive, within the context and could suggest improvements for future.

In order to minimise any potential threat to validity, I have followed Kain's (2004) suggestion by providing as rich an account of the processes involved in the study in order to allow the reader to judge the trustworthiness of the research

5.5 Teacher focus group

The purpose of the teacher focus group was to understand the way in which teachers approached the processes involved during collaborative problem solving in mathematics. The teacher focus group represented an historical account of the way in which students experienced group problem solving during mathematics. Various methods may have been used to do this. For example, I could have interviewed each class teacher who had taught the students throughout their school career. This might have produced an understanding of student experiences each year. However, validity of such an approach might have been compromised since teachers would be expected to remember their actions, potentially five years previously.

Another approach might have been to produce an historical account of the way in which teachers were trained to approach mathematical problem solving in Scottish schools. This method may provide accurate data, however it would not take account of issues such as the impact of local authorities; the head teacher; and each teacher's own beliefs about mathematics.

The use of the focus group allowed an insight to the experiences of students and teachers within a local situation. The focus group allowed a wide range of teaching experience to be accessed, together with the impact on local teaching that this experience might have had.

Focus groups allow not only an exchange between the researcher and participants but also participant to participant. This allows participants to discuss issues between themselves and corroborate information. This has the potential of uncovering issues which a researcher might not have considered, particularly if they have not shared in the experience of the participants. This allows the participants to guide the exchange rather than the researcher (Morgan 1998).

5.5.1 Participants

The eight teachers who participated in the focus group were from the school where the study was conducted. Teachers were asked to volunteer their participation.

5.5.2 Procedure

The focus group was conducted during the lunch break at the school. The session lasted one hour. It was made clear to the teachers that I was interested in their experiences and views on the questions which were to be asked. Furthermore, I was not looking for right or wrong answers. I began the focus group by raising a particular issue and then allowed the teachers to discuss this. The teachers spoke and interacted with one another during the discussion. When it seemed that each question had been exhausted I moved on to the next one. However, since time was limited, I did have to interrupt discussions on two occasions. The interview was recorded and the data were transcribed verbatim for analysis. Only verbal data were used.

5.5.3 Focus Group Questions

The questions used for the focus group were aimed at understanding the issues which might influence the way in which a teacher approaches mathematical problem solving. I was also interested to understand their experiences with trying to encourage metacognition and group problem solving. The approach adopted during questioning might be referred to as the *interview guide approach* (e.g. Cohen et al 2007). In this approach, questions are decided beforehand. However, during the interview it might be evident that one question would fit better in a different position. This is particularly relevant during focus groups when the direction of the interview might change quickly. It is therefore necessary to be flexible to allow participants to feel at ease and move in a particular direction if it is relevant so to do.

5.5.4 Analysis

The data were analysed through repeated listening and then categorising of data. The first grouping of data occurred in relation to the questions which were asked. However, second and subsequent groupings were derived from the data. For example, data which pertained to initial teacher training were grouped. Within these responses, further headings emerged and data were grouped accordingly.

5.6 Summary of chapter

In this chapter I have outlined the methods which were employed during this study. I have provided an overview of the study and addressed issues such as sampling and the role of the researcher. I have also provided detailed information regarding each method chosen, participants, procedures and analysis of data.

In the following three chapters I will provide the results from the data collection before providing an interpretation of the results in the discussion chapter.

Chapter Six: Collaborative Metacognition and Successful Versus Unsuccessful Problem Solving

6.1 Introduction

The purpose of this chapter is to report the results of the quantitative analysis conducted with regard to successful and unsuccessful problem solving sessions. Previous research in the area of metacognition, both individually and in groups, suggests that higher levels of metacognition are associated with successful problem solving outcomes (e.g. Artz & Armour-Thomas 1992). This chapter will therefore investigate the extent to which the use of *collaborative* metacognition, as defined in chapter three, might concur with previous research studies. The quantitative data I will present in this chapter will therefore be used to answer the main research question: *What proportions of talk that could be categorised as collaborative metacognition are displayed during successful versus unsuccessful problem solving?*

The use of the term *successful* in group problem solving may be interpreted in a number of ways. The way success is interpreted depends primarily on the perceived objective and outcome of the problem solving exercise. Objectives may be, for example, to help students develop social interaction skills. Another objective, might be to increase the level of level of metacognition used during problem solving. Alternatively, there is an objective which is perhaps most associated with school learning, to solve the problem. This being the objective, the outcome is the correct solution of the problem. That is the object of the problem solving sessions reported in this thesis. Therefore, successful problem solving was viewed as those sessions where the groups achieved the correct and full solution to the problem.

In this chapter, I will firstly report the quantitative figures which provide an account of the proportions of collaborative metacognition which were present during successful and unsuccessful sessions. As mentioned in the methods chapter, the data are present as *proportions* of utterances rather than actual counts (although the counts will be given in parentheses). Data have also been separated into teacher present and teacher not present. The teacher joined groups at various intervals and for different periods of time. In this chapter, data will in the most part be displayed under four conditions: successful teacher present; successful teacher not present; unsuccessful teacher present; unsuccessful teacher not present.

In order to obtain figures for successful versus unsuccessful sessions, the data were separated accordingly. Of the nine sessions completed by the students, six were successful in their outcome and three were unsuccessful.

I will firstly report the proportions of different utterance types displayed by students and teachers. As noted in the literature review, metacognition is in important element during problem solving and higher quantities have been recorded during successful sessions. Therefore levels of metacognition may be an issue in lack of success. I will then go on to look at levels of transactive talk.

As the focus of this thesis is collaborative metacognition, I will present findings regarding the proportions of collaborative metacognition between the two conditions of success. Finally, I will present the proportions of collaborative metacognition which occurred through teacher-student interactions as opposed to student-student interactions during successful and unsuccessful sessions. Collaborative metacognition occurs when individuals interact with one another's talk in a specific way. In order for students to work together on a problem, they must be able to interact in such a way. Therefore the levels at which they do this during successful and unsuccessful sessions is an important factor.

As previously mentioned, the purposed of this chapter is *investigative*. It is not possible to infer causality and say what caused groups to fail to complete a problem in the allotted time. A number of issues may have impacted this. Through the process of investigating both the patterns of utterances displayed and the patterns of interactions, it may be possible to highlight factors which are more likely than others to have contributed to the outcome.

6.2 Characteristics of successful sessions

The purpose of this section is to ascertain if there was a difference in the patterns of talk displayed by students and teachers during successful and unsuccessful sessions. I will firstly present the proportion of on-task talk which was recorded during successful and unsuccessful sessions. It is logical to consider a possible explanation for lack of success might be that lower proportions of on-task talk were displayed, which might infer that students were not focussed on the task. I will then go on to present findings for the proportions of each utterance type that were recorded during both conditions.

Was there a difference in the proportion of on-task utterances during successful compared to unsuccessful sessions?

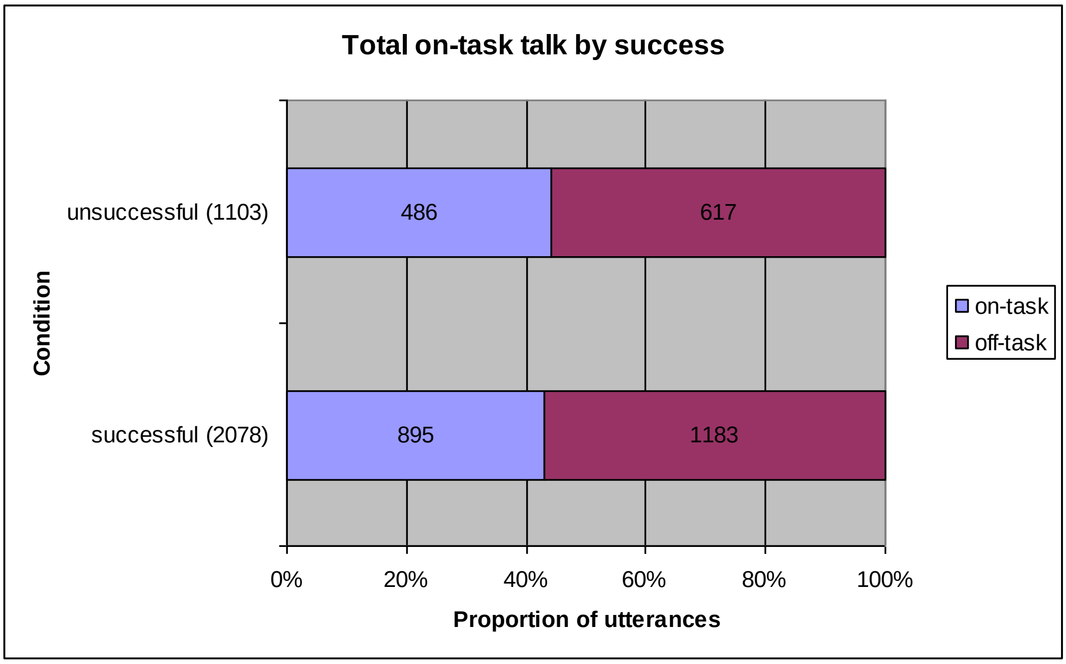


Figure 6- 1 Total on-task talk by success

Figure (6-1) shows that there were proportionately similar levels of on-task talk in both conditions. However, the actual counts of utterances were almost double during successful sessions. This might be accounted for by considering the actual *time* that the students spent on the task. Of the total time that students were recorded working, 67% was during successful sessions and 33% was during unsuccessful sessions.

There are a number of reasons to use caution when considering the actual time. Firstly, not all utterances were of a similar length. Also, when someone decided to speak, they may take a while to think about what they are going to say. Therefore, gaps may appear in the recording which use time rather than counts of utterances. Finally, when the teacher was present in the groups the total number of people present increased. Therefore, there were more people to speak which may or may not result in a higher number of utterances. These things considered, the actual counts of utterances bears a remarkable resemblance to what might be found when taking into account the actual *time* and the above issues. The quantities of utterances recorded in each condition therefore seems a reasonable reflection of the time spent in each condition.

Although the proportion of total off-task talk was similar between conditions, it may have been that a larger proportion of off-task talk was recorded when the teacher was not present in the groups. Furthermore, the teacher may have spent a larger proportion of time in the groups when they were unsuccessful. This might result in the above figures not showing a true reflection of the way the students interacted. In order to ascertain if this was the case, figures were produced which separated talk when the teacher was not present compared to when the teacher was present. Figures were also produced for the proportion of time the teacher spent in groups during unsuccessful (figure 6-3) versus successful sessions (figure 6-4).

Figure (6-2) shows that similar proportions of on-task talk were displayed when the teacher was not present in the groups for successful and unsuccessful sessions. A slightly higher proportion (29%) of on-task talk was recorded during unsuccessful sessions, compared to 27% during successful sessions.

When the teacher was present in the group, the proportion of on-task talk was higher. However, again, there were similar proportions recorded during successful versus unsuccessful sessions. Again, with a slightly higher proportion during unsuccessful 75% compared to 72% during successful sessions.

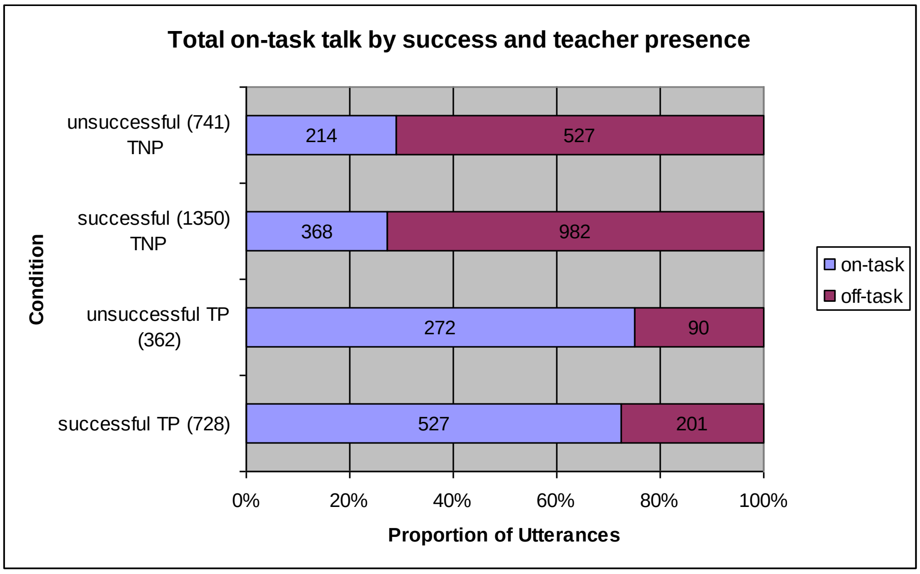


Figure 6- 2 Total on-task talk by success and teacher presence

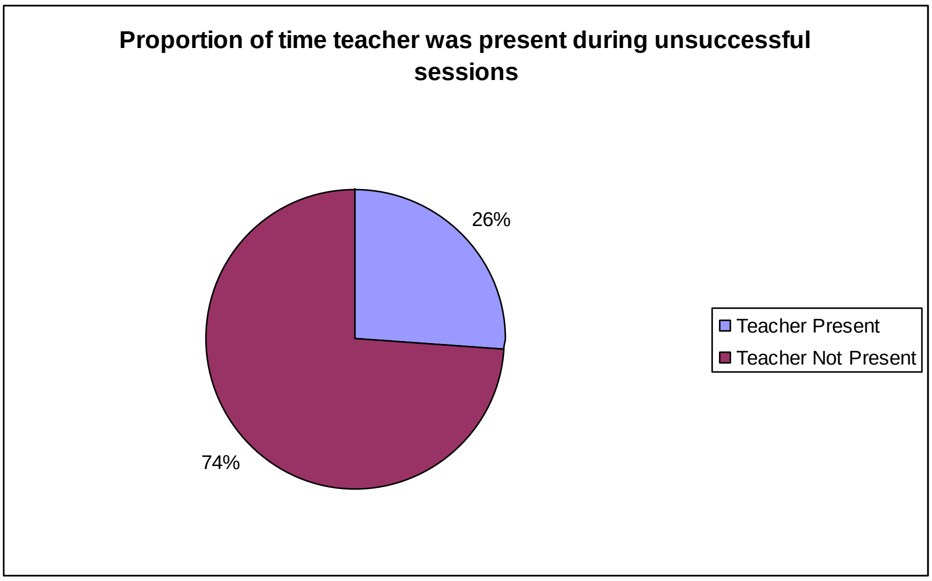


Figure 6- 3 Proportion of time teacher was present during unsuccessful sessions

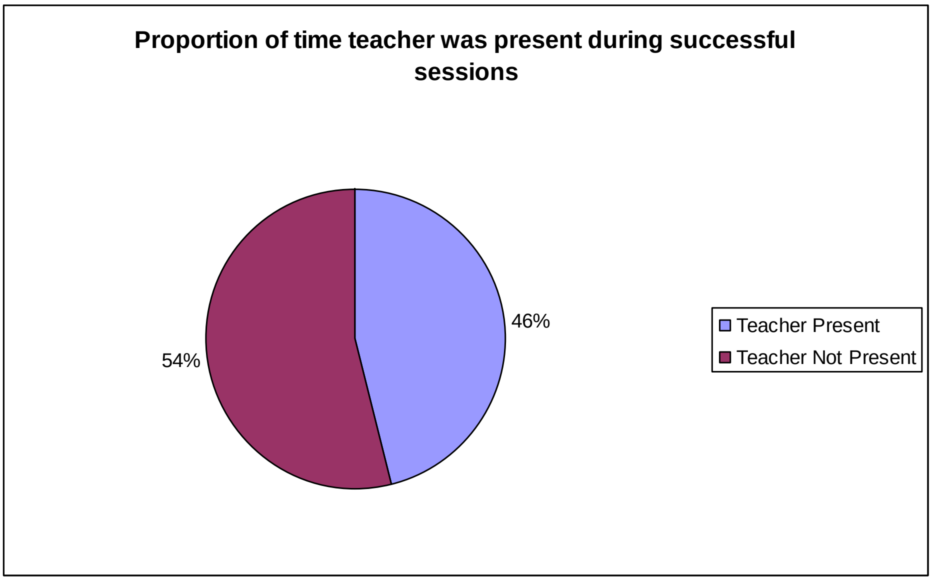


Figure 6- 4 Proportion of time teacher was present during successful sessions

These figures suggest that students were engaging with task at similar levels, through their talk, both when they successfully solved the problem and when they did not.

However, the teacher spent proportionately less time with the groups which may account for lack of success. Students struggling with the problem with less input from the teacher may fail to reach the solution of the problem.

Another potential factor in successful outcomes is metacognition. I will now present the breakdown of different utterance types during both conditions in order to ascertain if the data show similar pattern to previous research where successful problem solving was associated with higher levels of metacognitive talk.

What proportions of utterances were displayed during successful versus unsuccessful tasks?

Figures (6-5) and (6-6) give a breakdown of the utterance types displayed during successful and unsuccessful problem solving sessions at points when the teacher was present and not present in the groups. During successful and unsuccessful sessions, students displayed high proportions of social talk during both teacher conditions. When the teacher was present in the group, the overall proportion of social talk declined. However, the proportion of social talk was higher during successful sessions at 24% compared to unsuccessful sessions (15%).

During the points when the teacher was present, there was a further set of coding which accounted for teacher 'teaching' the group. When the students were not successful in completing the task, the proportion of total talk which was classed as teaching was only 3%. This figure increased to 19% when the students were successful in solving the problem.

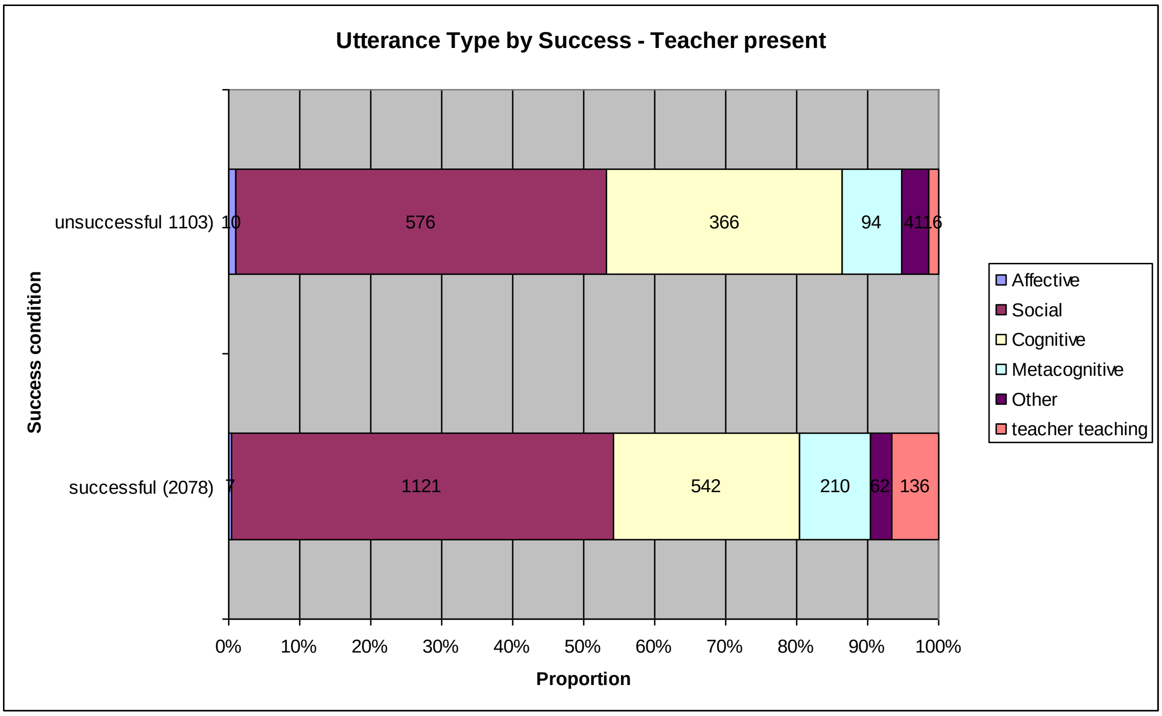


Figure 6- 5 Utterance type by success - teacher present

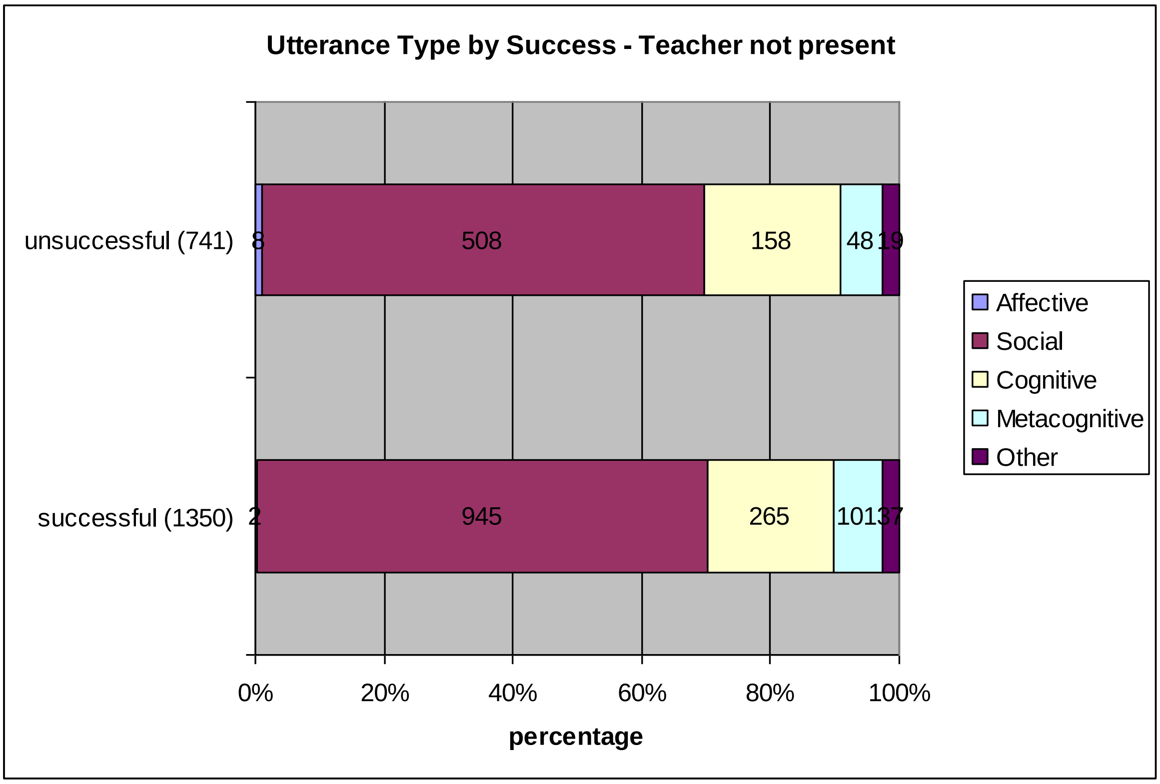


Figure 6- 6 Utterance type by success - teacher not present

In order to understand the types of utterances displayed by students, teacher talk was removed from figure (6-6). This was done because the contribution of the teacher may have distorted the overall proportions of talk and the charts presented previously may not be a reflection of what was displayed. Figure (6-7) below shows that the pattern of talk displayed by students was similar to that displayed when teacher talk was taken into account. During successful sessions, students displayed a higher proportion of social talk, a lower proportion of cognitive talk and a slightly higher proportion of metacognitive talk.

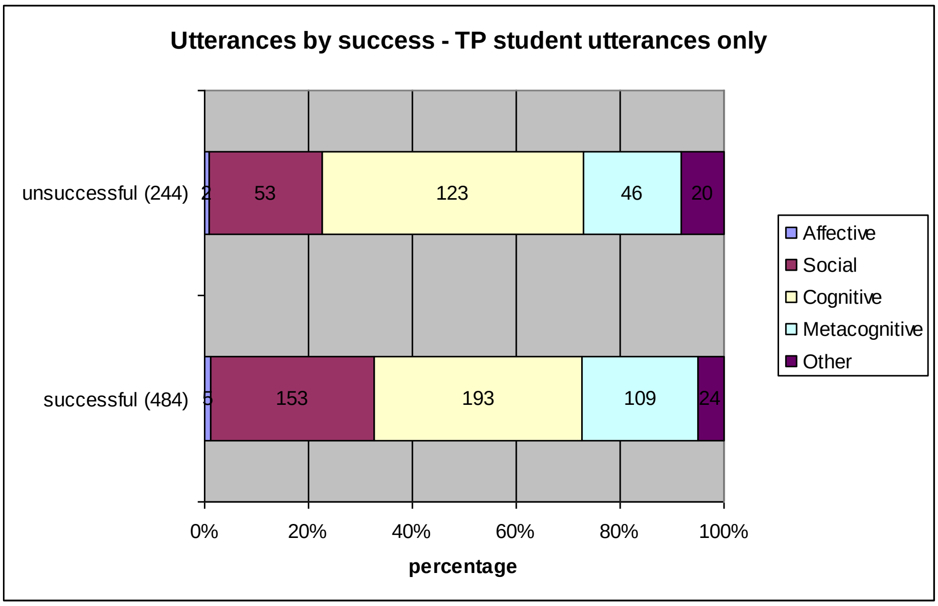


Figure 6- 7 Utterances by success - teacher present, student utterances only

By removing the large proportions of social talk from the data, a more detailed picture emerges of the breakdown of talk which was concerned with the task. Figures (6-8) and (6-9) give a breakdown of on-task utterances by success.

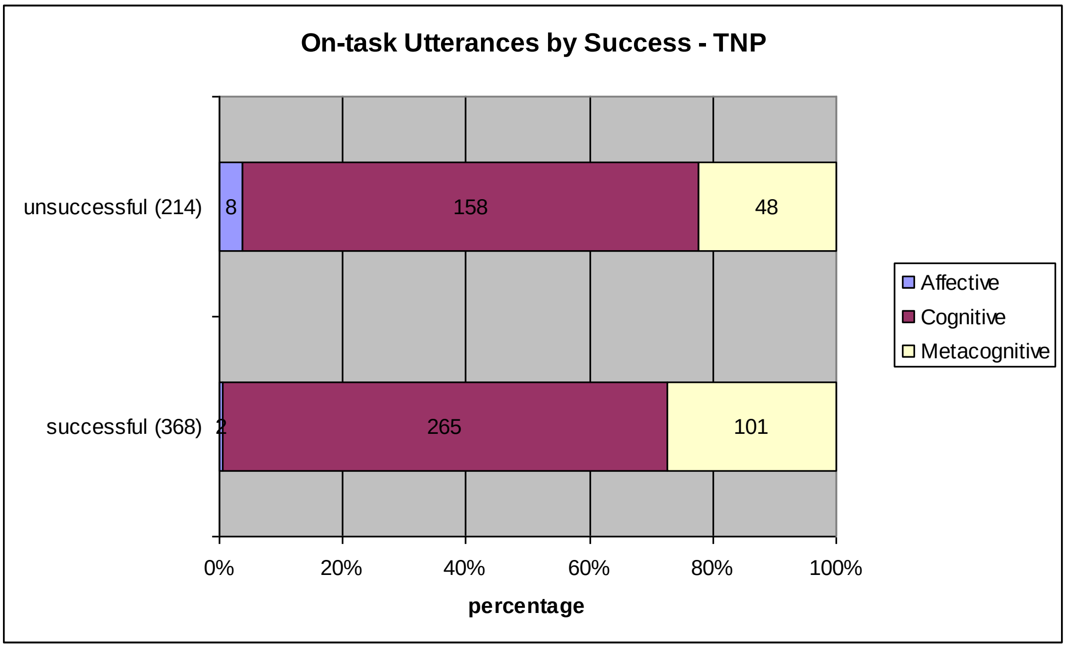


Figure 6- 8 On-task utterances by success - teacher not present

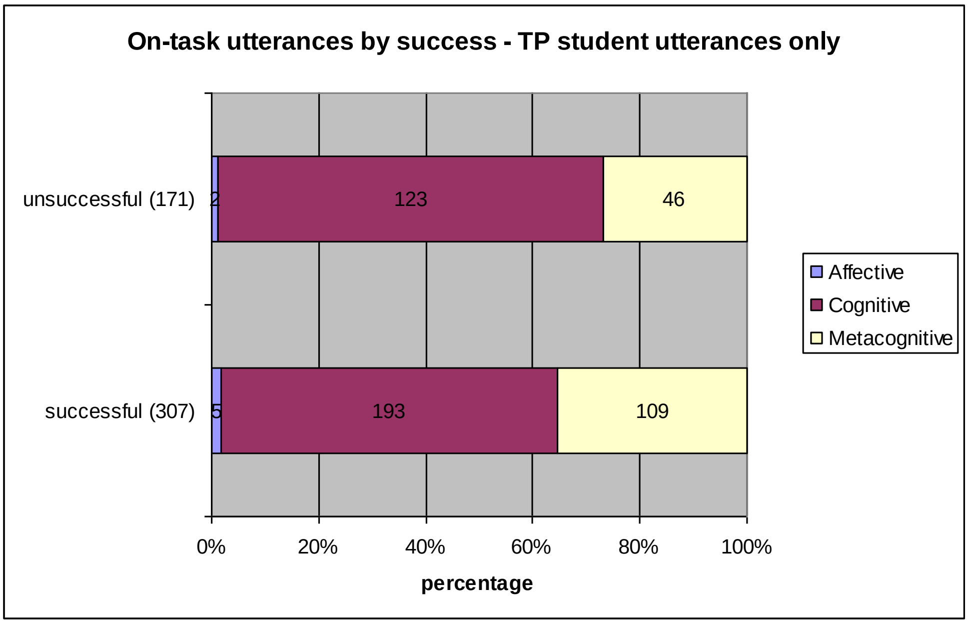


Figure 6- 9 On-task utterances by success - teacher present, student utterances only

The figures above show that the general pattern of student on-task talk is similar across the two teacher conditions. Success sessions were characterised by higher proportions metacognitive talk and lower proportions of cognitive talk.

It is also important to ascertain if the type of talk displayed by the teacher was different across both success conditions. As shown in figure (6-5), there was a higher proportion of teacher teaching during successful sessions. Figure (6-10) provides on-task data for the teacher during successful and unsuccessful sessions.

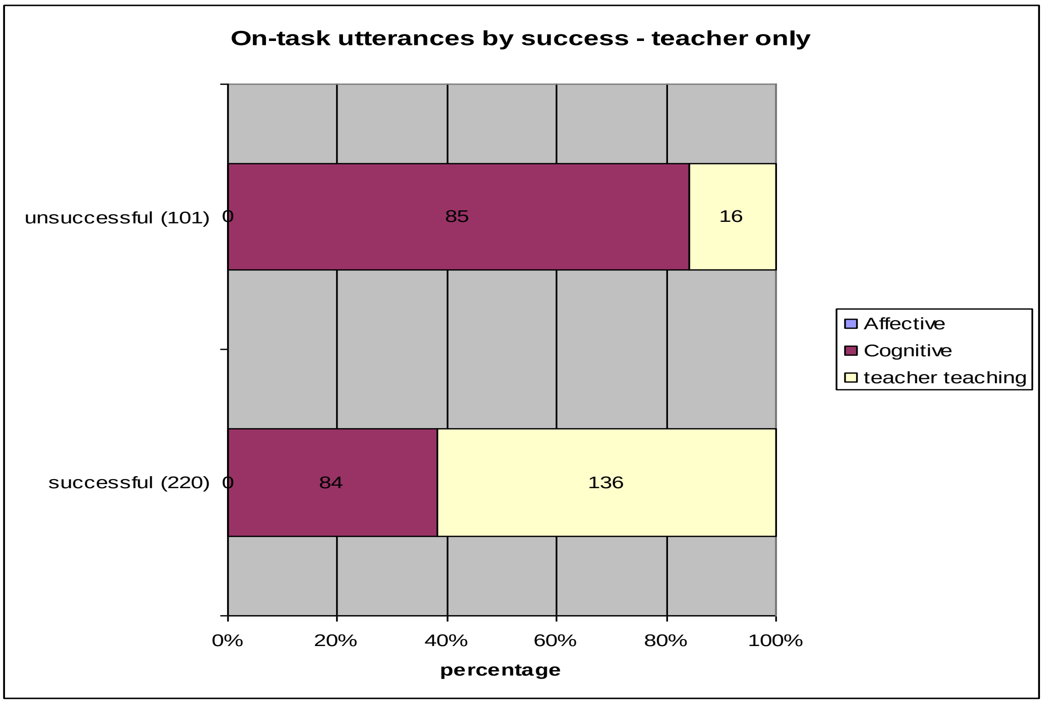


Figure 6- 10 On-task utterances by success - teacher only

As with the student on-task talk, the teacher also displayed a higher proportion of cognitive talk during unsuccessful sessions. However, the teacher also engaged in a lower proportion of *teaching* talk during unsuccessful sessions.

6.2.1 Summary

Successful and unsuccessful problem solving sessions were characterised by a change in the proportion of time spent by the teacher with groups and also a change in the talk displayed by both the students and the teacher. The teacher spent less time with groups during unsuccessful sessions and more time during successful sessions which may have contributed to the outcomes. Another explanation of lack of success may have been that students engaged in higher levels of off-task talk not concerned with the problem. However, this was not the case, with students displaying a slightly higher proportion of on-task talk, during successful sessions for both teacher conditions.

A change in the proportions of talk was evident when comparing each category of talk of the students and teacher. In both teacher conditions, successful problem solving sessions were characterised by students displaying higher proportions of social talk, higher proportions metacognitive talk and lower proportions of cognitive talk. However, the proportions social talk and cognitive talk displayed when the teacher was present was lower than when the teacher was not present for both success conditions. The proportion of metacognitive talk displayed when the teacher was present was higher when the teacher was present compared to when the teacher was not present for both success conditions.

The teacher also displayed a different pattern of talk during successful versus unsuccessful sessions. The proportion of teacher *teaching* talk recorded during unsuccessful sessions was lower than during successful sessions. In line with student talk, the teacher engaged in a larger proportion of cognitive talk during sessions when students were not successful.

These results provide a static illustration of the proportions of different types of talk recorded during successful and unsuccessful sessions. However, they do not provide any insight to the *interactive* nature of the talk. It may have been that during successful problem sessions students were more sociable to one another and more likely to interact to solve the problem. Or alternatively, they may have felt more able to interact with one another. When they were unsuccessful, they may have been less willing or able to interact in a positive way.

6.3 Transactive Talk

In order to understand the interactive nature of the discussion, I will present, in the following section, the proportions of transactive talk recorded during successful and unsuccessful sessions. I will then go on to consider the proportion of collaborative metacognition (i.e. metacognition which is followed by or which precedes transactive talk) displayed during both conditions. The sub-research question which was addressed in this section was: *What proportion of talk that can be categorised as transactive is displayed during successful versus unsuccessful sessions?*

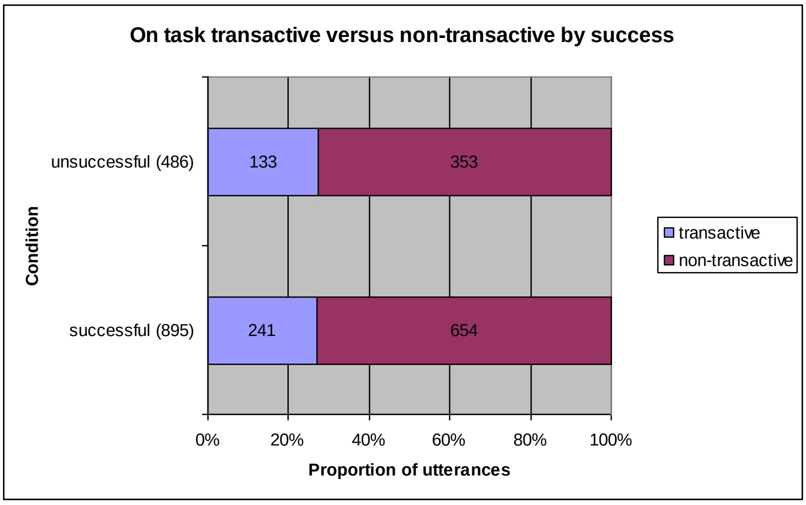


Figure 6- 11 On-task transactive versus non-transactive talk by success

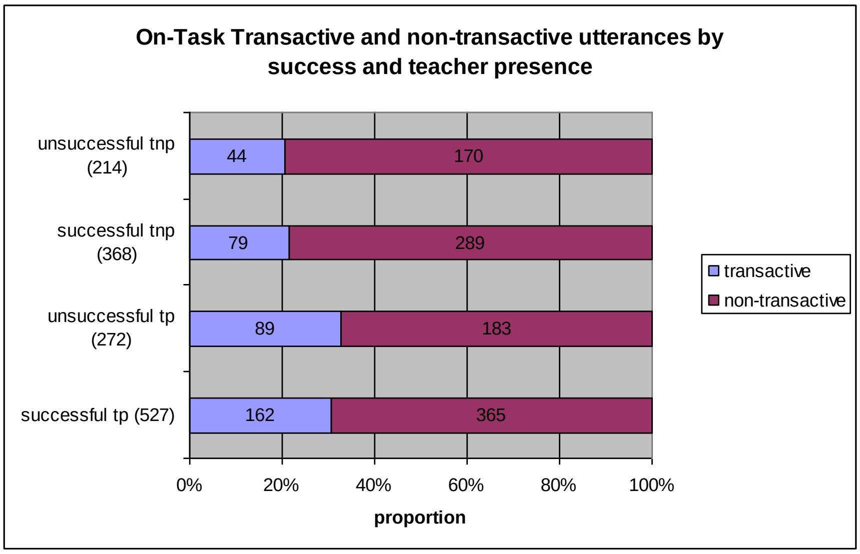


Figure 6- 12 On-task transactive and non-transactive utterances by success and teacher presence

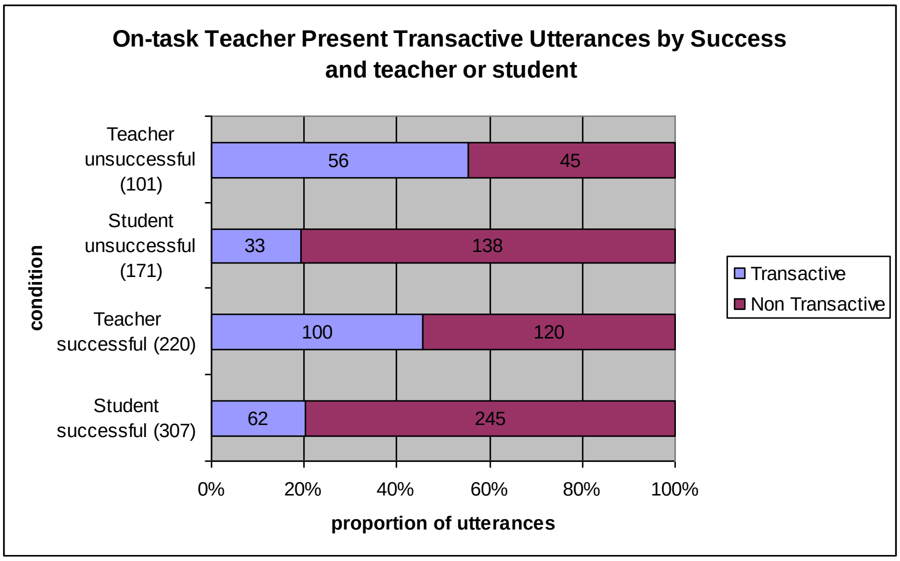


Figure 6- 13 On-task teacher present transactive utterances by success and teacher or student

Figures 6-11, 6-12 and 6-13 provide a picture of the transactive quality of talk during successful and unsuccessful sessions. Overall there was very little difference in the proportion of talk that was coded transactive between the two conditions. However, the teacher was in the groups for a proportion of the time and the previous section provided evidence that the pattern of teacher talk was different across success conditions. In order to ascertain if there was a difference in the proportions of transactive talk when the teacher was present in the group, figures were provided which separated both conditions of teacher presence and success.

Figure (6-12) shows that when the teacher was not present the proportion of student talk which was transactive was almost equal across success conditions at 21%. However, when the teacher was present in the group the proportion of transactive talk increased across both conditions. Also, during unsuccessful sessions, there were slightly higher proportions of transactive talk recorded at 33% (89) compared to 31% (162) during successful sessions.

It is difficult to ascertain from these figures why the transactive talk increased when the teacher was present in the group. Figure (6-13) provides a breakdown of transactive talk made by the teacher or students in both success conditions. These figures show that the teacher displayed a larger proportion of transactive utterances than all of the students together. Therefore, the higher proportion of transactive talk during both successful and unsuccessful sessions when the teacher was present, can be accounted for by the contribution of the teacher.

The proportions of student transactive utterances were similar across both conditions of teacher presence and success. When the contribution of the teacher is removed, student transactive talk during unsuccessful sessions accounted for 19% (33) of utterances. This proportion increased only slightly to 20% (62) for successful sessions.

A different pattern was observed for the teacher. During sessions when the groups were successful, transactive talk displayed by the teacher accounted for 45% (100) of total teacher utterances. This suggests the teacher was engaging with students in order to draw out their thoughts and ideas regarding the problem. In sessions when the students were not successful, the proportion of transactive talk displayed by the teacher rose to 55% (56). This is not to be unexpected as the teacher would naturally question, critique or extend thought processes which might be incorrect during an unsuccessful session.

6.3.1 Summary

Similar proportions of transactive talk were displayed by students regardless of success when the teacher was not present. This suggests that students interacted with one another's ideas both during successful and during unsuccessful sessions.

Similarly, when the teacher was present in the groups, the proportion of student transactive utterances was similar regardless of success. However, the overall proportion of transactive talk increased when the teacher was present. This can be accounted for by the transactive talk displayed by the teacher. The proportion of transactive talk displayed by the teacher was greater when the students were not successful in solving the problem compared to when they were successful.

These figures may be interpreted in different ways. The higher proportion of cognitive talk displayed by students during unsuccessful sessions (reported in previous section) may have prompted the teacher to engage in more transactive talk in order to encourage students to explain their thinking and possibly uncover flaws in their thinking. This type of intervention from the teacher seems likely to lead to a positive outcome for individual students and may result in higher proportions of collaborative metacognition being displayed. However, the intervention of the teacher may also have had a detrimental effect on the problem solving sessions. When students were working without the teacher in the group, they were able to contribute to the discussion at any point. However, when the teacher was present in the group there was, at times, more of a dyadic discussion, with the teacher focussing on one member of the group at a time. Although students were able to interject, the presence of a teacher may change the dynamic of a group and the teacher as an authority figure may have the effect of discouraging many people to join in.

It is not possible to claim that students would disengage from the problem solving process when the teacher was present. Nor is it possible to claim that they would engage simply because the teacher was not in the group. However, if the teacher focuses on one student in the group in order to ask questions, this *may* result in fewer student to student transactive interactions.

As previously mentioned, the students displayed similar proportions of transactive talk across all conditions and therefore it may be argued that the teacher interactions did not have a detrimental effect. However, the teacher was able to direct the discussion. If the teacher identified a particular aspect of the problem as one with which the students were having difficulty, the discussion might be directed towards that. If the teacher then continued to interact transactively with only one student, a lower overall proportion of student transactive talk would be observed than if the discussion was more open to all.

6.4 Collaborative Metacognition

The earlier section showed that successful sessions were characterised by slightly higher proportions of metacognition. This thesis is concerned with the interaction between metacognition and transactive talk and I will now consider this interaction during successful and unsuccessful sessions.

Findings in the previous chapter showed that when the teacher was present in the groups, there were higher proportions of transactive talk. There were also higher proportions of metacognitive talk which was followed by transactive talk and transactive talk followed by metacognitive talk. As noted in the previous section, during successful and unsuccessful sessions when the teacher was present, higher proportions of transactive talk were recorded. It might therefore be expected that a similar pattern be observed with higher proportions of transactive to metacognitive and metacognitive to transactive talk being recorded when the teacher was present during both successful and unsuccessful session. The research question addressed in this section is: *What proportions of talk that could be* *categorised as collaborative metacognition are displayed during successful versus unsuccessful problem solving?*

In this section I will first report the proportion of transactive utterances which were followed by a metacognitive utterance. I will then go on to present the proportion of metacognitive utterances which were followed by a transactive utterance. This will provide an account of the extent to which students engaged in collaborative metacognitive activity. Previous sections have shown that higher proportions of transactive talk were recorded when the teacher was present, which can be accounted for by the transactive contribution of the teacher. Therefore, data have again been separated to show sessions when the teacher was present in the groups compared to when the groups worked without the teacher. This allows an understanding of the contribution of both students and teacher to collaborative metacognitive activity.

6.4.1 Transactive to Metacognitive utterances.

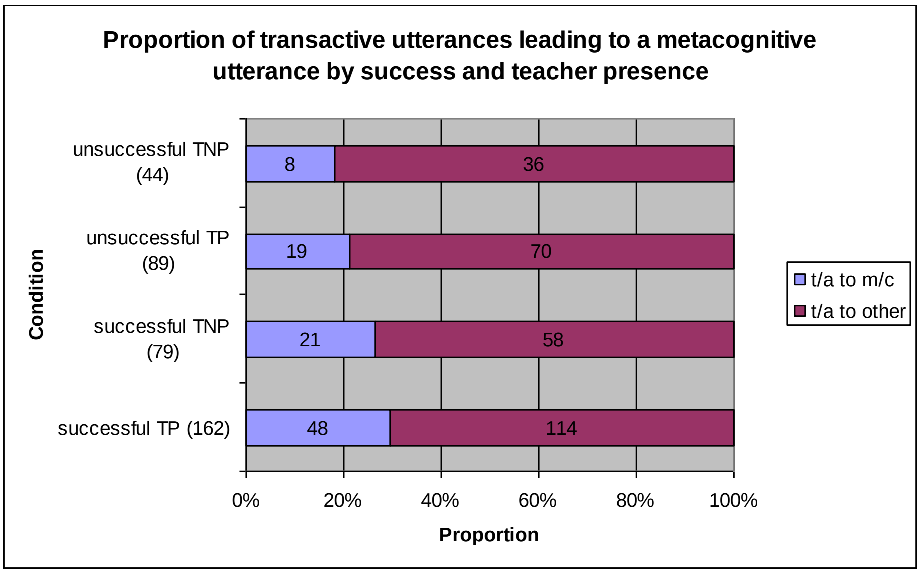


Figure 6- 14 Proportion of transactive to metacognitive utterances by success and teacher presence

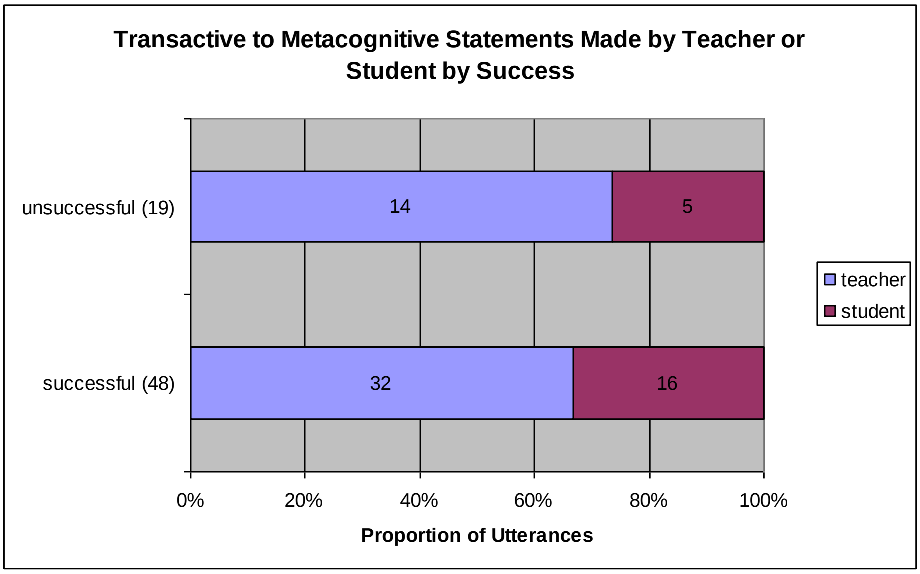


Figure 6- 15 Transactive to metacognitive statements made by teacher or student by success

During unsuccessful sessions, there was a difference in the proportion of transactive utterances followed by a metacognitive utterance when the teacher was present compared to when the teacher was not present. When the teacher was not present in the group the proportion was 18% (8) compared to 21% (19) when the teacher had joined the groups.

When the groups solved the problem successfully, a similar pattern was found across the teacher conditions. When the teacher was not in the groups 27% (21) of transactive utterances were followed by a metacognitive utterance. When the teacher was present this proportion increased to 30% (48). The increase in the proportion of transactive to metacognitive statements when the teacher was present is not unexpected as higher levels of both transactive talk and metacognitive talk were recorded when the teacher worked in the groups.

However, when the teacher was present during the unsuccessful sessions, the proportion of transactive to metacognitive statements was only 21%. This is a surprising finding since, as previously mentioned, the highest proportion of transactive talk was recorded during unsuccessful sessions when the teacher was present. In the previous section I considered the possibility that when the teacher was present in the group, the dynamics might have changed to more of a dyadic interaction rather than a whole group interaction, where the teacher may have dominated the transactive talk.

In order to investigate this further, figures were produced which showed if it was another student or the teacher who made the transactive utterances which were followed by a metacognitive utterance. Figure (6-15) provides this information. During unsuccessful sessions 74% (14) of all transactive utterances which were followed by a metacognitive utterance were made by the teacher. When groups were successful, this proportion decreased to 67% (32) and students were responsible for a higher proportion (33%) of the transactive talk which was followed by a metacognitive utterance. These figures suggest that it was the teacher who dominated the transactive nature of the discussion. Although students did share metacognition when prompted by the transactive talk of a fellow student, the proportion of this was low in comparison to the interactions with the teacher.

As mentioned in the previous section, the larger proportion of transactive talk displayed by the teacher might have had a detrimental effect on the interactions of the students. The figures presented here suggest that this might be the case. If all students were able to interact on an equal basis, it would be expected that the proportions of transactive talk leading to metacognitive would be higher for students since there are more of them. The high proportion of transactive talk by the teacher coupled with the dyadic nature of teacher-student interactions may have resulted in lower levels of student transactive talk. This may have been due to the teacher *participating* in transactive discussion rather than *scaffolding* this type of interaction.

The figures for metacognitive utterances which are followed by a transactive utterance will now be considered to ascertain if there is a similar pattern.

6.4.2 Metacognitive to Transactive Utterances

In line with the pattern displayed in the previous section, there was a difference in the proportion of metacognitive utterances which were followed by a transactive utterance when the teacher was present compared to when the teacher was not present. Figure 6-16 shows that during unsuccessful sessions when the students were working without the teacher present, 27% (13) of metacognitive utterances were followed by a transactive utterance. When the teacher was present in the group this proportion increased to 41% (19).

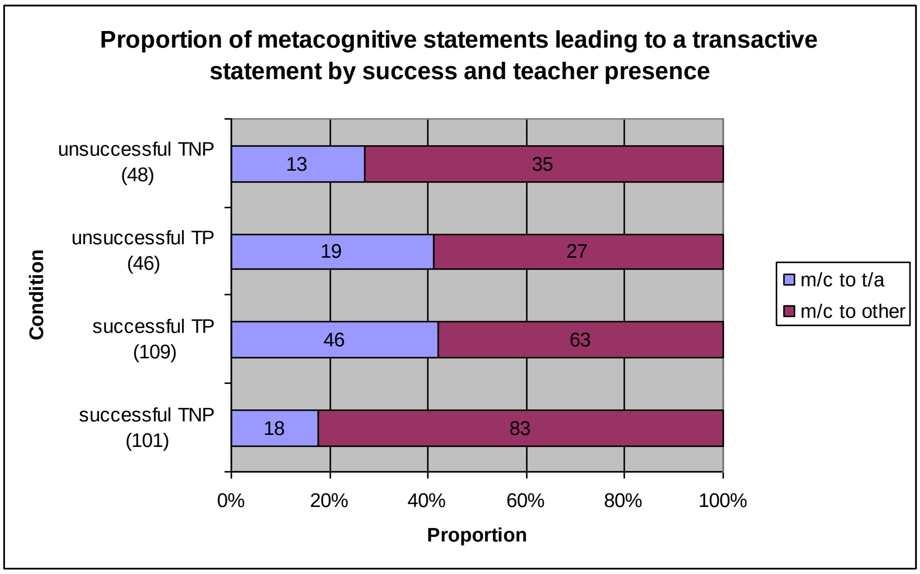


Figure 6- 16 Proportion of metacognitive to transactive statements by success and teacher presence

The pattern changed from the previous section when the groups were successful in solving the problem. The proportion of metacognitive statements which were followed by a transactive statement was only slightly greater than during unsuccessful sessions when the teacher was present. However, when the teacher was not present, a higher proportion of metacognitive statements led to a transactive statement during unsuccessful sessions 27% (13).

As with the previous section the proportion of transactive talk was higher when the teacher was present, which is unsurprising since the teacher made a higher proportion of transactive statements than did the students. However it is not clear if it was students who interacted transactively when another student made a metacognitive statement or if it was the teacher.

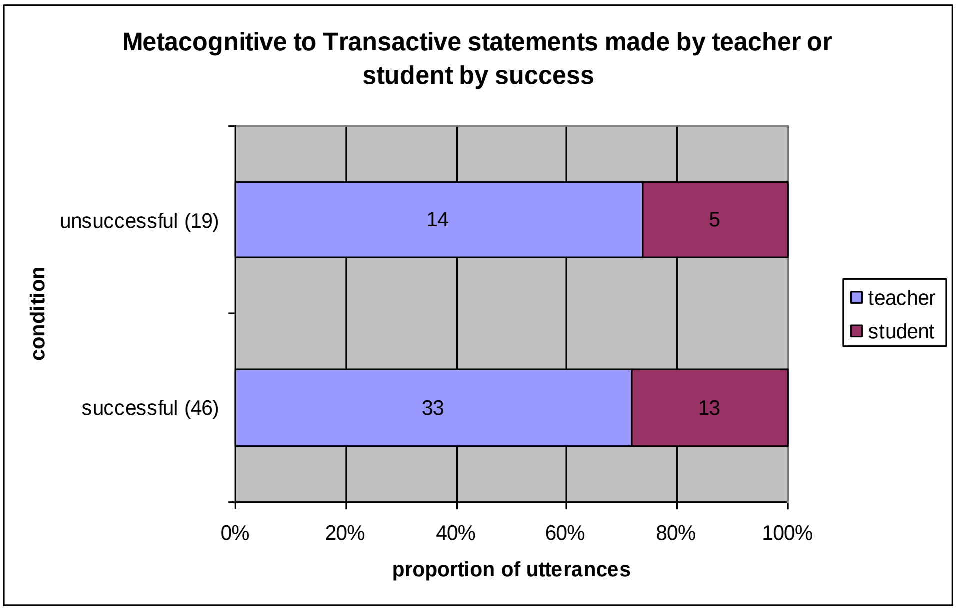


Figure 6- 17 Metacognitive to transactive statements by teacher or student by success

Figure (6-17) shows that the teacher was responsible for a large proportion of transactive statements which were made following a metacognitive statement by a student. During unsuccessful sessions, the teacher was responsible for 74%(14) of these utterances. During successful sessions, the students do show slightly more interaction with the teacher responsible for 72% and the students responsible for 18% of transactive utterances.

6.4.3 Summary

During successful sessions there were higher proportions of transactive to metacognitive statements recorded across both teacher conditions. The proportion displayed during unsuccessful sessions when the teacher was present was surprisingly low at 21%. This condition had displayed the higher proportion of transactive talk across all conditions and it had been expected that transactive to metacognitive talk would be higher. There was a slightly different pattern for metacognitive to transactive. Successful sessions had higher proportions when the teacher was not present. However, there was very little difference when the teacher was present. This is less of a surprising finding as it was the teacher who was responsible for the high proportion of transactive talk displayed. The teacher was therefore interacting transactively with the students.

During successful and unsuccessful session, it was transactive talk by the teacher which dominated the proportions of both transactive to metacognitive and metacognitive to transactive utterances displayed. When groups were successful, a higher proportion of transactive utterances were made by students which contributed to the proportions of transactive to metacognitive and metacognitive to transactive displayed by students. When the teacher was not present in the groups, the students displayed higher proportions of both transactive to metacognitive and metacognitive to transactive talk when they successfully solved the problem.

Therefore during successful sessions the overall proportion of student-student transactive to metacognitive and metacognitive to transactive talk increased.

6.5 Overall summary

Successful and unsuccessful problem solving sessions were characterised by different patterns of talk being displayed as well as by different patterns of interactions by both teachers and students. Specifically, higher proportions of student metacognitive and social talk and lower proportions of cognitive talk were recorded during successful compared to unsuccessful sessions. Successful sessions were also characterised by lower proportions of cognitive talk by the teacher as well as higher proportions of *teaching* talk. Student transactive talk showed similar levels in both conditions. However, the proportion of transactive interaction displayed by the teacher was higher during unsuccessful sessions.

Proportions of collaborative metacognition differed between conditions. The overall proportion of transactive talk which was followed by metacognitive talk was higher during successful sessions. When the teacher was present in the group, the majority of this strand of collaborative metacognition was produced from teacher to student interactions. However, during successful sessions, there was a higher proportion of student to student collaborative metacognition. This suggests that during successful sessions, when the teacher was present, students were more engaged with one another's thought processes.

The proportion of metacognitive talk which was followed by transactive talk produced a different pattern. The overall proportion of metacognitive talk which was followed by transactive talk was *lower* during successful sessions. Again, when the teacher was present in the group, the majority of this collaborative metacognition was produced from teacher to student interactions. Again, there was a very slightly higher proportion of student to student collaborative metacognition during successful sessions.

Whilst parts of these findings concur with previous research, they do not provide unequivocal support for a relationship between collaborative metacognition and successful group problem solving. One potential explanation for this is that the data are too few in number to fully understand the interactions. However, in the next section, I will argue that it is not simply *quantities* of collaborative metacognition which will impact success. A group might display high levels of collaborative metacognition yet be unsuccessful. Similarly, a group might display low levels of collaborative metacognition and be successful. Associations between quantities of a particular type of learning process and success allow a very limited understanding of that process and its relationship to outcomes.

Rather, I will argue that it is important to understand critical points in the solution process which might be impacted by the lack of collaborative metacognition. Furthermore, I will provide evidence that the lack of collaborative metacognition during successful problem solving can impact learning of group members. It is therefore crucial that issues which impact the use of collaborative metacognition are identified in order to fully understand its role, and enhance its use, in group learning.

Chapter Seven: Student-reported contradictions during collaborative problem solving

7.1 Introduction

In this chapter I will provide evidence from the critical recall interviews and argue that there are many issues which may impact the use of collaborative metacognition during both successful and unsuccessful sessions. As a result, proportions of collaborative metacognition are not sufficient data to develop an understanding of the use of collaborative metacognition. Rather, a deeper understanding of these issues is required through interview data with students.

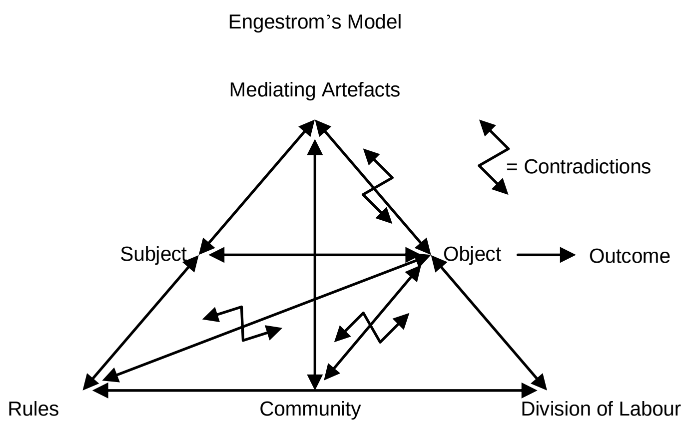
As noted in the chapter on collaborative metacognition, previous research has identified social aspects which might impact student interactions. For example, Artz and Armour-Thomas (1992) found that in some groups, one student might dominate the solution finding process whilst in another, all students may contribute. Furthermore, Larkin (2009) suggested that due to the complex nature of social interaction, the use of frequency counts alone does not allow a full understanding of issues which may impact these processes.

Of the three groups who were interviewed, one had been successful each session. The two groups who had experienced unsuccessful sessions were shown a portion of video which was deemed to be a critical point in the solution process. It was also a point where collaborative metacognition might have been expected to occur but did not. The group who were successful each week were shown a portion of video which represented a development in the way in which they had worked previously. Again, this was a point where collaborative metacognition might have been expected but did not occur. Through the reports of the students and the data from the videos, I will argue that there are many issues, during both successful and unsuccessful sessions which impact the use of collaborative metacognition. As a result, the methods employed to research this concept must develop beyond *traditional* metacognition methods such as measuring quantities of metacognition displayed.

7.2 Student Report Contradictions and the Impact on Collaborative Metacognition

The interpretation of the qualitative data presented in this section has been informed by Activity Theory. As detailed in the methodologies section, Activity Theory can be used to understand and explain learning situations. When the learning process is viewed as an *activity* there are many issues which might impact the outcome. Engestrom's model of Activity Theory (Engestrom 1999, figure 7-1) explains outcomes in terms of the relationship between mediating artefacts (or tools), rules, division of labour, community and those carrying out the task. Engestrom (2001) proposed that an important concept of activity is that of *contradictions*. Contradictions are *'historically accumulating structural tensions within and between activity systems'* Engestrom (2001, p 137). These contradictions are not merely transient issues which may have arisen during an activity. Rather, contradictions represent issues which are more deeply rooted, having a historicity as previously mentioned. Although contradictions might impact an activity in a negative way, they may also be the catalyst for positive innovation and change (Engestrom 2001). A more detailed discussion of this is provided in the methodologies chapter.

Here, collaborative metacognition is viewed as a *tool* which enables students to successfully participate in the *activity* of joint problem solving. When students were interviewed, three areas were highlighted where contradictions occurred and subsequently had an impact on the use of collaborative metacognition. The three areas were rules, mediating artefacts, and division of labour. No contradictions were evident in the area of community. In the following sections I will provide a more detailed account of the contradictions. I will present the data by group. For each group, I will provide an overview of the problem which was set. I will then give a brief overview of the group dynamics and the portion of video which was chosen for the recall interviews. Finally, I will present the student-reported contradictions, together with further evidence from the transcribed video data.



Object – generator of foci of attention, motivation, effort and meaning, the goal
Subject – individual or group at the focus of the study
Mediating Artefacts - instruments, tools and signs used in the activity
Division of Labour – division of tasks amongst subjects during the activity
Rules – norms and rules which influence actions and interactions
Community – those participating towards the object of the activity
Contradictions – the motive for change within the activity system

Figure 7- 1 Engestrom's (1999) Model of Activity

7.2.1 Group One: Contradictions in Rules

The problem which group one were unsuccessful in solving was one which considered *area*. The task was to work out the possible dimensions of a rectangular swimming pool of which the area was 36 metres squared. The students were told that the pool was not 9 x 4 metres and they had to compile possible alternative solutions: 1 x 36, 2 x 18, 3 x 12, 6 x 6. The teacher suggested that this would be a difficult task for the students due to the need to be able to differentiate between area and perimeter. Both of these concepts had been covered relatively recently.

Over the three sessions which were recorded, group one generally displayed positive interactions. However, they were prone to large portions of off-task talk. According to the teacher, at least two members of the group should have been able to solve the problem if working on their own and so it had been expected that they would have achieved the solution as a group. The group was not successful and on viewing the video data, it became clear that there was one particular point which might have proved critical in the solution process.

The portion of video which was shown to the group was from a point when one member of the group, Scott, appeared to have worked out the solution with the help of the teacher. The teacher then requested that Scott share this information with the rest of the group, and she left. However, the rest of the group seemed less than willing to listen to Scott, and he refused to interact with them until they displayed behaviours which he felt were acceptable. In this section the group members are displaying *contradictions* in the *rules* they apply to social interaction.

Engestrom (1993) suggested that *rules* could be both explicit and implicit rules which individuals use to guide their actions and interactions. Group one in the study displayed contradictions in the rules that governed the willingness of group members to engage in collaborative metacognition. The following text, taken from the problem solving session highlights this.

244	Teacher	Ok, fantastic. What do you know about this rectangle (referring to the sheet).
245	Scott	it’s 36 metres squared.
246	Teacher	Ok, so why did Elliot bring some lengths of rope?

247	**Duncan**	**Because 9 times 4 is 36.**
248	Teacher	Ok, if that's wrong, what have you got to do?
249	Lara	4 times 9?
250	Scott	No!
251	Duncan	thirty, thirty, thirty-six divided by four?
252	Lara	Which is nine!
253	Duncan	Thirty six divided by nine?
254	Scott	Oh No!!
255	Teacher	No, anything else?
256	**Scott**	**No you have to, with 36 , these bits are smaller (making a rectangular shape with his hands) so you need…. 36 metres altogether these bits (to opposite sides) are, we have to figure out two things, the two ones (sides) that are shorter and the two ones (sides) that are longer and make up 36.**
257	Teacher	Fantastic!
258	Duncan	What?
259	Teacher	Say what you just said, that's exactly what you've got to do.

In the above excerpt there are two points where there was collaborative metacognition between the teacher and a student. At line 247, Duncan was able to explain his reasoning behind his understanding of the problem, he also extended Scott's contribution of 36 metres squared. At line 256, Scott is able to explain to the teacher what he thinks he has to do in order to solve the problem, whilst correcting Duncan's suggestion. At the end of the interaction, the teacher encouraged Scott to share his thinking with the rest of the group and then left. In doing so, she presumably hoped that Scott would display metacognition in order to draw the group in to the discussion. This was a particularly critical point in the solution process as Scott had seemed to misunderstand the problem and was trying to work out the perimeter of the rectangle instead of the area. Had he explained his thought processes to the group members, there may have been the potential for them to engage in a discussion with Scott in order to correct his thinking. This type of interaction would have resulted in student-student collaborative metacognition.

However, the following excerpt provides evidence that social rules might impact the willingness of students to engage in collaborative metacognition, the result of which was that Scott's misunderstanding was not highlighted until much later in the session:

261	Scott	The two smaller bits, the two smaller bits needs to be the same length. Guys! (Duncan and Riana are laughing and joking together rather than listening to Scott).
262	Duncan	Yeah?
263	Scott	Mrs McKenzie just told me to explain it again.
264	Duncan	Keep explaining. Keep, keep explaining
265	Riana	(laughs and says something about her fingers)
266	Scot	I won't until Riana stops laughing
267	Duncan	Finlay… I mean… (laughs) Scott, Scott keep explaining
268	Scott	not until Riana stops laughing.
269	Duncan	(hides Riana behind his pencil case) Riana's not there any more. Scott just explain, just explain.
270	Scott	No
271	Duncan	Explain
272	Scott	I'm not
273	Duncan	I'll tell Mrs McKenzie.
274	Scott	I'm just gonna blame Riana then.
275	Riana	How can you blame me?
276	Scott	Cause I'm not doing it cause you are laughing.
277	Duncan	C'mon just explain it.
278	Scott	Well I am now, right.
279	Riana	(inaudible)
280	Duncan	Scott!! Scott just do it!
281	Lara	Riana stop laughing, you're making me laugh!
282	Riana	Lara's making me laugh.
283	Duncan	Just explain Scott, come on, hurry up I'm gonna get so bored!

The interactions above suggest a certain amount of tension between Scott and the rest of the students. Scott was adhering to certain social rules, whereby he would not explain to the rest of the group unless they stopped laughing. This interaction went on for some time and, to a large extent, contributed to the lack of success. Whilst this text clearly shows Scott's reluctance to explain the problem when the group was not giving him their attention, evidence from the recall interview highlights a deeper historical problem. Scott reported a dislike for working with others and a belief that he would learn more if he worked on his own. These *implicit* rules regarding the type of people Scott is willing to interact with on a level which requires collaborative metacognition seemed to be affecting his ability to interact during this problem:

Researcher	Can you tell me what was going on at this point in the film – what were you thinking?
Scott	They wouldn't stop giggling and it was getting me annoyed
Researcher	Scott, what did you think when Mrs McKenzie asked you to explain the problem to the rest of the group – were you able to explain the problem?
Scott	not really, they were all giggling.
Researcher	how did you all feel working in the group together – did you enjoy that?
Scott	I prefer to work on my own because you don't have to explain things
Researcher	What's wrong with explaining things – did you know in your head what you wanted to say?
Scott	I could work it out much quicker on my own
Researcher	did you enjoy explaining it to Mrs McKenzie?
Scott	yes
Researcher	and you looked really happy when she said you got it right so why couldn't you share that with other people – could you still remember the solution?
Scott	well it depends who it is – if it was John and Mark (his two friends) I wouldn't mind cause they would listen but they just all kept giggling at me.
Researcher	so why would John and Mark listen?
Scott	cause they're on the same level as me.

Scott reported here that he enjoyed explaining his thinking to the teacher. He also enjoyed explaining it to those he perceived to be *on the same level* as he is. Scott's *rules* for interacting in a manner which would result in collaborative metacognition were based on his perceptions of the intellectual abilities of others.

This preference to work individually rather than in groups was echoed by Duncan and Lara. Duncan's rules for deciding who he was willing to interact with were based on intellectual ability. However, Lara, preferred to work with friends. Only one member of the group, Riana, said she preferred to work with others. Duncan, Lara and Scott also viewed the group as a place where individual learning was less likely to occur:

Researcher	Scott feels it's quite difficult to explain things to people because it slows him down
Duncan	it is
Research	and do you find that?
Duncan	I do
Researcher	so would you rather work in a group or on your own?
Duncan	on my own – I like working individually
Scott	me too
Riana	that's what Scott says but I don't like working individually because I can never work it out
Researcher	so you quite like working in a group Riana because you feel you can't work it out on your own?
Scott	but you can't do it in a group if you keep on giggling
Researcher	but the group can get the answer right and you've maybe not learned anything
Scott	exactly – so it's better if you do it individually because you do learn something
Researcher	but what if you did it in a group and you all learned something?
Lara	well in that (video) situation what would have helped?
Duncan	if Scott had actually explained the problem

The text presented above shows that the willingness of students to make their thinking known to others was influenced by implicit rules which each individual created regarding who they were willing to interact with. By implicit, I mean that they were not made explicit during the problem solving session. They also had clear opinions on the likelihood of learning in a group situation. Three out of four of the group members believed that learning was less likely to occur in a group situation.

Later in the session further evidence of the impact of the contradiction in rules which the students used to guide their interactions was highlighted. Scott began to explain his thoughts on the problem to the other group members. As I mentioned previously, Scott was trying to work out the perimeter of the rectangle rather than the area. To do so, he was assigning measurements to the sides of the rectangle which might produce 36 (which referred to the area). Riana attempted to interact and tried to make helpful suggestions. However, Scott was unwilling to listen to her suggestions and kept cutting her off:

348	Scott	Right, these two sides are smaller than these two sides (makes shapes with his hands) so they, let me get this right.
349	Lara	Why is the long one 3 and the short one 15?
350	Scott	Because it's not supposed to be, it's not exactly. 15 and 15 and 3 equals 33 and 3, 36. So that's how long the rope should be.
351	Riana	Why don't you get..(Scott cuts her off)
352	Scott	These two sides are shorter than these two sides (make shapes with his hands) and it's 36
353	Riana	Why don't you get..(Scott cuts her off)
354	Scott	and these two sides should be 3cm, 3 metres, and these two sides should be 15 metres.
355	Riana	Why don't you get a big rope that's 36metres area
356	Duncan	and put it round
357	Lara	Aah (David hit her foot with the chair)
358	Riana	And put it roun…(Scott cuts her off)
359	Scott	We've factored [sic] the problem out! Hazzah!!

As previously mentioned, the difficulty in this task was that the students had to differentiate between perimeter and area. Scott was wrong in his choice and began to try and work out the perimeter. I believe that contradictions in rules for interactions displayed by the students contributed to the lack of collaborative metacognition. Had the students interacted in such a way, they may have realised that Scott was on the wrong track with his suggestions. However, Scott's *rules* which prevented him from interacting with the group when they were laughing, also prevented him from interacting when other group members made suggestions. Scott had suggested that he preferred to work on his own because explaining took too long. Furthermore, if he had to work with others he preferred to work with those on the *same level* as he is. Scott specifically referred to other class members whom he believed to be on the same level and did not include those in his group. He also noted that these class members would not engage in the behaviours displayed by those members of his group, such as constant laughing. Therefore, had Scott been in a group which contained members which fitted into his rules for engagement, then he may have engaged in the kind of interactions which result in collaborative metacognition.

Towards the end of the session, the teacher joined the group and realised that Scott had been working on the perimeter rather than the area. Despite the teacher correcting the students and suggesting that the group work together to find the area rather than the perimeter, it was only Scott who made any attempt to do so. Furthermore, he made no attempt to involve the rest of the group, who were interacting on a social level. The overall result was that the group was unsuccessful in completing the task.

7.2.2 Group three: Contradictions in Mediating Artefacts

This session was the first of those recorded. The problem set to the groups was a measurement question regarding ski jumping and the winter Olympics. The groups were given a distance measurement for one ski jumper (the American). They were then provided with details of the ski jumpers and were asked to work out how far each had jumped e.g. the British skier jumped one and half times as long as the American skier. The final task was for the groups to sort the answers to display the winners of the gold, silver and bronze medals. According to the teacher, this activity would be difficult for the class because it involved three steps. Students firstly had to establish that the problem involved multiplication. They then had to perform the correct calculations and finally sort the answers into gold, silver and bronze positions.

Group three was the least successful of the groups and only successfully solved one problem out of the three which were recorded. However, during the sessions that they were filmed, they had generally interacted in a positive way with one another.

The session in group one highlighted the way in which contradictions in the rules of social interaction might impact the use of collaborative metacognition. Another factor which might be impacted by contradictions is that of mediating artefacts or tools. The activity system requires the use of tools for the problem solution. These tools might be books and equipment, or they might be linguistic or cognitive tools, such as metacognitive ability.

Metacognitive ability, as noted in the literature review, differs between individuals. One aspect of metacognition is knowledge of cognition, where an individual will be aware of their cognitive processes and be able to describe these. Contradictions might exist between cognition and metacognition. An example of such a contradiction is when an individual is able to process information in order to produce a solution, but they are not able to access those processes in order to explain them. Evidence of this type of contradiction can be found in group three.

Although group three managed to successfully solve some of the multiplication problems, they were confused when trying to work out how long the Australian had jumped. The solution to this required the multiplication of 2 x 1.5. However, they were not able to work out how far the Australian jumped. Two of the students suggested different answers and an argument ensued:

249	Molly and Fraser together	Australian one and a half……..
250	Molly	what? Wait, wait, wait, six, right so that's (referring to previous answer)
251	Jonathon	right that is six.
252	Fraser	one and a half, one and a half is three centimetres.
253	Molly	no it's four and a half.
254	Fraser	No
255	Molly	four and a half centimetres, yes it is.
256	Jonathon	is it?
257	Molly	no, wait
258	Jonathon	ok.
259	Fraser	I think it's three centimetres.
260	Molly	one and a half, right? Three, three and a half, or four and a half, I don't know.
261	Fraser	say…
262	Molly	Three and a half
263	Anne	three…….
264	Fraser	the Swiss jumped two and a half.
265	Molly	three and a half, do three and a half cause that was like…

In the excerpt above, when Molly and Fraser disagreed on the solution, rather than engage in collaborative discussion regarding their different solutions, the group immediately sought the assistance of the teacher:

267	Teacher	Ok, well try and draw it out, maybe drawing it out, seeing this, using your ruler, see if that might help you. Would that help you? So if the American jumped 2, so the Canadian jumps twice as long, so you've got that. The Brit jumps three times as long, yeah, which is there. The Australian jumped one and a half times. So if you're saying…..
268	Fraser	oh right!
269	Teacher	he's jumped one and
270	Fraser	four
271	Teacher	that would be two, twice as long. So what's one and a half?
272	Fraser	**Three**
273	Molly	**Three and a half.**
274	Teacher	mmm hhh (meaning yes! Teacher leaves)
275	Fraser	three, that's what I said.
276	Molly	that's what I said.
277	Fraser	no you said three and a half. The Swiss jumped two and a half times as long.
278	Molly	that's the answer.

The involvement of the teacher, rather than bringing about agreement, resulted in the disagreement being continued. When the teacher joined the group, Molly and Fraser were both listening to her instruction. However, the teacher was focussing on Fraser and interacting primarily with him. When the teacher then asked for the answer, both Molly and Fraser gave their answer. However, importantly, both believed that the teacher was replying to them when she agreed that the answer was correct.

As previously mentioned, contradictions are not necessarily negative and are often catalysts for change within the activity system. Such a change would be necessary for Fraser and Molly to resolve their differences. The group had, until this point, been calculating their answers *individually* without any attempt at collaboration. However, the cognitive contradiction displayed by Fraser, should have invoked a situation which resulted in questioning and critiquing to resolve the disagreement.

This did not occur and the students continued to disagree. Fraser began to withdraw from the group whilst Molly continued to try and work out the answer on her own. Fraser did attempt to contribute to the final part of the question, however Molly did not want to interact and told him to be quiet. The other two members of the group, who had been for the most part spectators of the argument rather than participants, continued to watch Molly and Fraser pursue their different objects.

On a surface level, we might conclude that Molly and Fraser both thought they were correct and neither wanted to interact and find out the correct answer. However, the recall interview with the group suggests two deeper level contradictions which might have impacted the interactions of all four group members. The first of these was Fraser's ability to produce the answer cognitively yet not be able to explain it *metacognitively*. The second contradiction relates to the rules that the students used to decide on their level of interaction and subsequent decisions regarding the correct answer.

Group three: Cognitive/metacognitive conflict

I previously suggested the Fraser experienced a cognitive contradiction which might have acted as a catalyst for a change in the way in which the students were interacting. However, this did not happen. Fraser referred to his metacognitive ability as a possible explanation for the lack of change:

Researcher	Molly, …. What did you think of Fraser's answer of three?
Molly	I don't know – I just didn't think it was right.
Researcher	Do you think it was because it was Fraser that said it or do you think if it was Jonathan who had said it……
Molly	I said 'how did you work it out?' something like that because he went across to the teacher, and so it was just three and I never thought it was right.
Researcher	so did you think Fraser just plucked that out of his head?
Molly	yes
Research	(to Fraser) Do you think you just plucked it out of your head or do you

think you did something to work it out?

Fraser I think that I did something in my head that you couldn't actually see in the video and then I forgot cause like, it kinda did just come out my head

Researcher so you think you did something in your head but then you maybe forgot how you got three? So you couldn't then explain it to Molly?

Fraser yeah

Researcher so then Mrs Mckenzie came along and did that help you when she was showing you how to work it out on the ruler?

Fraser a bit yeah

Here, Fraser reported that he as unable to explain his solution to Molly. His metacognitive ability, his ability to explain the process of multiplication, was either not developed or not accessible during this process. However, there were another two members of the group present who might have been able to contribute to the discussion. During the course of the recall interview, Jonathon indicated that he did know what the answer was, yet he did not contribute during the disagreement between Molly and Fraser:

Researcher well Jonathon you weren't quite with Fraser on this one because you were still looking for a half and later on you were still saying it was something and a half – do you remember what you might have thought?

Jonathon well what was the sum again?

Researcher it was 1 and a half times 2

Jonathon that is three

Researcher yes but in this video when you are all trying to work it out you didn't think it was three – Fraser was the only one who thought it was three – that's what I was trying to understand

Jonathon I'm actually sure I thought it was three

Researcher Ok, so Jonathon you didn't actually commit to an answer and you weren't involved there so can you maybe explain why?

Jonathon Well, the thing is, I was just like watching them because they had a big interesting thing going on so I kinda just drifted off and was watching them in a trance or something like that! And then they were just going on with the answer so I didn't really know who was right at that point.

Researcher ok, so you hadn't actually worked it out yourself? So you were just listening in to see…

Jonathon	yeah, if I got any ideas for what it could be

Jonathon chose to be a spectator in the argument between Molly and Jonathon rather than trying to participate or even work out the answer on his own. He acknowledged that the arguing was a factor in his participation. Similarly, Anne highlighted that arguing was a factor in her lack of participation. However, Anne also acknowledged that she found problem solving difficult and did not always understand it, which influenced her participation:

Researcher	Is there anything, Jonathon, that you think would have encouraged you and Anne to take part more?
Jonathon	em, if they would stop arguing basically – because the thing is the big argument lasted the whole time and it was about one sum and I'm sure I would have got onto the next one and the one after that
Researcher	right, so you think the arguing put you off taking part?
Jonathon	yeah
Researcher	ok, and Anne, what about you?
Anne	I think that like, I didn't really, .like get involved that much because they were like arguing and like sometimes I think that like problem solving can be quite hard because like it gets confusing when there's like numbers and stuff to do in it.
Researcher	and what might help you, Anne, if it's quite confusing? Is there something that might help you? When you are sitting watching what's happening, are you trying to work the problem out? Are you trying to understand?
Anne	sometimes I'm trying to understand and to work out how to do it but like em, sometimes it's hard so I can't figure it out by myself
Researcher	but you think it's nice when everybody tries to explain what it's about – does that help you?
Anne	yeah

The contradiction between cognition and metacognition which Fraser experienced was a critical point in the success of the group. When other group members disagreed with Fraser, this contradiction should have acted as a catalyst for collaborative metacognition. However, this did not result. Anne admitted that she found problem solving difficult and would have benefited from such an interaction. However, the argumentative nature of the discussion between Molly and Fraser prevented her from interacting. Jonathon, who seemed to know that answer, also chose not to interact because of the argumentative nature of the discussion. The *rules* which Jonathon and Anne adhered to were in contradiction with those which guided Fraser's interactions. Fraser was willing to push his answer, although unable to explain it, and was also willing to interact for the rest of the sessions. However, Molly rejected his efforts, telling him to be quiet.

The result of these contradictions was that the group agreed an answer which was based on perceptions of the intellectual abilities of Molly and Fraser and the perceived consequences of *appearing* to apply a lot of effort to the solution. Molly was viewed as conscientious and willing to work at the correct solution. Fraser was viewed by his group members as a bit of a joker who liked to shout out answers without thinking:

Anne	He can't shut up
Jonathon	You should hear him in the classroom when like Mrs Mckenzie's talking. He sometimes shouts out really loudly. He tries to say it in his normal talking voice but it usually comes out as a massive shout that Africa can hear.

Molly referred to Fraser's ability in school and reported that she perceived him as a student who often got the wrong answer:

Molly	Well, I normally worked out the answer with Anne and normally Fraser just guesses and then we tell the teacher and she says it's wrong.
Researcher	(to Fraser) right, and Molly is saying that normally you just guess and sometimes it's wrong so were you (Molly) thinking 'Fraser isn't always right – he sometimes just says things'?
Fraser	yeah – but then I try and work them out again when I think about it
Molly	sometimes he just writes down random answers.

The three other members of Fraser's group were reluctant to accept his answer because he was perceived as often shouting out answers that were wrong. This represents a view of Fraser which has been built on and developed throughout the time the students have been at primary school together. These views seemed to be deep-rooted and were reflected in the way in which they disregarded his correct answer. However, the group did not simply disregard Fraser's answer on their perceptions of his ability. Rather, they combined this with their perceived consequences of effort. Molly spent a long time trying to work out the correct answer to the problem. Anne noticed this, which acted as confirmation to her that Molly was correct:

Researcher	So when Molly was saying 3-and-a-half or 4-and-a-half and Fraser was saying 3 – you thought maybe Molly was right – why do you think that was?
Anne	yeah, cos like Fraser just came out with it but Molly started working it out and she took quite a long time with it – but Fraser just said like, 3.

It is not surprising that Anne should attach great importance to effort during problem solving. Anne, by her own admission, found problem solving very difficult and so she might expect other students to have to work hard to solve the problem. This highlights yet another contradiction within the activity system. Anne's perception of problem solving as cognitively challenging contradicts Fraser's very quick calculation and apparent understanding of the problem.

The lack of success displayed by this group could be pinpointed to the incorrect calculation of 2 x 1½ . Fraser displayed a contradiction between his cognitive and metacognitive abilities. The result of this contradiction was a disagreement between Fraser and Molly, who suggested another wrong answer. This cognitive/metacognitive contradiction might have acted as an opportunity to develop and change the pattern of work which had been displayed up until this point, where the students had been working individually. However, this change did not occur. Through the use of recall interviews, the students reported various contradictions in rules for interactions to which they adhered. These rules, which included, perceived intelligence, had been developed over some time. Furthermore, individuals, such as Anne, who found problem solving difficult generally, reported another contradiction between cognitive ability. She found it difficult to understand that others could find an answer quickly and therefore agreed with Molly's answer since she had appeared to make more effort in computing it.

7.2.3 Group two: contradictions in division of labour

The previous two groups had been unsuccessful in their problem solving. However, as I reported in the previous chapter, groups could be successful in problem solving and not necessarily display collaborative metacognition (perhaps because only one person solved the problem). Alternatively, groups might be unsuccessful yet display high proportions of collaborative metacognition, where all groups members are jointly attempting to solve the problem. The two unsuccessful sessions highlighted the way in which contradictions might influence interaction and therefore the use of collaborative metacognition, resulting in an unsuccessful session.

However, even during successful sessions, the use of collaborative metacognition is not guaranteed. In the previous chapter I outlined the criteria for success. This was the traditional view of success which is often adopted in school education. This understanding of success is quantifiable and requires nothing more than a *tick* by a teacher to confirm its existence. I would argue, however, that this type of success is not an entirely helpful notion when considering collaboration and specifically collaborative metacognition. When a group of individuals work together, there is little guarantee that all will interact or that all will learn and understand the problem. Therefore, successful sessions might have contained very little collaborative metacognition. This session by group two represents such a situation.

Group two was the only group to successfully solve all of the problems. The final session was the one that was chosen for their recall interviews. The problem set to the class that week was one where they had to work out the correct sequence of moves to swap the position of a rabbit and a hedgehog in a grid. The groups had to work out a strategy based on the rules they were given. They also had to record the moves so that they could make sure they did not waste time repeating mistakes.

Despite being ‘successful’ in each task, this group had previously displayed a high proportion of negative interaction. Generally, it was the boys, Liam and Christopher, who spent a lot of time attempting to solve the problems. The girls, Amelia and Beth, often engaged in off-task talk. However, in this final session, the girls became more involved in the task.

The interactions of this group might be understood in terms of a contradiction in the *division of labour*. As previously mentioned, contradictions are not necessarily negative and can result in a change or development of the activity. This group displayed such a development. However, although the students felt more involved, the development did not encourage collaborative metacognition, rather it was one which was more of a mechanical involvement where students were given a specific job to do.

One of the group members, Liam, had already encountered the problem at home and had completed it. Liam therefore immediately began to solve the problem by giving the others instructions as to where to move the pieces:

30	Liam	There, ok, that's the hedgehog, put them there, that's the rabbit, right. You move that there, that across over there, that there, that there.

However, one of the group members, Christopher, was confused and asked if they could start again to help him understand what was happening. This lack of understanding represented an opportunity for the group to engage in collaborative metacognition, in order to question Liam and ensure that they all understood what they were doing. However, what actually developed was a situation where Liam included the other members by assigning them roles. He then continued to give instructions regarding the solution:

43	Christopher	No, I don't get that so let's start that again
44	Beth	Let's start it again.
45	Liam	Let's do it again and then you (Amelia) write. We moved that there, and that's what they've got so far (meaning what is on the sheet).
46	Beth	Right, wait
47	Liam	And then we need to, you need to draw, right. You need to draw h, h, r, nothing, r.
48	Beth	Right, wait a minute youse guys, wait, right.
49	Liam	Right I'll tell you what to write. That's already done, so now you go down to that line and you just draw how that would be, ok? So that's eh

In this excerpt Liam was clearly taking charge of the problem solving session as he was familiar with the problem and the solution. However, rather than involve the other group members with processes involved, he assigned them a task and proceeded to instruct them on the solution. Although the group successfully, and quickly, solved the problem, the group members did not seem to understand what they had done or why.

During the recall interviews the students were asked what they felt their contribution had been to the task. The group members were all able to acknowledge their roles. Whilst Liam was the one to work out the solution, Amelia acknowledged her role as the person to move the pieces whilst Beth was the person who wrote everything down. Christopher, who hadn't understood the problem reported that he didn't have a role:

Christopher: And I was sitting down – that was a big help

Although the two girls seemed to be involved, and indeed felt they were involved, their involvement was at a mechanical level. They were following instructions rather than collaborating to solve the problem. This lack of collaborative involvement led to a situation where the three members of the group who had not encountered the problem before did not fully understand what they were doing. Christopher reported:

Christopher: Well when we were doing it I didn't really understand it at first but then I did start……..I wouldn't have known how to do it – it would have taken me a while.

Although Beth reported that she understood the problem and would have managed to solve it if Liam had not, Amelia reported that she would have required more time. Despite not being fully aware of the problem or solution, the group felt that they had worked well together, compared to previous weeks. This was due to the perception by the group members that they were *involved* in the solution process.

This *division of labour* was a recurring theme each week with group 2. In the first two sessions which were recorded, most of the work had been done by Liam and Christopher, with Liam tending to *instruct* Christopher on the solution. With such interactions, there was very little possibility of collaborative metacognition.

Beth reported that over the previous weeks of group work, the two girls had felt more isolated and felt the boys had done most of the work:

Beth:	yeah, cause they always used to do it and as soon as Mrs Mckenzie put the sheet down they always used to grab it and they wouldn't let us see it.
Researcher:	And what did you do?
Christopher:	half the time you got the sheet
Beth:	and then you snatched it off us

The group also reported that there had been tensions between them during the processes of problem solving. However, one main tension was their use of resources to solve the problems.

Beth:	sometimes we weren't really a good team – we were fighting quite a lot
Christopher:	fighting about what the answer was
Beth:	how to solve it the most because Mrs Mckenzie didn't really tell us anything that we were allowed (resources).

For the members of this group, being involved in the *process* of problem solving was important. The contradictions which developed over the weeks of problem solving seemed to produce a development towards the end of the sessions. Liam, who knew the solution to the problem, assigned roles to the other members. It may have been that the other members accepted these roles as they had felt excluded previously. The desire to feel part of the problem solving process, seems to have resulted in a development in the activity system.

Whilst the students were pleased with the change of nature of their group problem solving, this development did appear to be detrimental to the process of collaborative metacognition.

7.3 Socially mediated fixed role allocation on the use of collaborative metacognition

I have argued in this chapter that the use of collaborative metacognition was influenced by the contradictions displayed by students during the problem solving sessions. Whilst these contradictions were deep rooted, they were not insurmountable. For example, in group one, when Scott refused to share his solution with his group, the other members might have tried to work it out without him but they did not. Instead they continued to attempt to interact with him. Similar situations occurred in all three groups and I would propose that a potential explanation as to why the contradictions were so damaging was that in each group, socially mediated fixed role allocation occurred. This role allocation seemed to centre on producing within each group a *perceived holder of knowledge.* In this section I provide a brief overview of the potential interactions which might have been expected during the sessions, together with an explanation of the role allocations which occurred in each group.

Potential for collaborative metacognition

In chapter three I defined collaborative metacognition as consisting of the interaction of two utterances. Therefore when a group of four students work together on a problem, there is a possibility of collaborative metacognition as shown in figure 7-2. Each member of the group has the potential to interact with every other member in order to produce collaborative metacognition.

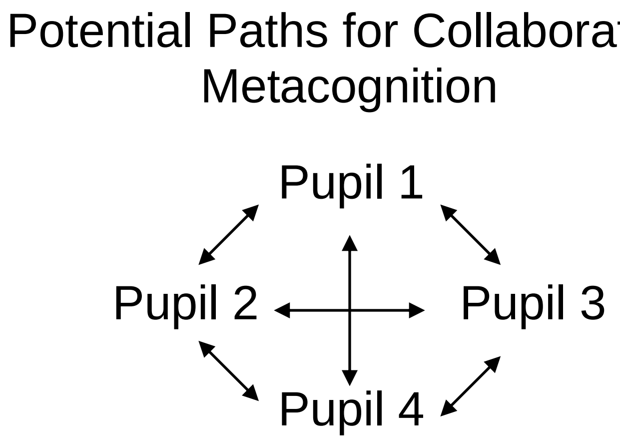


Figure 7- 2 Potential paths for collaborative metacognition

For the three group sessions described in the previous section, this interaction pattern seems to have been influenced by the roles which were assigned during the session. In each group, there emerged a *perceived holder of knowledge.* The individual holding this role either self-allocated or they were allocated the role by someone else. However, what is important is that once the role was assigned it appeared to be fixed throughout the session. I would suggest that it is this fixed role allocation which made the contradictions so damaging to the use of collaborative metacognition by the group members.

In each group, the potential for collaborative metacognition changed from that depicted in figure 7-2 to a situation more strongly resembling that which is depicted in figure 7-3. The strength of the potential interactions seemed to change whereby only the perceived holder of knowledge had a strong potential to interact with the other members of the group to produce collaborative metacognition.

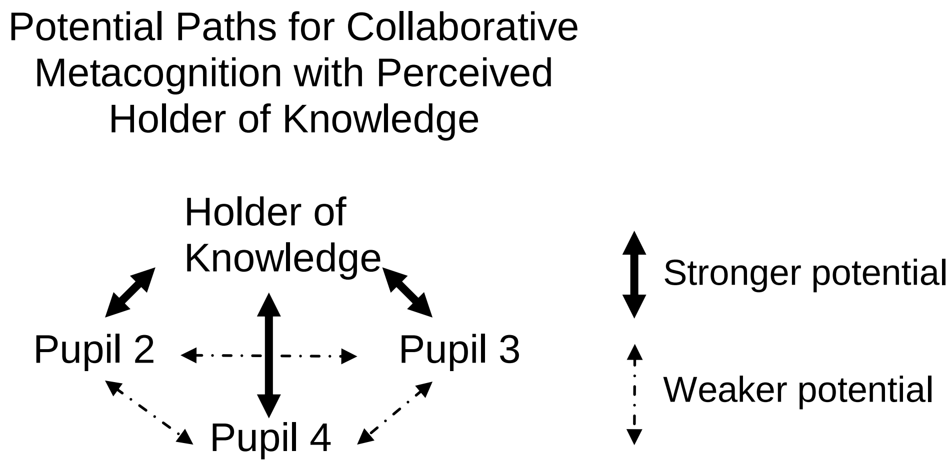


Figure 7- 3 Potential paths for collaborative metacognition with perceived holder of knowledge

Group 1 - Holder of knowledge assigned by the teacher

In group one, the teacher assigned the role of perceived holder of knowledge. Having spoken with Scott regarding the solution, she then asked him to explain this thoughts to the rest of the group. What is interesting in this situation, is that the teacher provided an opportunity for collaborative metacognition to occur. Rather than simply accepting Scott's answer, she encouraged him to share it with his group members. But in doing so Scott became the perceived holder of knowledge.

The other members of the group then engaged in an interaction pattern similar to that shown in figure 7-3. As I mentioned previously, the group members attempted to interact with Scott to hear his views on the problem. However, when Scott failed to interact in this way, it might seem reasonable to expect that the other group members would change the pattern and begin to work amongst themselves. However, the role assignation provided by the teacher seemed to continue once the teacher had left the group.

Group 3 - Holder of knowledge assigned by group members

In group three the perceived holder of knowledge was Molly. This role was assigned by the other group members and was influenced by their perceptions of the abilities of both

Fraser and Molly and their conscientiousness. Fraser was perceived as not really applying himself, whereas Molly was perceived as being hard working and conscientious.

The group members were faced with two potential solutions to the problem. Rather than try to ascertain the correct solution by working collaboratively, it seemed a preferable course of action to assign the role of *holder of knowledge.* Although Molly was incorrect, she was assigned this role which seemed to be fixed for the session. Again, rather than attempt to work collaboratively to solve the problem, the group members allowed Molly to take the lead and work on the rest of the problem. Fraser, who was unable to articulate his answer then withdrew from the session. By assigning Molly the role of holder of knowledge, the rest of the group failed to interact with the problem which then limited the use of collaborative metacognition.

Group One - Perceived holder of knowledge self-attributed

In group one, Liam assigned himself as the holder of knowledge as he had already completed the task out of school. The remaining members of the group immediately accepted this role which, again, became fixed throughout the task. Although the other group members did not always understand the task, they followed instructions from Liam in order to complete the task successfully.

The contradictions reported by this group were concerned with the extent to which each member felt they were part of the solution processes. By assigning roles to each group member, Liam addressed this issue. However, the remaining group members did not choose to question Liam, regarding the solution, nor did they attempt to work on the problem amongst themselves. Rather, the contradictions which emerged from previous weeks where some members of the group felt excluded, led to them being seemingly content to be involved, regardless of their level of involvement. The fixed nature of these roles again potentially limited the use of collaborative metacognition.

7.4 Summary

In this chapter, I have argued that student-reported contradictions influenced the use of collaborative metacognition. Furthermore, socially mediated fixed role allocation within the groups made these contradictions more damaging. The first two groups which were interviewed had been unsuccessful in solving the problem set whilst the final group had been successful. Three areas emerged from the critical recall interviews where contradictions in the activity system impacted the use of collaborative metacognition.

Group one reported contradictions in the area of the *rules* they used to guide their interaction processes. This group was unsuccessful in the task because one student had misunderstood the question. At the point where collaborative metacognition might have highlighted this misunderstanding, the students failed to interact successfully, due to their rules.

The failure of group three might be understood in terms of contradictions in mediating artefacts and rules. The mediating artefacts were cognitive and metacognitive. When two members of the group disagreed on an answer, collaborative metacognition might have moved them forward towards the correct solution. However, one group member experienced a contradiction between his cognitive and metacognitive ability. Despite this, the other group members might have found a successful solution. However, they too experienced contradictions between the rules they used to guide their assessments of who to believe.

Finally, group two provided evidence of contradictions in the division of labour. Two group members, the boys, had steered the majority of the problem solving sessions. This had led to the girls feeling left out and unwilling to contribute. However, this contradiction produced a development in the activity system. By the final week, the girls had become involved in the process, having been assigned roles by Liam, who had completed the problem previously. Although this development resulted in the girls feeling more involved, it did not result in collaborative metacognition. Liam instructed the other team members on the solution. When he was questioned, he continued to instruct, rather than engage with them in a manner which might have produced collaborative metacognition. Although the team members were successful and felt more positive about their interactions, the lack of collaborative metacognition resulted in them reporting that had Liam not been there, they would have found the task difficult and would have required more time to complete it.

In each of the groups a *perceived holder of knowledge* emerged. This role was allocated in different ways and did not always come from within the group. For example, in group one, the teacher assigned the role. The importance of these roles was that students did not seem to be able to deviate from them once they had been set. Had they done so, the contradictions might not have been so harmful to the use of collaborative metacognition.

These data provide evidence that quantifying levels of collaborative metacognition is not sufficient for understanding its use and its relationship to successful outcomes.

In the next chapter I consider the role of the teacher on the use of collaborative metacognition.

Chapter Eight: Collaborative metacognition and the presence of the teacher

8.1 Introduction

This chapter is concerned with the impact of the teacher on collaborative metacognition. I will argue that although the impact seems a positive one in terms of overall proportions of collaborative metacognition displayed, the *pattern* of interaction changed when the teacher was present. This change might be understood in terms of a change of the overall *activity* of the group. The evidence to support this claim will be taken from the data produced during the teacher focus group.

The research questions I have addressed are:

- *What proportions of talk that could be categorised as collaborative metacognition are displayed when the teacher is present compared to not present?*
- *What explanations exist for the patterns of collaborative metacognition displayed during problem solving sessions?*

Data for the first question are taken from the quantitative content analysis of interactions as detailed in the methods section. These data were separated into two *teacher* conditions – teacher present and teacher not present. I then compared the proportion of each statement type that was present in each condition. Finally, I analysed the proportion of collaborative metacognition present in each condition. Without pre-empting the results still to be reported, I will argue that although the impact of the teacher on levels of collaborative metacognition seemed to be a positive one in terms of overall proportions displayed, the change in *interactive patterns* led to a lower proportion of *student to student* collaborative metacognition and greater *teacher to student* collaborative metacognition. I will argue that a possible explanation for this change in pattern is that there are two activities occurring during collaborative problem solving. The activity occurring when the students are working to jointly solve the problem *changes* when the teacher joins the group. Although the students may still be working to solve the problem, the teacher, I will argue, is involved in an activity which seeks to ascertain *individual* understanding of the problem. In order to support my claim and provide further explanation for it, I will refer to the qualitative data from the teacher focus group, where teachers shared their perceptions and experiences of mathematical problem solving. I will argue that one explanation of this interaction pattern is that when the teacher joined the group, the *activity* changed. When the students were working together, there were four individuals collaborating towards a goal. However, when the teacher joined the group, a clear leader emerged who appeared, at times, to influence and shape the interactive pattern. These different activities impacted the levels of collaborative metacognition. Data from the teacher focus group highlighted two potential explanations for such different activities. The first of these is that in the area of mathematical problem solving, there is often a focus on strategy rather than process. As I noted in chapter four, multiple activity systems might focus on a shared object. We might therefore understand the presence of the teacher as another activity system joining the shared object.

Chapter structure

This chapter will be divided into two sections. In the first section I will provide quantitative evidence for my assertion that different activities are occurring when the teacher is present compared to when the students are working on their own, specifically focussing on the impact of the teacher on both proportions and patterns of collaborative metacognition. I will argue that higher proportions of collaborative metacognition when the teacher was present were due to a dyadic interaction style between the teacher and students rather than collaborative metacognition amongst students. I will then present the qualitative data from the teacher focus group in order to consider potential explanations for the interaction pattern displayed.

8.2 What proportions of talk that could be categorised as collaborative metacognition are displayed when the teacher is present compared to not present?

The purpose of the data analysis in this section is to establish the impact of the presence of the teacher on proportions of collaborative metacognition. As detailed in the methods section, I have used proportions of talk rather than actual quantities.

In the previous chapter I operationalised the theoretical term collaborative metacognition as consisting of two strands. The first was a metacognitive statement which led to a transactive statement. The second was a transactive statement which led to a metacognitive statement. In this section I will report the proportions of each of these strands when the teacher was present and I will compare them to points when the teacher was not present. Transactive and metacognitive talk were not the only categories of talk which were coded. I will therefore report on the other categories of talk which were identified in order to provide a coherent account of the interactions. In order to provide clarity throughout the quantitative sections, I will report each data set under the heading of a sub-research question.

The research questions will firstly address the types and proportions of talk displayed during both teacher conditions. I will then provide an analysis of *on-task* talk before concentrating on collaborative metacognition.

What proportion of each statement type was displayed in each teacher condition?

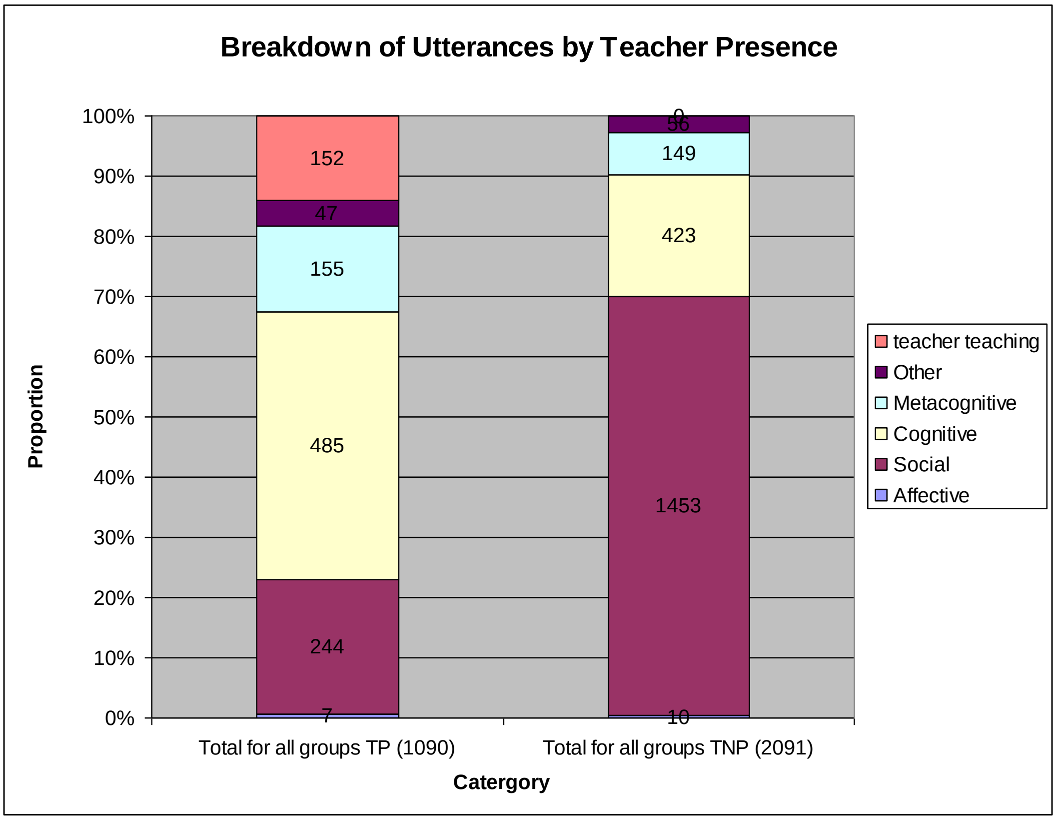


Figure 8- 1 Breakdown of utterances by teacher presence

Figure 8-1 shows that there was a different pattern of communication displayed across the two teacher conditions. When the teacher was not present, social statements dominated (69.5%). There were smaller proportions of cognitive (20%) and metacognitive statements (7%). Students also displayed a very small proportion of affective utterances 0.5% (10). Of the total student utterances when the teacher was not present, 3% (56) were coded as *other*.

The social statements generally appeared as large chunks of social interaction not concerned with the problem on which students were working. These were interspersed with smaller periods of talk where students concentrated on the problem.

A different picture emerged when the teacher was present. Statements were more focussed on the problem solving effort. The largest proportion of statements was cognitive at 45%.

Although there were still social statements when the teacher was present, these accounted for only 22%. Furthermore, these social statements were interspersed with statements which were mainly concerned with the problem to be solved. Again, the proportion of metacognitive interactions was low (14%).

The proportion of statements which were coded as teacher teaching in the group was 14%. Affective statements accounted for only 1% and *other* statements was 4% (47), similar to when the teacher was not present.

Summary

These figures suggest that a different pattern of talk occurred in the two teacher conditions. When the students worked alone they displayed large periods of social interaction not concerned with the task. They also displayed relatively low proportions of cognitive and metacognitive statements. However, when the teacher was present in the group, social talk decreased greatly and became interspersed in larger periods of talk concerned with the problem solving activity. The majority of talk was cognitive, with lower proportions of metacognitive talk.

The large proportion of social statements when the teacher was not present make it difficult to assess the impact of the cognitive and metacognitive talk when the students were actually working on the problem since the proportions are so low. In order to provide more meaningful data for the points when students were engaged in the task, I removed the off-task talk from the totals. The results of this will be addressed in the following research question.

When considering only on-task utterances, what proportion of each type of utterance is displayed?

Data were divided into on-task statements and off-task statements. Following the coding scheme, I defined off-task statements as those which were of a social nature or coded in the *other* category which consisted mainly of nonsense talk or talk which was indistinguishable.

Figure 8-2 shows that when only taking account of statements which are relevant to the problem solving task, the proportions are similar across both conditions. In both conditions, the largest proportion of talk was cognitive in nature. There were relatively low proportions of metacognitive talk in both conditions, however it was higher when the teacher was not present (26%) compared to when the teacher was present (19%). The proportion of cognitive talk was also higher when the teacher was not present. However, the addition of *teacher teaching* coding provides an insight as to the influence of the teacher on the interactions. Around one fifth of the statements made when the teacher was present were coded as *teacher teaching*. An initial interpretation of this data might be that when the students worked alone they displayed more *spontaneous* metacognition and when the teacher was present she had a prominent role in the discussion. I will re-address this interpretation when I consider the teacher focus group data.

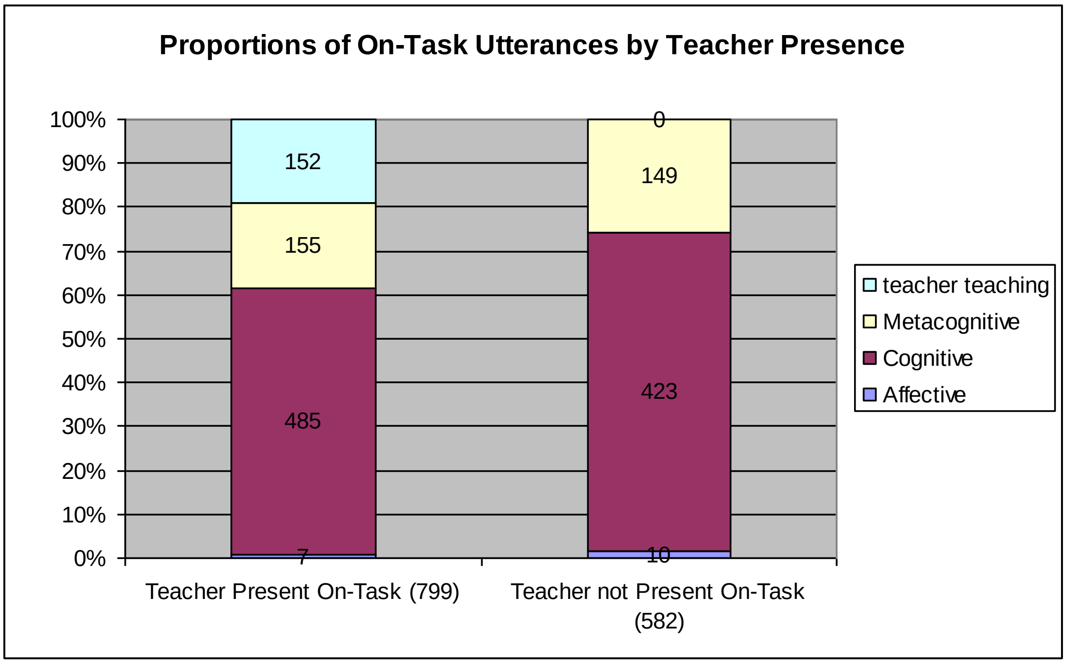


Figure 8- 2 Proportion of on-task utterances by teacher presence

Overall the pattern of talk was mainly cognitive during the problem solving sessions with lower proportions of metacognitive talk. As the primary focus of this thesis is collaborative metacognition, I will now address this. Collaborative metacognition is defined as a metacognitive statement which leads to a transactive statement or a metacognitive statement which follows a transactive statement. Since a transactive statement is central to the concept of collaborative metacognition, I will provide an account of transactive statements across conditions. This will provide an understanding of the extent to which students and the teacher are interacting in a transactive way with any of the statement types identified.

What proportions of transactive talk are present across the teacher conditions?

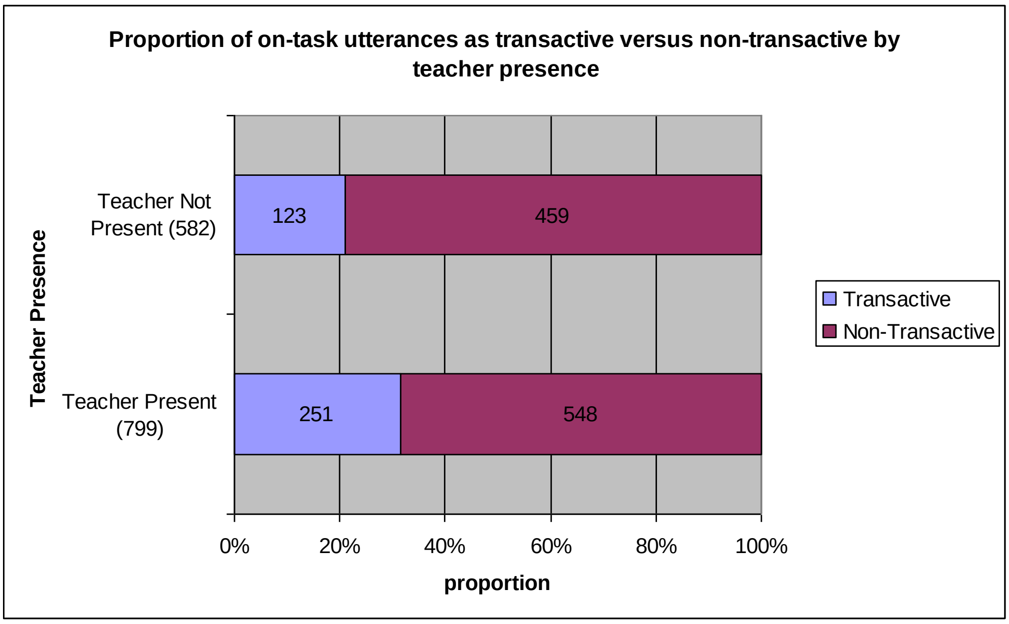


Figure 8- 3 Proportion of on-task utterances as transactive versus non-transactive by teacher presence

As outlined in the methods section, all utterances were coded once in order to understand their role in the learning process (e.g. cognitive, metacognitive, etc.) and a second time in order to understand their *transactive* quality.

Figure 8-3 shows that the proportions of transactive talk across both teacher conditions was relatively low, although it was slightly higher when the teacher was present (31%) compared to when the students worked alone (21%). However, it is not clear if the increase was due to students participating more in transactive talk, or if the interactions of the teacher might account for the increase. This is addressed in the following research question.

What proportion of transactive utterances can be attributed to the teacher compared to the students?

Figure (8-4) shows that the pattern of talk displayed by the teacher is different to that of the students. A large proportion (43%) of the teacher's talk was transactive in nature whereas only 15% of statements made by the students were transactive. This compares to 21% of student statements being transactive when they worked alone. Of the 251 transactive statements made when the teacher was present, it was the teacher who made the large majority of them (62%). As with the metacognitive statements, we might infer that students were less spontaneous in their transactive talk when the teacher was present, a suggestion which will be addressed more fully later.

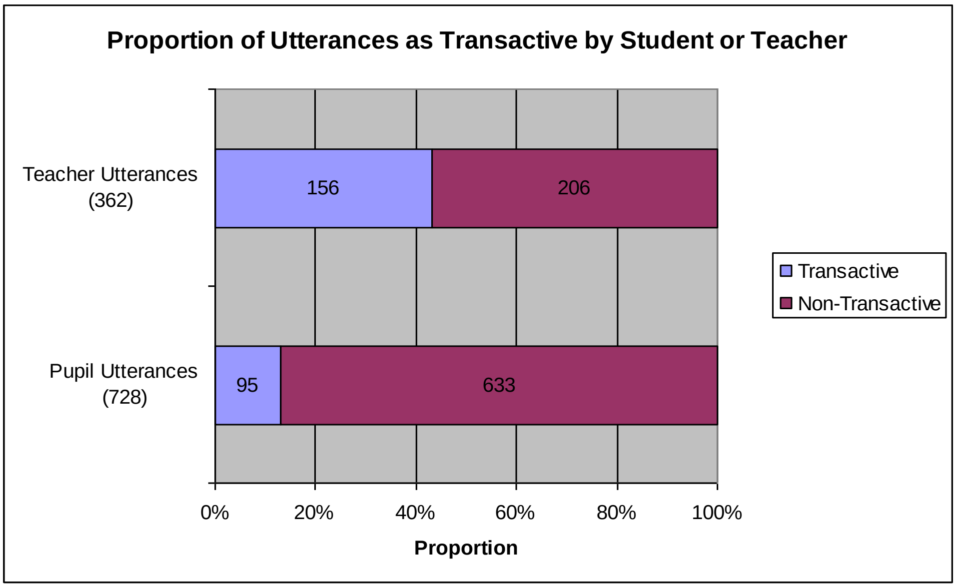


Figure 8- 4 Proportion of utterances as transactive by student or teacher

Summary

When considering on-task talk there was a difference in the proportions of talk displayed when the teacher was present in the group compared to when the students were working alone. Over both conditions there were relatively low proportions of metacognition displayed. However, when students worked on their own, on-task talk consisted of higher proportions of metacognitive talk than when the teacher was present.

The proportion of transactive talk was higher when the teacher was present. However, this can be attributed to the contribution of the teacher. When student talk was analysed, the proportion of transactive talk was higher when the teacher was not present.

These findings suggest that students displayed higher proportions of transactive interaction and spontaneous metacognition when the teacher was not present in their group. As previously mentioned, collaborative metacognition consists of an interaction between these two types of talk. I will now consider this interaction, firstly presenting figures for metacognitive statements which led to a transactive statement and then for metacognitive statements which were preceded by a transactive statement.

Collaborative metacognition

In order to ascertain the extent to which these transactive statements interacted with the metacognitive utterances, figures were calculated for metacognitive statements which led to transactive statements and transactive statements which led to metacognitive statements. (A more detailed explanation of the coding can be found in the methods section). The coding of a transactive statement was dependent on it having the capacity to draw other students into the discussion in order to extend, critique or question an assertion. When a statement was made by a student which was then followed by a transactive statement, students indicated that they had heard the first statement and were now responding. If the initial statement had a metacognitive quality then the metacognition was deemed *collaborative* because it appeared to have initiated an act of *collaboration.* Similarly, when a transactive statement was made and followed by a metacognitive response, this was also deemed *collaborative* since it appeared to have resulted from an act of collaboration.

Metacognitive to transactive

This first section of the analysis on collaborative metacognition deals with metacognitive statements which led to a transactive statement. I will provide an analysis of all statement types which led to a transactive statement to ascertain if a metacognitive statement was more or less likely than other statement types to result in a transactive statement.

What proportion of each statement type led to a transactive statement during each teacher condition?

Figure 8-5 shows that a higher proportion of metacognitive statements led to a transactive statement than any other when the teacher was not present in the groups (21%). This pattern is consistent with the analysis provided in the chapter on collaborative metacognition. The utterance type with the lowest proportion of statements which led to a transactive statement was social.

An important point to note here is that whilst representing a smaller overall proportion, the actual number of social and cognitive statements which led to a transactive statement is higher than the number of metacognitive statements. This has occurred due to the very high level of social and cognitive statements recorded in relation to the metacognitive statements.

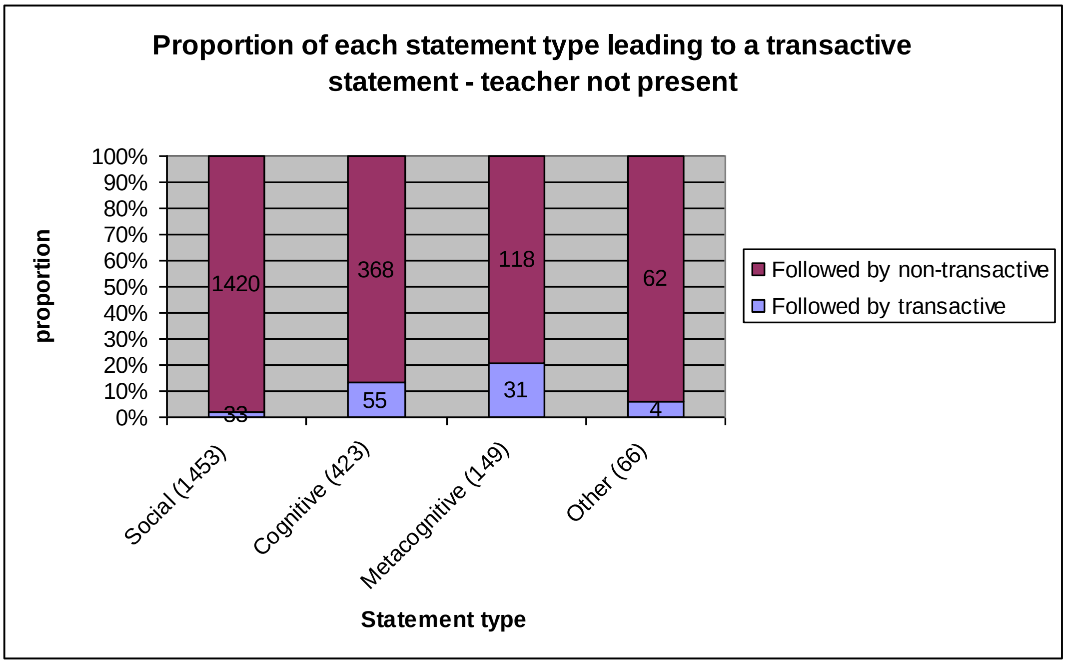


Figure 8- 5 Proportion of each statement type leading to a transactive statement - teacher not present

As can be seen from figure (8-6), a similar, although more pronounced, pattern occurred when the teacher was present in the groups. A higher proportion of metacognitive statements led to a transactive statement compared with cognitive, social, other and teaching statements.

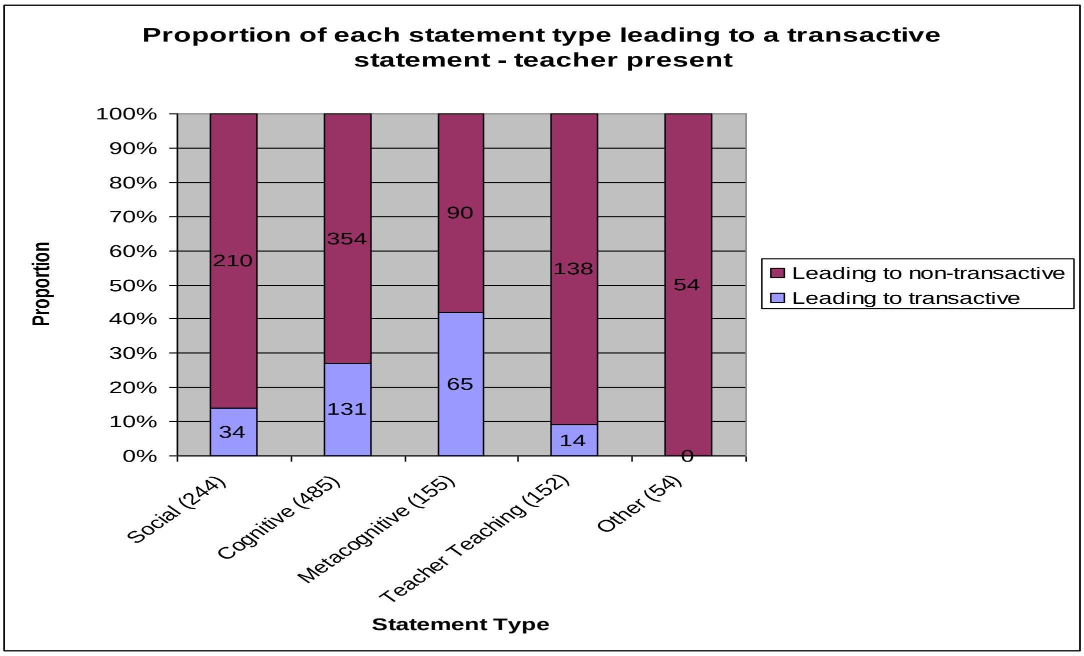


Figure 8- 6 Proportion of each statement type leading to transactive statement, teacher present

Therefore during both teacher conditions a higher proportion of metacognitive statements led to a transactive statement than any other statement type. However, when the teacher was present, the overall proportion of collaborative metacognition was higher.

These figures should be understood in the context of the previous findings that the teacher made a greater amount of transactive utterances (70%) than did the students (30%). It is therefore likely that when students made a metacognitive statement, it was more likely to be the teacher who followed it with a transactive statement, rather than another student.

Figure (8-7) shows that this is the case. The teacher made 72% (47) of the transactive statements which led from a metacognitive statement. The students only made 28% (18), despite the students outnumbering the teacher four to one.

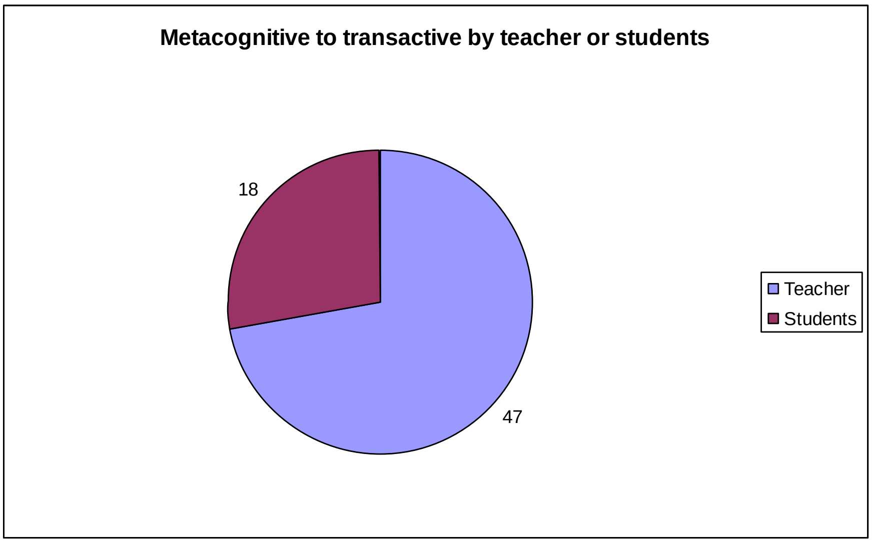


Figure 8- 7 Metacognitive to transactive by teacher or students

Summary of metacognitive to transactive

The figures presented in this section follow a similar pattern to those reported in the chapter on collaborative metacognition. A higher proportion of metacognitive statements led to a transactive statement than any other type. However, when the teacher was present in the group the proportion increased greatly and can be explained by the transactive statements made by the teacher. When students worked without the teacher, there were low proportions of transactive talk which followed a metacognitive talk. This implies that students were not interacting with one another's thought processes. Possible explanations for this might be that the students lacked the skills required to interact in such a way, or other issues may have impacted their willingness to interact in such a way.

This analysis only covers one part of collaborative metacognition. I will now provide an analysis of the figures for transactive to metacognitive statements.

Transactive to metacognitive

As with the previous section, I will now provide an analysis of the proportions of each statement type which were preceded by a transactive statement in order to ascertain if a metacognitive statement was more likely to occur following a transactive statement in relation to the other statement types.

What proportion of each statement type was preceded by a transactive statement in each teacher condition?

Figure (8-8) provides figures for when the teacher was not present in the group. Although the overall proportions of each statement type being preceded by a transactive statement were low, metacognitive statements provided the highest proportion at 19%. Again, this is in line with the pattern reported in the chapter on collaborative metacognition.

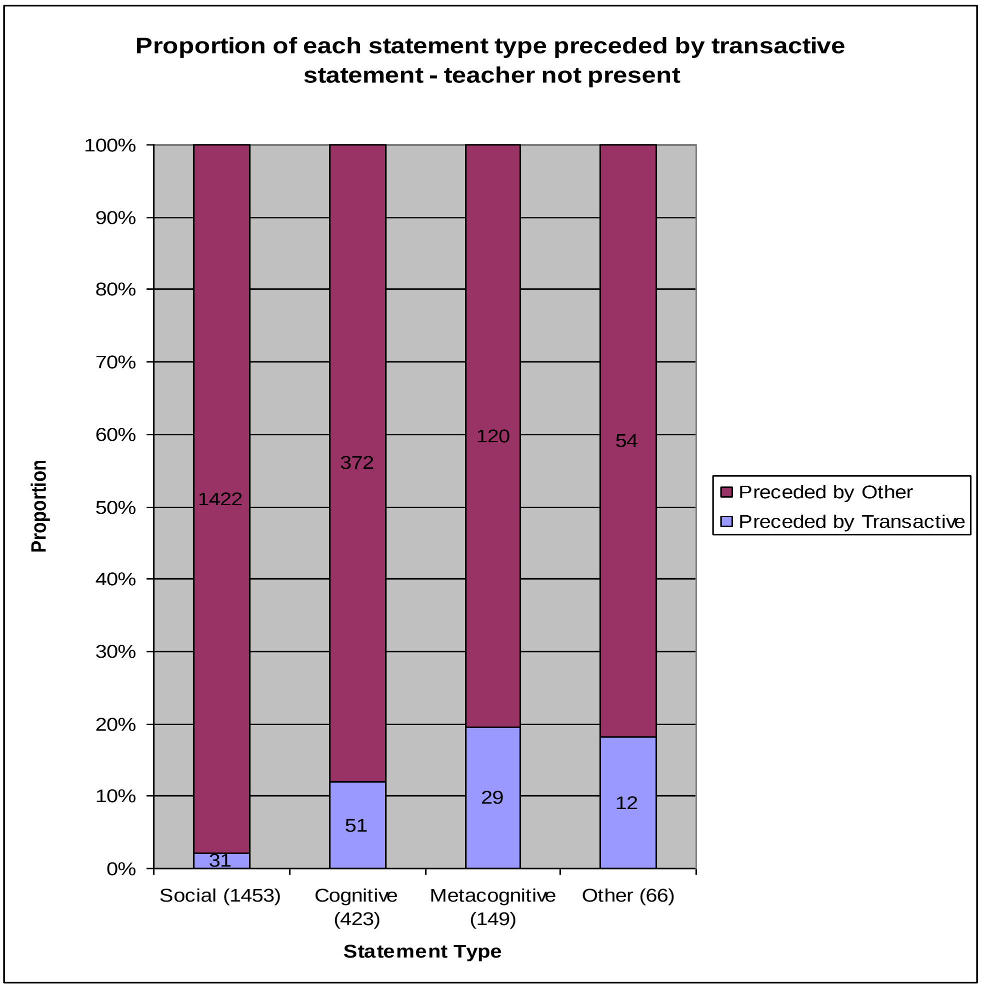


Figure 8- 8 Proportion of each statement type preceded by transactive statement, teacher not present

Figure 8-9 shows that when the teacher was present, again, a higher proportion of metacognitive statements were preceded by a transactive statement compared to proportions of other statement types.

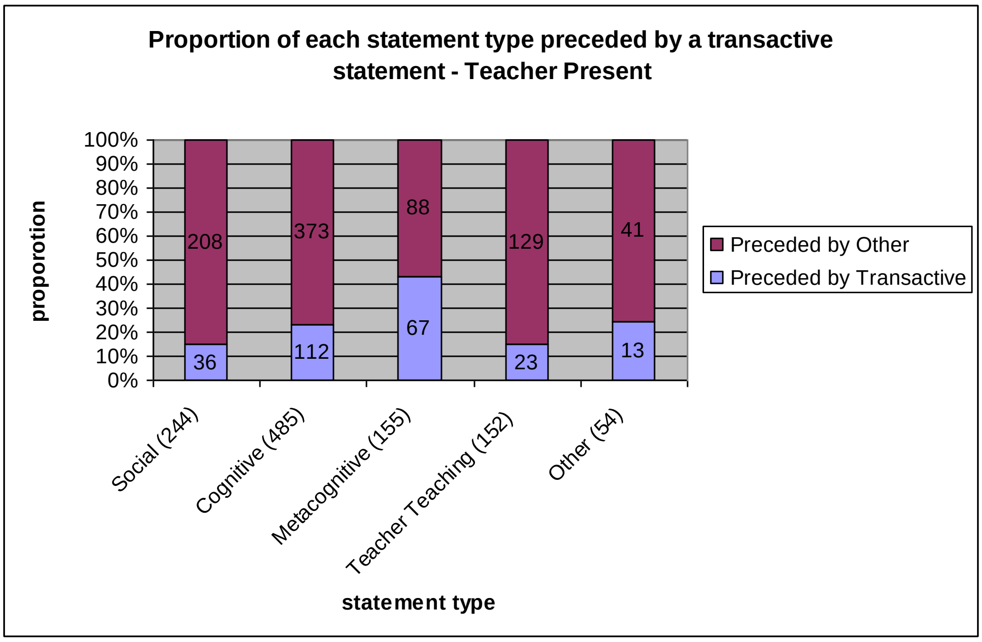


Figure 8- 9 Proportion of each statement type preceded by a transactive statement, teacher present

As previously mentioned, the teacher accounted for 62% (156) of the total transactive statements made. Therefore, it would be reasonable to assume that a higher proportion of metacognitive statements preceded by a transactive would be from transactive statements made by the teacher. This is indeed the case. As shown in figure 8-10, of the 67 transactive statements which led to a metacognitive statement, 47 (70%) were made by the teacher and 20 (30%) were made by students.

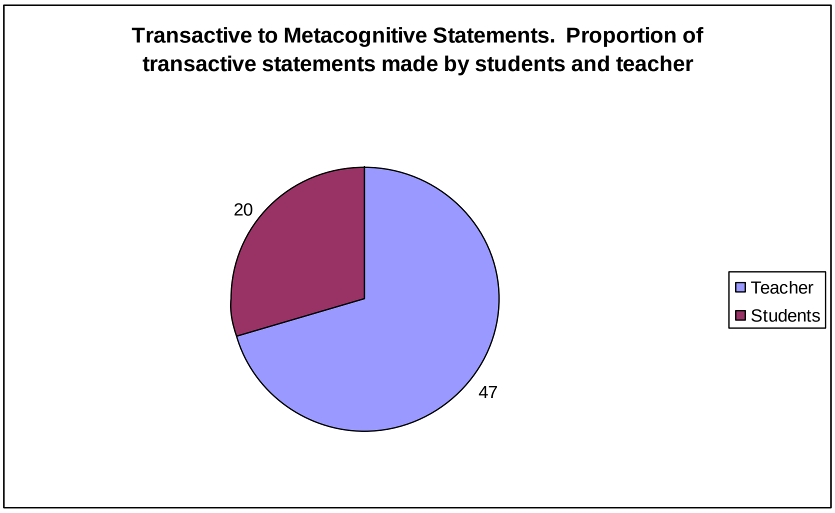


Figure 8- 10 Transactive to metacognitive statements by student or teacher

When the total number of student metacognitive statements which were followed by a *student* transactive statement is considered, the figure falls to only 13% (20).

Summary of transactive to metacognitive

These figures show that when students were working in groups without the teacher, there were very low proportions of metacognitive statements which were preceded by a transactive statement. One explanation is that students were not metacognitively competent and therefore could not respond in such a way to transactive talk. However, when the teacher joined the group, the proportion of transactive to metacognitive statements increased, suggesting that students *were* able to respond metacognitively. As previously reported, the higher proportion of transactive statements during this condition were due to the teacher. Students were therefore able to respond to metacognitively when the teacher was present. Alternatively, the students may not have had the appropriate skills to interact in a transactive way, or other issues may have impacted their ability or willingness to make their thoughts known to others when prompted.

These quantitative data, suggest that when the teacher joined the group, she interacted as one of the group members, questioning and probing thought processes. The students responded to the teacher in line with classroom etiquette where students are used to being questioned by, and responding to, the teacher. However, a potential implication of the teacher interacting in such a way is that students might not learn how to effectively question one another. When the teacher joined the group, the *activity* in which the students were participating changed. Without the teacher, the students were jointly attempting to solve the problem. When the teacher joined the group, the interaction patterns changed.

Summary of transactive to metacognitive and metacognitive to transactive

The analysis reported in this chapter suggests that the teacher was instrumental in the transactive nature of the talk during problem solving sessions. Furthermore, in line with the findings in the collaborative metacognition chapter, when the students worked on their own, or with the teacher, there was a relationship between metacognition and transactive talk. However, when the students worked alone, there were very low proportions of both transactive to metacognitive and metacognitive to transactive statements. One important finding in this section was that when the teacher was present in the groups, the proportion of teacher to student collaborative metacognition was much higher than student to student collaborative metacognition, suggesting a change of interaction pattern.

This difference is important since, in order for students to interact successfully, the collaborative metacognition should occur between *students*, rather than between a student and the teacher. These findings suggest that when the teacher is in the groups the interactive patterns change. In order to understand this further I analysed data from teacher focus groups. The purpose of the focus group was to provide an understanding of teachers' experiences and perceptions on collaborative problem solving during mathematics and the use of metacognition. By doing so, it is possible to gain a more meaningful understanding of the quantitative data. Further details of the focus group participants are outlined in the methods section. The following section will provide qualitative data from this analysis in order to understand the change of focus when the teacher joined the groups.

8.3 Understanding the impact of the teacher on collaborative metacognition

In the previous section I suggested that there was a change of interaction pattern when the teacher joined the group. When the teacher was not present, all collaborative metacognition was student to student. When the teacher joined the group, the overall proportions of collaborative metacognition increased. This increase was explained by the transactive contribution of the teacher. This meant that a large proportion of collaborative metacognition was teacher to student rather than student to student.

It is important to note that the proportions of metacognition talk displayed by students were slightly *lower* when the teacher was present and the proportion of transactive talk was much lower. One way of understanding this is that students were able to offer *spontaneous* metacognition regardless of the presence of the teacher. This metacognition would be termed collaborative if it preceded or was followed by a transactive utterance. However, students were less likely to display transactive talk which might result in collaborative metacognition when the teacher was present. Possible explanations for this are that the students were less willing to interact with one another when the teacher was present, or they had less opportunity to interact with one another when the teacher was present because the focus of the teacher was on what each individual was able to do. I would suggest that the latter is a more plausible explanation since the students did display (albeit low) levels of collaborative metacognition when working without the teacher, therefore showing willing and ability to communicate in this way.

When students were working together, their focus was on *jointly* solving the problem. In order to be successful in this, they had to question, probe, offer suggestions and reach agreement. A result of such interaction is the use of collaborative metacognition. However, I will argue that when the teacher joined the group, the activity changed to one where the teacher was concerned with what strategies individual students were aware of and why these were implemented. This also resulted in the use of collaborative metacognition. However, this was between the teacher and one student. The *activity* was therefore a student to teacher activity.

Evidence for this assertion comes from the teacher focus groups. Two distinct areas were highlighted as contributing to the change of activity. The first of these was the initial teacher training which teachers experienced. The use of *strategies* was often promoted over group processes which led to a focus on what individual students were able to achieve. Secondly, once in the classroom, many different factors impacted on the decision by a teacher to promote collaborative group work skills. I will now address these areas.

As with the previous chapter, we might understand this change in terms of socially mediated fixed role allocation. I will propose that the potential for student-to-student collaborative metacognition was changed when the teacher was present in the groups.

8.3.1 Initial teacher training and collaborative metacognitive activity

Primary teaching in Scotland requires an initial training period of either a one-year post-graduate degree or a four-year undergraduate degree. There is also a requirement of 35 hours continued professional development time per year for teachers (http://www.scotland.gov.uk/Publications/2003/01/18713/31241). Training and development are therefore important factors for teachers and a natural area to discuss in order to understand if teachers were aware of important factors regarding the problem solving processes. Teachers were questioned about the extent to which mathematical problem solving in general, and collaborative problem solving specifically, was promoted during training. They were also questioned about the extent to which they were given guidance on the type of interactions which might be useful during mathematical group problem solving.

Teacher experiences during initial teacher training varied depending on when and where they had trained. However, a main theme which emerged from the data was a focus on *strategy* use during mathematics rather than the *processes* involved in accessing or implementing these strategies. Teachers felt that their university experience encouraged them to focus on the strategy they would adopt to solve mathematical problems. One teacher highlighted this by describing her university experience:

"….. I remember sitting in lecture theatres for quite a bit of maths and there was often on the projector, we were actually asked to do something ourselves and just to work out, so actually that was your strategy, so we were actually put on the spot quite a bit by the lecturer…."

Another teacher highlighted her experience of mathematical problem solving during her university training:

"… a lot of it was you were never actually taught how to teach problem solving or the aspects of it – it was like here's graphs – what would you do with it?"

The use of strategy is apparent in the experience of one teacher who felt that teaching was segmented into different strategies. During training, strategies for each area of mathematics had been covered individually. She recalled her training as *'this is how you should teach addition'* . However, once in the classroom she discovered that

"addition ran through from primary one to primary seven… But it didn't actually prepare you for having your own class and putting into practice. Because when you went into the class, there were so many things you had to think about and not just the maths".

This thought was developed in the words of another teacher:

"I do remember going into groups and we took an aspect of maths and we did lots of discussion around how you would teach it… going away and working completing tasks and coming back and saying how you did it"

Although these student teachers were in groups to solve problems, the focus was very much on their use of strategy rather than the interactive processes which led to the use of such strategies, or indeed, to solving the problem.

The responses of these teachers suggest that during their initial teacher training, there was a focus on the strategies that were useful when solving mathematical problems. Clearly, when students come together to work on a problem, strategies are important. However, the *processes* involved in accessing these strategies will potentially impact on the outcomes.

Metacognition, as described in the literature review, represents this process whereby students must decipher what the problem is, decide if they have the strategies solve it and evaluate the outcome. Collaborative metacognition, according to the new definition proposed in this thesis, is metacognition which is *impacted* by others with whom a student is working. The process of arriving at a strategy may involve more than one student and it is therefore crucial that individuals are able to interact in such a way that they can question, critique and extend one another's thought processes. When teachers are concerned only with the strategy that might be used, the process by which students arrived at this strategy may be overlooked. Furthermore, potential issues with these processes will not be addressed.

Although the teachers were aware that wider issues might impact student's interactions, these issues had not been addressed during initial teacher training. Such issues are referred to in the following statement:

"We were given an aspect of maths that we all looked at in small groups …we all were given maybe a problem to solve using that particular aspect… and then going out into the 'real world' and having to - it was a completely different experience going into the classroom where you've maybe got four or five different groups all doing completely different things and it's more a sort of juggling act."

This teacher acknowledges that whilst initial teacher training was able to equip teachers with the strategies to be used during problem solving, the actual processes which occur during group work had not been addressed.

These data suggest that the teachers viewed the focus of their initial teacher training in mathematics problem solving as being on strategy use by students. Teachers were often encouraged to work in groups and think what strategies they would use to solve a particular problem. However, the focus was on the strategies, rather than the interactive processes which might occur when a group of individuals work together. It was often not until teachers were in the classroom that they discovered other issues impacted the way in which students might work. One such issue was differential ability as one teacher noted:

"learning how to differentiate – they can tell you in university as much as they like about skills but once you go into a class there's all these different abilities and you didn't learn

that at university".

When students work together, some may be more advanced in their mathematical ability than others. Similarly, as noted in the literature review, there is evidence that metacognitive ability and social interaction skills are also often differentiated. In such cases, I would argue that the processes involved in promoting collaborative metacognition *between* students are all the more important, rather than merely strategy use alone. In order for such processes to develop, it is necessary for students to be exposed to situations where they can practice them, such as collaborative problem solving. In the next section, I will consider the extent to which such practices are promoted at across and within schools.

8.3.2 Issues which may impact on the use of collaborative problem solving across and within schools

The operationalisation of collaborative metacognition which was previously outlined has two strands which require a specific type of interaction between students. The thought processes involved in collaborative metacognition, as with individual metacognition, require what might be termed *higher order thinking skills*. As I outlined in the literature review, the development of such skills is thought to be influenced by factors such as age and experience. It is reasonable to assume therefore, that practice and scaffolding might aid the development of collaborative metacognition amongst students. However, in order for this to happen, teachers and educationalists must view the development of such skills important enough to promote them. It is therefore important to ascertain the extent to which such skills might be developed through, for example, a whole school approach to collaborative problem solving. Whilst initial teacher training might not highlight processual skills, individual schools have the capacity to promote learning pedagogies such as collaborative learning as well as the resulting skills of interaction. The teachers were therefore questioned about the extent to which they had experienced such an approach, either during their initial teacher training placements, or during service.

Although all of the teachers agreed that it was at school level that decisions were taken regarding the use of collaborative problem solving during mathematics, they acknowledged that, at this current school, staff had been given more freedom to deviate from the whole school approach than in most of their previous schools. There were many factors which impacted a teacher's decision to employ collaborative problem solving. These included the previous experiences of the teacher, experiences of students and the teachers' perceptions regarding the capabilities of their students.

Teacher experience as an influence on the use of collaborative problem solving: Teachers had experienced various levels of collaborative problem solving. One teacher was able to highlight the way that the focus of teaching changed *within* one school dependent on the age of students:

"I had the experience when I was doing my probationary as you were going through the year I found that the children – the further up the school they were getting, the more heads down they were. When I did my upper placement I think I hardly taught any maths at all. It was about please open a text book – you wrote up on a board what they had to do and that was it! That's what I was being guided to do [by the class teacher] they were like this is how you do it, this is the forward plan, they must do these pages over the next few weeks. They come in, heads down, jotters – self taught!"

This excerpt shows clearly that in that particular school, students were expected to learn in a different way as they got older. Instead of developing collaborative skills as they matured, students were led to develop *individual* learning skills. In such a situation, the development of collaborative metacognition might be impacted since the students were directed away from interactions. Also, probationary teachers might be influenced through their placements, to either adopt such approaches, or indeed reject them.

The influence of such experiences can be seen in the words of another teacher who was experienced in the use of problem solving during supply work. Despite having a lot of experience in collaborative problem solving, she highlighted difficulties which she had encountered when students had not been used to collaborative work as a whole school approach:

"I think it's very much how it's done as a school because I've done supply in a lot of different schools in different areas. One particular school em I was doing (collaborative) problem solving and mental agility right the way from p1 to p7 … I really tried to make the problem solving classes as active as possible but I found it very, very difficult to get the children engaged in the activities with any amount of control because they were so used to sitting down and working from a text book or worksheets. They had no idea how to handle themselves with a more active lesson. ***.*** *They found that very, very difficult. I remember*

going in at one stage – I could have set the work for the week at the start and then you just taught as you needed. I had a grid for p7 and they all knew that's what they were going to do. They couldn't do something til I'd 'starred' it – they couldn't do that because that was a teaching aspect. That's the way we were shown to do it – that's what was expected.

From these excerpts, and the previous section regarding initial teacher training, it is reasonable to infer that collaborative problem solving skills were not considered 'core skills' which should be expected throughout the school. Rather, other issues were clearly priority as one teacher notes:

"We were also going through levels – we were driven by what you were supposed to be achieving by the end of a level and you had your planner – that's what the school said you were using – I don't want to use names – that's the planner it was an area planner. Everyone was using it – you didn't want to be different from any other school – you were going through the planner."

Whilst teachers had experienced various levels of collaborative problem solving, none had experienced a whole school approach. This lack of continuity may result in the type of interactions which were recorded in the quantitative section of this chapter. Whilst teachers are skilled at assessing individual learning and understanding, there is no core requirement within the curriculum to develop *and assess* interactive skills which might promote the use of collaborative metacognition.

Students as an influence on the use of collaborative problem solving:

During the focus group, teachers referred to the nature of their students as a potential determining factor when considering the use of collaborative problem solving during mathematics lessons:

"And another thing that I think influences your – how you teach maths – obviously we have school programmes that we all kind of stick with, but it's once you get to know your class it's working out exactly what works for them. You know you've got some kids who really thrive by sitting and they only really get the concept by sitting with their head down. And other children who are going to need the activity and so you've got to kind of get to grips with your own class and be given that freedom of 'can I do this' and this at the same time. Or can I have some lessons that are really focussed and quiet and just having the

confidence and feeling that you're allowed to do that once you get to know your own kids."

This teacher was clearly able to consider balancing out the needs of her students. However, whilst individual learning is unquestionably the focus of teaching, the skills required for successful collaborative interaction, and collaborative metacognition, may be viewed as merely an 'add-on' if students appear to be interested in such interactions. A potential outcome of such a scenario is that one group of students may have very well developed social interaction skills *naturally*. In such a class collaborative interaction would work well. However, for those who lack such skills, practice and instruction are vital if they are to develop them. Therefore, if these skills are driven by perceptions regarding student ability and preference, those who are lacking such skills will not be provided with the opportunity to develop them.

Clearly, different issues impact the decision by a teacher to promote collaborative problem solving skills. However, as noted in the introduction, such skills are vital throughout the school career and into adult life. It is important therefore to fully understand the issues which might impact on the promotion and development of such skills. For example, although a class might appear to be lacking the necessary skills for successful group interaction, were teachers influenced by this or did they feel they should try and encourage such skills?

One main point that teachers raised with respect to this was that, a certain points, there was a great deal of time pressure on them to achieve core curriculum skills such as strategy use in mathematics as opposed to group interaction skills:

"I do think one thing though – the speed that you're expected to teach at – not so much now – but certainly when I first started here – it was like you were always getting rushed. I suppose it's like the pace thing – it's the pace and I can understand there has to be pace. But there's sometimes children who take, well they need the time to learn the basics before you start building up on the that. I did feel the first year that I was having to go through things. Actually I thought I was going too slowly because they (management) were saying you were meant to get through this this week and I thought there's just no way you know? So, but the pressure isn't there at the moment but whether or not that would change if we had another inspection I don't know".

"Well this pace and challenge is a difficult thing to deal with as a teacher when you feel like your children aren't actually able to move on to the next thing and you can say ok you just leave that there and you come back to it in the future but if that goes outwith your hands – if that goes to the next teacher you never really have any feedback on whether that's the case or not. I think you have to be careful not to spend a long time on something they're just not ready to learn yet. But you also have to have the confidence that when you pass that on it's going to be tackled again otherwise they're going to end up with that gap in their learning that might well impact on them in the future fairly seriously."

These teachers acknowledged that there were often times when they felt pressured to complete core aspects of the curriculum. It is a natural consequence that if teachers feel under pressure to complete work and teach strategies, the *processes* required for effective collaboration might be impacted. For example, when using resources which are specifically designed to promote metacognitive awareness, during group work, teachers acknowledged that these created more work. This extra work was the mediation that was required by the teacher to promote the social interaction skills necessary for successful collaboration. This can be seen in the short discussion by teachers regarding a resource designed to promote metacognitive thinking during collaborative problem solving:

"And there's the 'let's think maths' and I was trained in it a few years ago but being in primary one I couldn't really use it – it was too difficult for the primary ones. I tried it again last year in primary two. A lot of it is obviously group work and trying to get the children to think what their ideas are in the group. The problem I've had is that they all think they've got the right answer and they all think what they think is right so there's the training as well that's got to come with it - so you listen to other people and try to use all your ideas together. I think as you get older it would be easier in a group I would imagine to say you're right I don't think my idea's that good."

"It's having an adult mediating that"

"Yes that's what you have to do and that can be quite uncomfortable for the teacher. You start off problem solving and then you have the social conflicts coming and it's happening at one bit and then you're trying to help another group – it can become very, very stressful and difficult to manage."

"…they need mediation. Not to guide them but just to make them think how they have to work in a group".

"*…and there's got to be a lot of input into that initially before you get near any problem solving".*

One interesting comment regarding the difficulties encountered by students and teachers during collaborative problem solving was the acknowledgement that many adults find it difficult:

"well sometimes you are asking them (students) to do stuff that adults couldn't do as far as group work's concerned."

Although the teachers acknowledged that there were many pressures on them to complete the core work with students, some had tried to introduce other skills such as collaborative problem solving. However, the mediation required in such tasks took a great deal of effort and was viewed as a negative impact. Therefore, even where teachers introduced group work, the focus still remained on individual strategy use rather than the more cumbersome processual skills. One obvious way to counter the difficulties that students face with being presented with group situations is to incorporate such pedagogies from an early age. I proposed this to the teachers however, again the focus of individual ability and strategy use was heard in the following dialogue:

"I think you would lose the 'can you do it by yourself?' because then you don't get that"

"Especially for some children who socially are on their own a lot they maybe don't cope very well at the group bit and I can think of 2 or 3 children in our class who say nothing in these situations."

"you get the opposite too where children are always in groups and they begin to rely on their peers. They're not independent and I think there needs to be a balance."

"Yes, it's not really encouraging independence. Yes, it's like a coping strategy thing – some children will go down the coping strategy route rather than just get on with it and you've asked them to do it because they perceive that as maybe being easier but the whole

idea is that they need to have a go at it and in a group you might lose that chance for them to have a go [because they might sit back]."

These teachers have expressed their concerns about the impact of social interaction processes which occur during collaborative group work. Their perceptions are that most students require scaffolding to develop the necessary skills to interact effectively. However, the *extra* work involved in promoting such skills successfully was viewed as a drawback rather than a development opportunity. Furthermore, teachers were often driven by their perceptions of their students' abilities and desires to interact in a collaborative way. Finally, the teachers felt that promotion of collaborative skills throughout school would detract from *individual* learning, with some students choosing to sit back and let others do the work.

8.3.3 Summary

The purpose of this section was to provide an insight to the experiences and perceptions of teachers surrounding collaborative group work during mathematics. In the previous quantitative section, I suggested that there was a change in *activity* during the problem solving sessions when the teacher joined the group. When students worked without the teacher, their collaborative metacognition was student to student. However, when the teacher joined the group, this pattern changed and a higher proportion of teacher-to-student collaborative metacognition was recorded.

Evidence from the teacher focus group suggested that there were two distinct areas which shaped the way in which teachers approached mathematical problem solving: initial teacher training and then the many factors which impact *actual* teaching in the classroom.

Teachers reported that during initial teacher training, there was a great emphasis on how to teach strategy rather than processes. Such an approach can result in teachers focussing on individual strategy use. When a teacher interacts with a group, they are then more likely to ask what strategies the students are using and why they are using these. However, if a teacher is focussing on processes, they may instead question how the group arrived at decision to use such strategies. In this latter case, when a strategy has been incorrectly applied, a teacher might be able to pinpoint which part in the process the students did not understand or complete accurately. It is at this point that the teacher may be able to *scaffold* collaborative metacognition *between* students, rather than teacher-to-student.

Once in the classroom, teachers reported that there were many other issues which impacted the way in which they approached problem solving. There were three strands to these issues: previous experiences of the teacher, experiences of students and teachers' perceptions regarding the capabilities of their students. These experiences and perceptions infer that within the Scottish schools that these teachers have worked, there has been no whole-school approach which has focussed on collaborative interaction skills. Furthermore, the development of such skills has not been viewed as a priority but has instead been perceived as requiring *extra* work in an already stretched workload. However, individual learning and strategy use within mathematical problem solving has been promoted and is viewed as central to the educational process. The teachers who participated in the focus group had begun their training with such an emphasis and this continued throughout their teaching careers.

The evidence provided here suggests that even when students are working together to solve a problem, the focus of the teacher will be on what strategy has been adopted by the group. In order to understand which strategy has been used and why, the teacher must question individuals, thus creating a situation where teacher to student collaborative metacognition may occur. However, if a teacher focussed on the processes, the interaction patterns may develop whereby the teacher would *scaffold* interactions between students in order to understand the processes which led to decision making.

When adopting a Vygotskian perspective, the use of *scaffolding* is a crucial element in learning. However, different approaches might be adopted, depending on what is being *scaffolded.* I would suggest that the teacher was scaffolding strategy use by students. This was done through the promotion of a transactive style of interaction by the teacher which resulted in teacher to student collaborative metacognition. However, as noted by teachers, other issues can impact the interactions of students. I would argue therefore that a focus on *scaffolding* transactive interaction patterns between students is a more appropriate approach in order to develop collaborative metacognitive ability.

As previously mentioned, teachers were required, during their initial teacher training, to *report back* and discuss the strategies they had used. The ability to do so implies that they were engaging metacognitively with what they had done. However, the outcome and purpose of this metacognitive reflection was to reflect on the cognitive strategies which they had implemented and which could be taught to students. One implication of this is that teachers might view mathematical problem solving from the perspective of trying to ascertain what strategies individuals (or the group as a whole) may have considered and implemented. Such an approach would result in the type of interactive styles I have reported earlier where the teacher engages in transactive discussion with a student in order to encourage metacognitive thought processes. This might be likened to the type of training that teachers received which involved thinking about the strategies that they used and *reporting* back. One teacher highlighted this when talking about the difference between mathematics and problem solving:

"I think with the problem solving lessons you are more expecting the children to tell you how to solve it whereas with maths you are saying ok this is how we do this."

Whilst the teachers did not feel that mathematics and problem solving were distinct, they did feel the lessons would look different and the outcomes would be different. The quote above implies a certain level of access to metacognition during problem solving. However, this is a retrospective look at what the students did. Although the teachers might expect the students to be able to report back to them, collaborative metacognitive activity requires that students are able to adopt the role of critical assessor of one another's thinking.

By interacting in a *teacher to student* pattern, the teacher would be able to uncover some of the processes which have occurred. However, I would suggest that only by *scaffolding* transactive interaction between students can they learn and develop the necessary skills to promote successful collaborative metacognitive activity.

8.4 Fixed Role Allocation During Teacher Presence

In the previous chapter I proposed that one way to understand the results was that students were engaging in fixed role allocation which may have been detrimental to the production of collaboration metacognition. I would suggest that this understanding of the group dynamics might also be applied to periods when the teacher was present in the groups. The evidence from both the quantitative and qualitative analysis in this chapter suggests that when the teacher was present she tended to lead the discussion. One potential implication of this, which is confirmed with the quantitative analysis, is that there is a stronger potential for collaborative metacognition to occur between the student and teacher and a weaker potential for student-to-student collaborative metacognition to occur. This is depicted in figure 8-11.

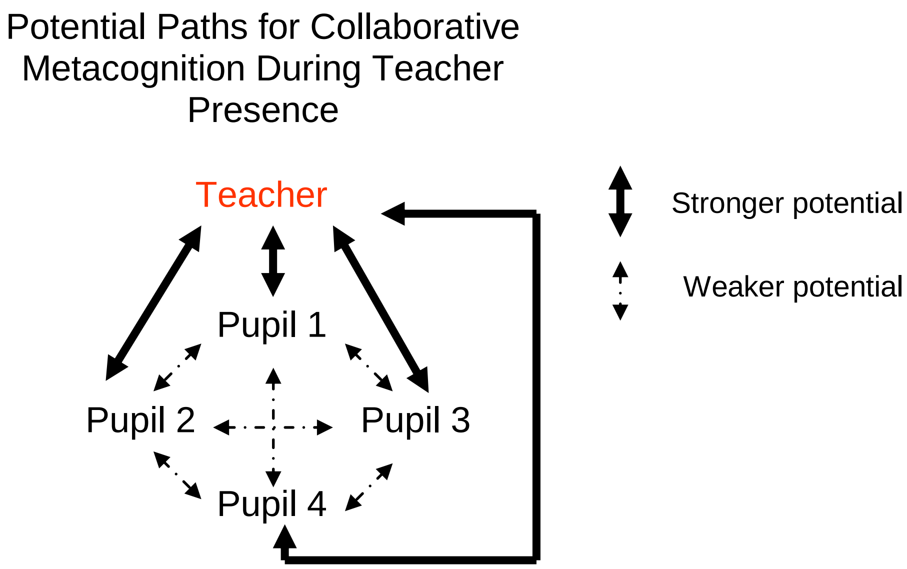


Figure 8- 11 Potential paths for collaborative metacognition during teacher presence

I would suggest that this situation occurred because the students were allocating the role of holder of knowledge to the teacher. I highlighted in the previous chapter that there were occasions where the teacher tried to actively encourage collaborative metacognition between students. However, the results of the quantitative section provided in this chapter suggest that this did not occur often when the teacher was present in the groups.

In the previous section I discussed the role of scaffolding during group problem solving. I suggested that the teacher was scaffolding individual metacognition. However, I proposed that an alternative approach would be to scaffold collaborative metacognition amongst students. In doing so, the teacher might be viewed as more of a facilitator, rather than holder of knowledge. Figure 8-12 depicts the potential for collaborative metacognition should the teacher have adopted such a role.

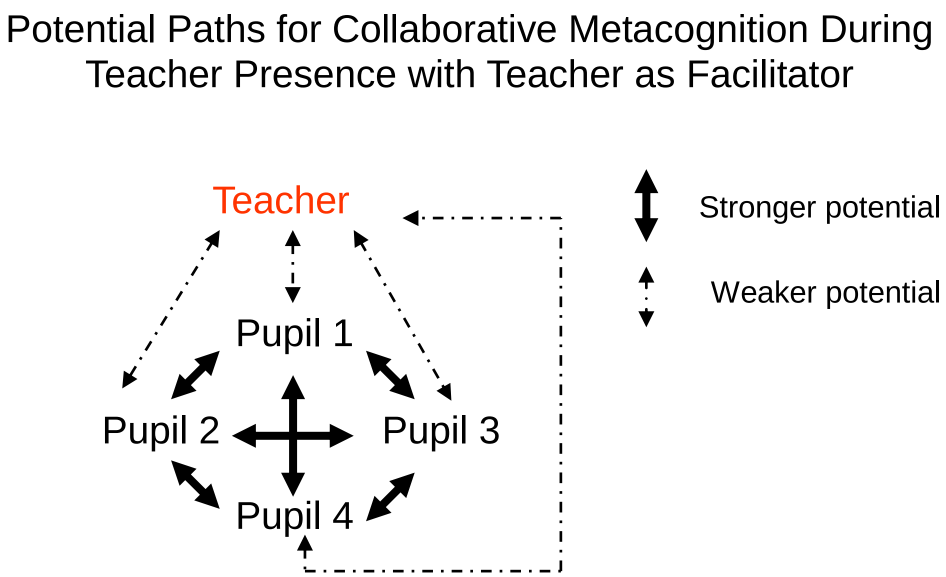


Figure 8- 12 Potential paths for collaborative metacognition with teacher as facilitator

In suggesting that the teacher adopts the role of facilitator in the group, we can see that the weighting of the lines for potential collaborative metacognition are simply reversed. Whilst there is still a potential for the teacher to interact in such a way with students, there is a stronger potential for the students to interact with one another in a way that is more conducive to producing collaborative metacognition.

8.5 Overall Summary

In this chapter I have considered the impact of the teacher on levels of collaborative metacognition. In the quantitative analysis, I showed that when the teacher joined the groups, there was an increase in the proportions of collaborative metacognition which were displayed. This increase could be explained by the transactive contribution of the teacher to the discussion. However, while this seems to be a positive contribution, I have provided evidence that the result of such an interaction style was a higher proportion of teacher to student collaborative metacognition rather than student to student. In order to explain this style of interaction, I have suggested that a change of *activity* occurred when the teacher joined the groups. Without the teacher, students were working collaboratively to solve a problem. However, when the teacher joined, the activity changed to one where the teacher was focussed on understanding individual learning and strategy use. Effectively, the teacher was assigned the role of *perceived holder of knowledge*. Evidence for this claim comes from the focus group conducted with teachers.

Teachers cited various factors which impacted the way in which they approached collaborative problem solving in mathematics. Firstly, during initial teacher training, there was a focus on strategy use rather than group processes. Once in the classroom, teachers suggested that there was a lot of pressure to cover core aspects of the curriculum. They also acknowledged that there was a great deal of mediation required when students worked in groups. Furthermore, teachers felt that many students were not suited to group work and therefore were less likely to promote it. I have argued that issues such as these would lead to an interactive style which has been reported in the quantitative section of this chapter. When the processes of group interaction (such as transactive talk) are not promoted, the focus of interaction by a teacher will revert to the individual. A consequence of this will be that students do not develop the necessary skills to interact in a manner which promotes the successful use of collaborative metacognition.

I have suggested that a potential way in which to understand these interactive patterns is that the students have assigned the teacher the role of holder of knowledge. I have also suggested that the teacher may also have adopted such a role. By changing the role of the teacher from holder of knowledge to facilitator of interactions amongst students, I would suggest that the necessary skills for successful collaborative interaction, and subsequently collaborative metacognition might be developed by students.

Chapter Nine: Discussion

The aim of this thesis was to contribute to the field of metacognitive research through increasing our understanding of the way in which metacognition occurs during collaborative problem solving in mathematics. As I mentioned in the introduction, the research I have conducted might be understood as illuminative research. I sought to investigate and try to understand, rather then generate and test hypotheses. In this discussion chapter, I will provide an overview of the study together with the findings. I will discuss the implications of this research in terms of metacognitive theory. I will also address the usefulness of the research to teacher practice.

In order to extend our understanding of metacognition during collaborative problem solving in mathematics, I conducted a case study in a primary five classroom in a Scottish school. I addressed five main research questions:

1. How can collaborative metacognition be conceptualised and operationalised in a way that is both conceptually rigorous and empirically tractable?
2. To what extent do students use collaborative metacognition during problem solving?
3. What proportions of talk that could be categorised as collaborative metacognition are displayed during successful versus unsuccessful problem solving?
4. What proportions of talk that could be categorised as collaborative metacognition are displayed when the teacher is present compared to not present?
5. What explanations exist for the patterns of collaborative metacognition displayed during problem solving sessions?

Students worked in groups of four during their problem solving sessions. The teacher joined the groups at various points in the sessions for different periods of time. Students who were not part of the study worked in the same way, with the teacher joining their groups also. Those students for whom consent had been received were videotaped during three of their problem solving sessions. Each session lasted approximately 90 minutes.

The research study was informed by Vygotsky's (1986) socio-cultural theory of learning and the later development of this – Activity Theory (Engestrom, 2009). I sought to understand issues which would impact the use of collaborative metacognition through the activity theory concept of *contradictions* which was outlined in chapter four.

In order to address the research questions a number of methods were employed. The conceptualisation and operationalisation of the term collaborative metacognition was developed through a review of current relevant literature, both on metacognition and the concept of group learning. The efficacy of the construct was tested through the use of content analysis on the data from the problem solving sessions. This content analysis also provided the basis for analysis of the research questions which sought to understand the relationship between collaborative metacognition and successful problem solving and collaborative metacognition and the presence of the teacher. However, these quantitative data alone, did not provide a rich account of any issues which might have impacted the use of collaborative metacognition. The use of critical recall interviews with students and focus groups with teachers addressed these gaps.

9.1 Research Question One

The first contribution of this thesis to current knowledge is the conceptualisation and operationalisation of the term collaborative metacognition as defined in the thesis. I would suggest that this is a useful tool in developing our understanding of the use of collaborative metacognition during group problem solving. It is also vital for developing a research field which will allow consolidation of results across numerous and varied research studies. Furthermore, I have also shown that primary school students appear to be capable of interacting using collaborative metacognition, however, there is scope for these skills to be developed further.

The research community which considers individual metacognition has, to a certain extent, agreed that the construct consists of two elements – *knowledge of cognition* and *regulation of cognition* (Larkin 2009). However, the construct is interpreted in different ways and appears in the literature under different terms. Despite this, there is a large body of literature which can be consolidated in order to understand the construct. Interpretation of findings in light of previous research is possible. However, this is not currently the case for metacognition during group work.

A review of the relevant literature highlighted that the term *collaborative metacognition* has appeared, together with pseudonyms such as group metacognition and socially mediated metacognition. However, it also established that no suitable conceptualisation or operationalisation of the term collaborative metacognition was available. The first contribution of this thesis therefore was establishing a definition.

Collaborative metacognition was defined within this thesis as “metacognition which can be identified as having contributed to, or arisen as a result of, participation in the group activity”. The operationalisation of collaborative metacognition was achieved through the use of coding schemes applied to the verbal data collected during the problem solving sessions. Collaborative metacognition was said to occur when a metacognitive statement was followed by a transactive statement, or when a transactive statement was followed by a metacognitive statement.

This construct is important in developing our understanding of the use of metacognition during group problem solving. By making explicit our own thinking we provide others with the opportunity to question it; to agree with it or to ask for more information. When we work with others we must be able to understand their perspectives and their thoughts in order to ascertain if they are compatible with our own. We also must be able to articulate our thoughts in order to be able to explain to others why we might disagree or why we should follow a specific path.

The operationalisation of the construct is important from a methodological perspective because it allows researchers to be consistent in their interpretation of term. When someone makes a metacognitive statement in a social situation we might assume that the intention was for others to hear it. However, unless someone explicitly interacts with that statement, we cannot assume even as much as they have heard it. We cannot assume that they agree or disagree. However, if someone interacts in a transactive manner with that statement, we can infer collaborative activity. When someone offers a transactive statement which then results in a metacognitive response, we can reasonably (although not absolutely) attribute that metacognition to the collaborative nature of the talk.

The operationalisation of the term is also important from a theoretical perspective. Chi square tests for association, reported in chapter three, showed that there was a relationship between transactive talk and metacognitive. A higher proportion of metacognitive utterances were preceded by a transactive utterance, compared to the proportion of cognitive utterances preceded by a transactive utterance. Similarly, a higher proportion of metacognitive utterances led to a transactive utterance, compared to the proportion of cognitive utterances which led to a transactive utterance. These results indicate that transactive talk was an important component of these group interactions in *mediating* the use of metacognition. Furthermore, metacognitive talk was important in *mediating* interaction.

This represents a two-fold development of the work of Goos et al (2002) who referred to the term collaborative metacognitive activity as talk with both transactive and metacognitive qualities. Firstly, it highlights the recipocracy of the communicative process which transactive talk produces. It also provides evidence of the mutually mediating qualities of both metacognitive talk and transactive talk.

9.2 Research Question Two

A second contribution to the field of metacognition is the finding that primary school children are capable of the advanced interaction skills which constitute collaborative metacognition. There is, to my knowledge, no published evidence which relates to primary school students in Scotland. The study by Goos et al (2002), from which the concept of collaborative metacognition was developed, concentrated on the interactions of secondary school students. The study by Larkin (2009) which focussed on primary school students in England, was in the domain of learning to write.

The results of the study reported here showed that whilst primary school students did display collaborative metacognition, very low proportions were recorded. Previous research has shown that there are generally low levels of metacognition present during group work compared to other types of talk (e.g. Artz & Armour-Thomas; Larkin 2009). It would be an impossible task to attempt to ascertain appropriate levels of metacognition which are required for successful problem solving. Rather, it is more appropriate to attempt to understand the use of collaborative metacognition during successful and unsuccessful sessions.

When students engage in a problem solving endeavour, one of the expected outcomes is generally the correct solution of the problem.

9.3 Research Question Three

As previously mentioned, the purpose of this research was investigative and illuminative. It was not my intention to generate hypotheses regarding the relationship between a specific type of interaction (i.e. collaborative metacognition) and successful problem solving. Rather I have argued that the construct of collaborative metacognition, as defined in this thesis, is a useful tool to further our understanding of group problem solving.

The analysis of data, which was separated into successful and unsuccessful sessions, showed that there were different patterns of talk associated with both sessions. Successful problem solving sessions were characterised by higher proportions of metacognitive talk and lower proportions of cognitive talk than unsuccessful sessions. This concurs with previous research in the area of individual metacognition (e.g. Artz & Armour-Thomas 1992). Furthermore, the teacher was present in the groups for a larger proportion of time during successful sessions. For the sessions when the groups were successful, the teacher was present approximately 48% of the time, whereas when the groups were unsuccessful, the teacher was present only 26% of the time. Higher proportions of *teacher teaching* talk were also a characteristic of the successful sessions.

We might therefore suggest that low proportions of metacognitive talk, higher proportions of cognitive talk and less input from the teacher are all contributory factors during unsuccessful sessions.

However, these figures only provide information on individual metacognition during the problem solving sessions. It may have been that during the successful sessions, there was one group member *thinking out loud* in order to solve the problem on their own with no or relatively little input from the rest of the group. These figures do not provide information on the *dynamic* nature of collaborative interactions.

The analysis of the use of collaborative metacognition suggested that it was a factor in successful problem solving sessions. When students were working, without the presence of the teacher, there were higher proportions of collaborative metacognition displayed during successful sessions compared to unsuccessful sessions. When the teacher was present in the groups, again, there were higher proportions of both strands of collaborative metacognition displayed. However, the metacognitive to transactive strand was only very slightly higher.

This finding might be interpreted in conjunction with previous findings by Goos et al (2002) and Hurme et al (2006) referred to in chapter three. Goos et al (2002) found that there were higher proportions of metacognitive talk followed by transactive talk and transactive talk followed by metacognitive talk during successful sessions. Hurme et al (2006) found that higher levels of interaction between student pairs was related to higher levels of metacognition.

Whilst both of these studies have been critiqued regarding their designs and methods, the findings are nonetheless congruent with those reported in this thesis. This, I believe, strengthens the claims contained within this thesis regarding the efficacy of collaborative metacognition as a research construct. However, this thesis also extends those findings to include data when the teacher was present in the groups.

During the time when the teacher was present, the majority of transactive talk was made by the teacher, rather than students. It was therefore important to ascertain if the collaborative metacognition was produced by teacher-to-student interactions or student-to-student. During successful sessions, there were higher proportions of student-to-student collaborative metacognition displayed than in unsuccessful sessions. However, this difference was greater for transactive to metacognitive than for metacognitive to transactive.

This analysis of the way in which students interacted during the problem solving sessions provided a more dynamic account of the type of talk displayed. When students were successful, a higher proportion of their talk was collaborative metacognition than during unsuccessful sessions. Furthermore, when the teacher was present, a higher proportion of collaborative metacognition was student-to-student than during unsuccessful sessions.

This type of quantitative analysis is important in providing an understanding of the types of talk which might be associated with successful problem solving outcomes. However, they do not provide an understanding of *why* there were low proportions of collaborative metacognition overall; *why* proportions were lower during unsuccessful sessions specifically; nor do they provide any indication of the potential importance of student-to-student collaborative metacognition during teacher presence.

The employment of critical event recall interviews addressed the issue of lower proportions of collaborative metacognition during sessions.

9.4 Research Question Five (with reference to successful versus unsuccessful sessions)

The critical event recall interviews were interpreted through the concept of *contradictions* as posited within Activity Theory. The purpose of the interviews was to contribute to the current research by understanding the influence of the group situation on students' use of collaborative metacognition *from their own perspective*. In their concluding remarks, Hurme et al (2006) proposed that such an approach would be beneficial to the research area as it would provide a valuable insight to issues which guide student interactions. Without the use of recall interviews, researchers are left to *imply* what might be occurring, rather than ascertaining what actually occurred. A critique of such methods is provided in chapter four (methods) and so will not be addressed here.

Contradictions have been described as being the motive for change or development within the activity system. They can be positive or negative and can disturb the activity or transform it (Engestrom 2001). One important element is that contradictions might not be identifiable at the time of the activity (Capper & Williams 2004). It is therefore crucial that researchers employ methodological techniques which will allow access to such contradictions. As previously mentioned, contradictions might occur during successful or unsuccessful activities. Three recall interviews were conducted, two of which were during unsuccessful sessions and one was during successful sessions. The findings of these interviews provide illuminative evidence of the need to understand learning environments from a number of different perspectives. The recall interviews highlighted three main areas within the activity system which impacted the use of collaborative metacognition: rules; mediating artefacts and division of labour.

Contradictions in Rules – Group one

Engestrom (1993) suggested that *rules* could be either explicit or implicit rules which individuals use to guide their actions *and* interactions. Group one in the study was unsuccessful in solving a problem regarding the area of a rectangle. Had the students been working alone, at least two, and possibly, three of the members should have been able to solve it successfully. Yet this did not happen. Contradictions in the rules which students applied to shape their interactions seemed to impact the levels of collaborative metacognitive activity. These contradictions occurred when students were asked to do a task which was contradictory to their feelings and beliefs regarding that task.

The students reported that their interactions were influenced by the use of *social rules* regarding with whom they would interact. For example, one student was not keen to interact with those whom he felt were less able than he was. Whilst he claimed the process of explaining his thoughts to others would 'take too long', he was quite willing to take time to explain his thoughts to the teacher.

Three out of the four group members reported that they preferred to work individually and they did not believe that individual learning would occur during a group situation. These *implicit* rules were not addressed explicitly at the time of the problem solving, yet they impacted the willingness of students to interact in a manner which would produce collaborative metacognition.

This appeared to have had a major impact on the outcome. One student seemed to have misunderstood the question and even the teacher had not noticed this. However, had he engaged in collaborative metacognitive activity with the rest of the group, this issue may have been highlighted. Later in the session, the issue was addressed by the teacher. However, when the one student who preferred group work attempted to make suggestions, these were ignored.

Mediating Artefacts – Group three

Mediating artefacts, or tools, may be used within the activity system towards the outcome or goal of the activity. These tools can be physical tools such as books, equipment, etc, or they may be cognitive tools. A contradiction between cognitive tools was reported in group three. However, this on its own, was not entirely the apparent cause of the group being unsuccessful in the task. A further contradiction in rules which students applied in order to decide which group member to believe also influenced the outcome.

The contradiction which one student reported between cognitive and metacognitive tools contributed to the lack of collaborative metacognition displayed in the group. Whilst the student was able to verbalise the answer, he could not, when questioned, explain his thoughts to the other group members. Another student offered a different, incorrect answer. Rather than this being the catalyst for collaborative metacognitive activity in order to ascertain the correct answer, the students began debating which answer they should accept, based on their previous perceptions of the cognitive abilities of the two students.

Such instances have been highlighted in previous research. For example, Goos and

Galbraith (1996) suggested that unhelpful social interactions resulted in failure when one student failed to adopt another student's strategy. However, that study did not attempt to understand from the student's perspective, this reluctance to adopt another's strategy. The critical event recall interviews may fill that gap and provide a richer account of what might guide student interactions.

The outcome of the activity was impacted by contradictions in the cognitive tools of others in the groups, as well as the perception of task difficulty. The group chose to adopt the incorrect answer because the student proposing it seemed to have been perceived as being more thoughtful in her work and responses than the other student. These perceptions may have been built on over many years of schooling together. Furthermore, for at least one member of the group who found problem solving difficult, the perceived effort of one group member seemed to impact her decision to accept that incorrect answer.

Division of Labour – Group Two

As previously mentioned, contradictions are also found in successful problem solving sessions and add to our understanding of the role of collaborative metacognition during such sessions.

Group two represented a group and session where the group was successful in completing the task, yet three of the four group members reported they did not really understand what they had done. The interactions of the group had developed from an initial situation where the two boys had generally interacted to solve the problem, to the final week when the two girls were also involved.

The crucial element in this development had been the contradiction in the division of labour. The girls had been asked by the teacher to participate, yet the boys consistently took charge of the problem solving and did not involve the girls. Over the weeks, the girls continued their attempts to become involved. By the final week, the group was presented with a problem which one of the boys, Liam, had already completed at home. He therefore proceeded to solve the problem without involving the others.

However, the lack of understanding of the other group members, prompted them to interact with Liam. This lack of understanding might have been addressed through collaborative metacognitive exchanges, where all students questioned and critiqued different approaches to the problem. However, Liam resisted such interactions and instead gave the others different roles. For example one girl became the scribe. The result of this was that there was no collaborative metacognition required in order to complete the task. However, importantly, the students reported that they had felt included and that they had all worked well together.

These findings further highlight the importance of moving beyond a simple quantitative analysis of collaborative metacognition. This group had been successful each week during their problem solving attempts, yet they did not always work collaboratively. Furthermore, the contradictions within division of labour led to a change in the working pattern of the group. However, this did not lead to interaction which resulted in collaborative metacognition. Rather, it resulted in a mechanical interaction where students were assigned roles which seemed to require very little thinking on their behalf.

These differential interaction patterns have been highlighted in previous research (e.g. Artz and Armour-Thomas 1992, Hurme et al 2006). However, there has been no previous attempt to *explain* such interactions using recall data from the students. The evidence gathered from the critical event recall has therefore been a crucial addition to the interpretation of the quantitative data. Very low proportions of collaborative metacognition were recorded overall. Whilst this might be due to any number of factors, it is helpful to understand it through the concept of *contradictions* within the activity system.

9.5 Research Question Four and Question Five (for teacher presence)

The very low proportions of collaborative metacognition, together with the data from the critical recall interviews, suggested that students have difficulties in interacting in such a way as necessary to produce collaborative metacognition. Many issues may impact the interactive skills of students, but the research reported here highlights specific areas. The Vygotskian notion of zone of proximal development is useful in understanding the role of the teacher in *scaffolding* the necessary skills for successful collaborative metacognition.

Accordingly, the impact of the presence of the teacher was addressed. Quantitative analysis provided support for the notion that the teacher impacted the proportions of collaborative metacognition displayed. There was a large increase when the teacher was present in the groups. Further analysis showed that the majority of the collaborative metacognition was from teacher-to-student interactions rather than student-to-student.

These findings may be understood as a possible change to the activity when the teacher was present in the group. While students were working on their own, their activity was to solve the problem jointly. However, when the teacher joined the group, the activity changed to one where the teacher took control of the session and directed discussion. This resulted in dyadic interaction between student and teacher, rather than a group interaction.

This type of interaction is unsurprising as many interventions which are designed to facilitate metacognition in the classroom require the teacher to question and probe *individual* students. These interventions may, to some extent, have been developed and shaped by a specific theoretical understanding of learning mathematics. As noted in chapter three, Schoenfeld (1992) suggested that learning mathematics may be viewed as acquiring facts, procedures and relationships. When mathematics is viewed in such a way, the focus of the teacher will naturally fall on the ability of students to recall and use such information. Furthermore, the education system in Scotland has been developed in such a way as to promote individual learning and assessment. The aim of the focus group was therefore to uncover issues which might have impacted the use of interactive strategies which promoted teacher to student collaborative metacognition as distinct from student to student collaborative metacognition. Teachers highlighted issues during their initial teacher training and also issues which developed once in the classroom as possible contributory factors in such interactions.

The teachers reported that during their initial teacher training, there was a great emphasis on supporting strategy use by students. Strategy use is of course important for successful problem solving. However, as the data from the critical recall interviews showed, students can adopt incorrect strategies or answers when they are in a group. The adoption of these can be influenced by many issues which are concerned with the interactive processes between group members. It is therefore important that the focus moves beyond what individual students may propose. Focus should turn to the collaborative interactions of other students in ascertaining the effectiveness of a strategy, or the accuracy of an answer. However, the teachers reported that no such focus was provided during their initial teaching training.

Teachers continue in their professional development throughout their careers and they also experience different approaches to teaching within different school and local authority areas. However, none of the teachers interviewed had experienced a whole school approach and commitment to collaborative problem solving in mathematics. The skills required for collaborative problem solving have not therefore been viewed within the curriculum as *core* skills. However, as I mentioned in the introduction, such skills are a focus of the Curriculum for Excellence and are also cited by the SQA in being vital for promoting successful learning.

One final area that the teacher focus group highlighted was the perception they had of their students' willingness or ability to work in groups. For example, teachers reported that some students just seemed to be good at working independently whereas others seemed to enjoy the interaction of group work. Teachers also reported that when students worked in groups there was a danger of one or two doing all the work and the others not contributing. This is congruent with the findings of the critical recall interviews and previous research which suggests that different interactive patterns might occur during group work. However, rather than address such issues, for example through developing students' group work skills, the use of group work is seen as a less favourable option.

This is also fuelled by the perceived difficulty in *teaching* group work skills. The teachers felt that young students were often not capable of such interactions and therefore the use of group work was not promoted.

The use of group problem solving during mathematics in this study was therefore influenced by many factors. The focus on strategy use and individual assessment has, I would argue, contributed to a situation where group work has not been promoted. As a result, the necessary skills have not been scaffolded by teachers during group work, resulting in low overall proportions of collaborative metacognition and high proportions of teacher-to-student collaborative metacognition compared to student-to-student collaborative metacognition.

We might understand these findings in terms of the way in which mathematical learning is viewed by teachers and teacher educators. As I suggested in chapter three, mathematics might be viewed as a *social* activity requiring dialogical interaction (Schoenfeld 1992). Collaborative problem solving, I would suggest, is an example of the social activity which is mathematics learning. It is the arena where mathematical knowledge might be applied and where communication is vital to reach consensus and understanding.

Interestingly, the response of the teachers suggested that they understood mathematics in two different ways – mathematics required students to apply formulae and rules, whereas problem solving required a different approach, involving language and communication. Teachers were aware that problem solving, and particularly collaborative problem solving required different skills than doing mathematics per se. They were also aware that students had different capabilities and preferences regarding such skills. These different skills are the communicative processes referred to by Sfard and Keiran (2001), who suggest that such processes must be taught as something distinct from the mathematical procedures required to solve problems. They are also, I would argue, the communicative processes which might result in collaborative metacognition.

9.6 Interpretation of findings with reference to metacognitive theory

The findings reported in this thesis represent a contribution to our understanding of the metacognition during group work. Current theoretical models of metacognition have been produced from research concerning individual group work. However, there is an increasing body of evidence, referred to in chapter three which has highlighted social factors which influence students' use of metacognition.

As I referred to in chapter three, researchers concerned with metacognition during group work have considered it an individual attribute which may be mediated by the group situation (e.g. Goos et al 2002) or an attribute of the group itself (e.g. Iiskala 2010). My understanding of the term is that it is an individual attribute mediated by the group situation. The findings contained within this thesis provide support for the efficacy of such an understanding through the triangulation of data. I have highlighted instances where I would expect collaborative metacognition to have occurred, yet it didn't. Through the recall interviews with students and focus groups with teachers I was able to highlight potential socially mediated explanations for this.

There are still many gaps to be filled in order to develop a full understanding of the mediating influence of the group. However, the trend in the research area, which is supported by and extended to within this thesis, is that the group situation does influence the use of metacognition. It is therefore vital that research continues in this area in order to develop new models of metacognition for use by the research community.

However, as I mentioned in the introduction, this study might be understood in terms of the illuminative phase of longer research project. As such, I have sought to understand the use of collaborative metacognition during group work. I have suggested that one way of understanding the overall findings contained in the thesis is that the use of fixed role allocation of perceived holder of knowledge may limit the use of collaborative metacognition between students.

When students were working without the teacher, there emerged the role of *holder of knowledge*. For each of the groups this assignation came from a different source. For one group it was the teacher who assigned the role. For another group the role was assigned when the group members were presented with conflicting solutions. For the final group the role was self-assigned by a group member.

Once roles were assigned, the group members did not easily deviate from them. I have suggested that a result of these role allocations was a potential limitation on the use of collaborative metacognition between students.

When the teacher was present in the group, I have suggested that the role allocation may have resulted in similar limitations. The role allocation of the teacher as holder of knowledge may have been more of an intrinsic understanding between all of those present. When the teacher joined the group, the majority of collaborative metacognition was between the teacher and another student. However, I have suggested that in order to develop student to student collaborative metacognition, the role of the teacher might change to that more similar to a facilitator. Whereas the teacher was able to scaffold individual use of metacognition, the interaction patterns displayed, did not suggest that the same was the case for collaborative metacognition.

Understanding group interactions in this way has important implications both for teacher practice and the development of metacognitive theory which I will now discuss.

9.7 Implications of findings for teacher practice

One main aim of this study was to understand the use of collaborative metacognition during group work in a naturalistic setting. It is therefore relevant to provide suggestions for teacher practice in light of the findings.

The Vygotskian notion of zone of proximal development suggests that teachers might help students learn through scaffolding the necessary skills. In order to be effective in the use of collaborative metacognition, there are two skills which need to be developed: collaborative interaction skills and metacognitive ability.

Students within this study did display collaborative metacognition, but in very low proportions. They also reported various issues which impacted their use of collaborative metacognition. These issues did not only occur during unsuccessful sessions but were present in successful sessions also. This suggests that there is scope for skills to be developed in this area.

Teachers possess the potential to impact the use of collaborative metacognition by scaffolding this type of interaction *between* students. This is in addition to scaffolding the use of metacognitive talk through teacher to student collaborative metacognition.

In order to do so, a simplified version of the coding scheme used to detect collaborative metacognition might be produced. Teachers would then be able to learn and then encourage the types of talk which might result in collaborative metacognition amongst students. They might also use such a guide to gauge the level of interaction displayed by students in their classroom.

Scenario cards might also be produced in order to help both teachers and students. For example, the cards might contain potential situations were fixed role allocation might occur. These might include potential behaviours to look out for, such as students withdrawing from the group or dominating the group. Ideas on how to change these role allocations might be developed based on the types of talk which encourage collaboration.

Changes might also be required throughout the education system. Teachers in the focus group reported that the skills required to potentially facilitate the use of collaborative metacognition were not promoted during their initial teacher training, nor had they experienced any whole school approaches to group work during their service. If such skills are to be promoted within the curriculum, then this should be converted to a change within the classroom.

One important finding was that teachers were often influenced in their use of collaborative group work by their perceptions of their students' capabilities to interact in such a way. This view was, perhaps, confirmed by the recall interviews with students. The students cited various issues which impacted their interactions. For example, they made judgements based on their perceived cognitive abilities of others in order to decide which answer to accept. It is reasonable, therefore, for teachers to assert that often students are not capable of interacting effectively in groups.

Whilst these issues cannot be completely eradicated, it is important that they are highlighted within group work situations. By addressing the contradictions, which students have reported, steps may be taken by teachers within the classroom to improve the interactive experiences of students.

It is vital, therefore that students are *taught* how to interact successfully in order to promote collaborative metacognition. In line with previous research (e.g. Larkin, 2009, Sfard & Keiran 2001), I propose that communication skills such as this do not necessarily develop naturally and when they are influenced by many other factors, the role of the teacher becomes even more important in the scaffolding process.

As previously noted, the theoretical understanding of mathematics education will influence the way in which teachers approach the subject. This may in turn impact the pedagogical approach being adopted. Mathematics education has been understood in terms of *constructing* meaning through the acquisition of facts, procedures and relationships. However, I would propose that mathematics education must also be understood in terms of the social interactions which are required for the *application* of acquired knowledge. It is through these social interactions that potentially new understanding might develop and new knowledge will be created (e.g. Paavola et al 2004). Sfard (2001) suggests that it is by giving communicative processes precedence in the mathematics classroom that learning will develop. I would suggest therefore, that there is scope to consider the theoretical component of initial teacher education programmes, with specific focus on the relationship between this and resulting pedagogy.

9.8 Limitations of the study

This study is limited in a number of ways. Methodological limitations are evident in the data received from the teacher focus groups (chapter five); the relationship between collaborative metacognition and successful problem solving (chapter six) and the interpretation of data from teacher presence (chapter eight).

Teacher focus group limitations

Teacher focus group data – I have critiqued the use of focus group and the generalisability in chapter five. However, there does exist another limitation within the data since there were no newly qualified teachers present. With the introduction of a Curriculum for Excellence, there also came a review and recommendations of change of initial teacher training. It may be that a newly qualified teacher would have a different experience to those teachers who have been teaching for a number of years. In order to address this, it may have been useful to interview newly qualified teachers. However, as there were no newly qualified teachers available to participate, it was not possible to do this. Future studies might implement such a change in order to ascertain if there has been any development to the experiences of teachers in training. This might also have been addressed through the inclusion of an historical overview of initial teacher training in Scotland, relating to primary school mathematics.

The relationship between collaborative metacognition and successful problem solving

Whilst the data presented did suggest that higher proportions of collaborative metacognition were associated with successful problem solving, the differences between the two conditions were very low. This may have been due to the relatively low quantities of metacognitive and collaborative talk displayed overall. However, the quantities recorded in this study were either similar to or higher than previously published papers (e.g. Goos et al 2002, Hurme et al 2006, Larkin 2009).

One of the claims of this thesis is that there is a relationship between collaborative metacognition and successful problem solving. However, there are limitations to the strength of this claim. For one of the strands of collaborative metacognition – metacognitive to transactive – there was only a one percentage difference between unsuccessful and successful sessions. Whilst this represents only a very small increase, it is an increase in the correct direction nonetheless. However, the small sample size further limits this claim. I would suggest however, when it is interpreted in light of the other findings and previous studies the potential strength of claim may be increased slightly. Previous research studies which have found a relationship between metacognition and successful problem solving in mathematics have all, to my knowledge, used students who either display higher proportions of metacognitive talk in general, or express an interest in group work (thereby suggesting they will be more skilled or motivated in such situations).

Furthermore, many studies have removed students from the classroom situation during data collection. The study by Larkin (2009) was conducted in a natural classroom environment, however that was concerned with learning to write. However, all of those studies reported either lower or similar quantities of metacognitive interactions in their analysis.

The study reported in this thesis took place in a completely natural environment with no manipulation of participants or environment (apart from the presence of video recording equipment). Furthermore, the students had not received instruction on how to interact in a collaborative manner prior to the study. Some students reported that they enjoyed working in the groups, whilst others did not. Within each group there were students of different abilities in mathematics.

I would suggest, therefore, that *tentatively proposing* a relationship between collaborative metacognition and successful problem solving, however small, is a reasonable interpretation of the findings, particularly when interpreted in light of previous findings. However, in order to provide a more valid case for generalisation of results, this limitation should be addressed through a larger scale study to determine the relationship between collaborative metacognition and successful problem solving.

Interpretation of data from teacher presence

Limitations also exist in interpretation of data from the chapter on teacher presence, particularly concerning the role of the teacher during the problem solving sessions. Inferences have been made in this thesis that the teacher adopted a role which encouraged dyadic interaction with one pupil in the group. However, there was no attempt to establish the teacher's view or interpretation of this. It may have been that the teacher disagreed with such an assertion. This may have been addressed by conducting teacher recall interviews, similar to those conducted with the students. Similarly, the students might also have been shown points in their sessions when the teacher was present in order to ascertain their understanding of the role of the teacher.

9.9 Future Research

The research contained within this thesis, particularly the conceptualisation and operationalisation of collaborative metacognition, represents an exciting opportunity for future development and research within many different areas.

Future research in this area is crucial, both as an evidence base for a Curriculum for Excellence and also to ensure that a culture of collaboration is promoted in order to encourage the use of metacognition during problem solving situations. This thesis represents a case study of one primary school class. Future studies should consider extending this across all primary school stages in order to understand the use of collaborative metacognition at different ages. Once we are able to understand the types and levels displayed by students, interventions may be produced in order to promote the use of collaborative metacognition.

Teachers are crucial to such research and their views and understandings of metacognition and the processes involved in mediating it during group work should be sought. Furthermore, an investigation into the provision of training for teachers in this area during initial teacher training and continual professional development programmes should be carried out in order that any gaps may be addressed.

From a theoretical perspective, the development and use of the concept of contradictions in understanding collaborative metacognition would be beneficial. For example, by understanding if contradictions appear to be consistent over time, or if they change frequently.

The concept of contradictions is an important one for future research studies, particularly since they often go unacknowledged at the time of the activity (Capper & Williams, 2004). Research which seeks to develop novel tools which will allow students to become aware of contradictions *in vivo* would be an exciting addition to the research field.

The mutually mediating relationship between collaboration and metacognition would also be an interesting concept for future research. In particular, investigating if particular types of collaborative (transactive) talk influence specific types of metacognitive talk (e.g. knowledge of cognition or regulation of cognition).

I would suggest that an important area for future research is that of fixed role allocation and the potential for limiting the use of collaborative metacognition between students, which arose from the unique combination of methods in the research design. I believe that the tentative interpretation of findings where a *holder of knowledge* emerges has potential implications for group work design. For example, if there is a wide range of ability within the group, the members may *default* to the thoughts and suggestions of the individual they perceive to be more likely to get the answer correct. This in turn may impact negatively on collaborative metacognition between group members. However, if students perceive one another as similar ability, such a situation may be more conducive to collaborative metacognition between students and joint solving of the problem. Future research questions could therefore focus on determining the optimum group design.

Future research might also consider the application of this design to other domains. The nature of the problem solving sessions reported in this thesis were closed problems where a final answer was achievable. However, this might have, to some extent, contributed to the finding that a holder of knowledge emerged from the group. In instances where no precise answer is possible, the interactive patterns may change. For example, the application of the approach adopted within this thesis to the area of writing would be an interesting extension of the research. Writing is a creative process and collaborative input would be qualitatively different from that required when solving a mathematical problem.

As I mentioned in the methodologies chapter, the design adopted in this study might also be applicable to research domains outwith education. One potential area is that of organisational behaviour. Through an in-depth analysis of collaborative decision making processes within organisations, training and intervention programmes may be implemented in order to develop these processes through the understanding of potential contradictions.

Chapter Ten: Conclusion

A number of tentative conclusions can be associated with the research reported in this thesis. The use of an activity theory framework to understand metacognition during collaborative problem solving has facilitated the use of multiple perspectives in interpreting the data. Furthermore, the concept of contradictions has been useful in guiding the research process and analysing data.

The concept of collaborative metacognition, as defined in this thesis, has also been a useful one in studying the use of metacognition during group work in primary school mathematics. This represents a contribution to the field of metacognitive research, since no previously published papers have made such a proposal. Furthermore, the mutually mediating influence of collaborative talk and metacognitive talk has been confirmed through statistical analysis.

Bearing in mind the small sample size, the quantitative investigation into the use of collaborative metacognition resulted in the following tentative claims:

1 Whilst students do display collaborative metacognition during their problem solving sessions, proportions are very low
2 The relationship between successful problem solving sessions and collaborative metacognition is not conclusive
3 Successful sessions are associated with higher proportions of teacher to student collaborative metacognition
4 The presence of the teacher is associated with higher proportions of collaborative metacognition
5 These higher proportions are accounted for by teacher-to-student collaborative metacognition rather than student-to-student

Interpretation of these quantitative data is very limited since it does not provide details or explanations of the type of issues which may impact the use of collaborative metacognition. Nor did it provide an explanation for the higher proportions of teacher to student collaborative metacognition rather than student to student.

The use of critical recall interviews, together with teacher focus groups highlighted a number of potential areas which contributed to these results. The data from the critical event recalls represent for the first time an understanding of student–reported issues which might impact the use of collaborative metacognition during problem solving. The data also highlight, in line with previous research, the complexity of social interaction. Specifically, even during successful problem solving attempts, there is no guarantee that all students will contribute equally (e.g. Artz & Armour-Thomas 1992). Furthermore, the use of frequency counts alone when attempting to understand learning in such a complex environment is not sufficient.

Analysis from the critical event interviews suggested that students' interactions, and specifically their use of collaborative metacognition, were influenced by many factors. For example, students were unwilling to interact if they felt it would slow them down. Similarly, if students were unable or unwilling to interact in a manner conducive to collaborative metacognition, they would resort to making decisions about the problem based on other factors. For example, students chose an incorrect answer based on the perception that one student had worked harder than the other to arrive at the answer.

This data, combined with the previous quantitative findings suggest that students require scaffolding of such skills. The teacher is the key figure within the classroom to provide such scaffolding. However, when the teacher was in the groups, the patterns of collaborative metacognition were mainly teacher to student rather than student to student. Teacher focus groups highlighted areas which might have influenced such interaction styles. Two of such areas were the lack of focus on group processes during initial teacher training and teachers' perceptions of students' abilities to interact in such a way.

These findings highlight potential gaps in initial teacher training which, I have suggested, might stem from the theoretical understanding of mathematics education. If mathematics education is understood as both the acquisition of mathematical knowledge as well as the communicative processes required to apply such knowledge in collaborative situations, then pedagogical approaches might develop to allow the scaffolding of such communicative processes.

Teachers acknowledged that such communicative skills were not naturally present in all students and the development of such skills would be time consuming and difficult to manage. However, I would suggest that if the learning outcomes proposed in a Curriculum for Excellence, as referred to in the introduction, are to be realised, such skills should be a focus of mathematics education. The quantitative analysis has provided very tentative evidence that students *can* interact in such a way, however such skills need to be developed.

Interaction skills which mediate the use of metacognition do not only represent skills that are required for successful problem solving during mathematics. They represent the responsibilities that each individual should take for their own knowledge acquisition. Children and adults make many decisions in many situations throughout life. I would suggest that it is the responsibility of educators to ensure that children know how to make informed decisions in the presence of their peers.

The interpretation of these findings through the proposal that socially mediated fixed role allocation may have been detrimental to student-to-student collaborative metacognition is, I believe, a helpful notion in beginning to understand the many complex issues which impact group work.

I believe that if students are to become responsible citizens capable of making informed choices, they must learn skills which allow them to say what they think and know about a situation. They must learn to listen to another's argument, to question that argument in light of their own and the knowledge available to them. They must also resist the sometimes comfortable path of *following* a perceived holder of knowledge. This type of interaction is difficult, especially with peers. However, if such skills are taught from an early age, if the culture of the education school system was such that it was normal practice, then the end result may impact not only mathematical skills, but many other areas also.

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Appendix A Coding System

Transactive Reasoning Coding Scheme

Definitions of transactive reasoning (or discussion)
Teasley (1997) transactive discussion is 'a type of interaction in which each child uses his or her *conversational turn* to operate on the reasoning of the partner or to clarify his or her own ideas'.

Nucci (2006) research on transactive discussion focuses on the 'efforts by each speaker to extend the logic of the prior speaker's argument, refute the assumptions of the argument, or provide a point of commonality between competing positions.

Wahlstedt & Lindkvist (2007) "A turn is considered transactive if it extends, paraphrases, refines, completes, critiques an other's reasoning or the speaker's own reasoning"

The study used the following categories for transactive reasoning:

- Clarification
- Elaboration
- Justification
- Critique of own reasoning
- Critique of other's reasoning

Types of transacts: statements
Questions
Responses to transactive questions

Orientation of above:
Own thinking or
Partner's thinking

Data were therefore coded as follows:

	Statements	Questions	Response to transactive question
Own thinking	Stown	Quown	Resown
Other's thinking	Stother	Queother	Resother

Teong (2003) *"metacognitive behaviours could be exhibited by statements made about the problem or about the problem solving process while cognitive behaviours could be exhibited by verbal or nonverbal actions that indicated actual processing of information"* p141

Cognitive

Code	Description	Example	Reference
Instruction relevant to solution	Pupil gives another an instruction to do something which is directly linked to solving the problem	'Now we've got to discuss'	Artz & Armour-Thomas *implementing* AND Veldhuis-Diermanse
Instruction not relevant to solution	Pupil gives another an instruction to do something which is not directly linked to solving the problem	'talk'	
Step or solution without explanation	A pupil provides a step towards the solution or a possible solution without explaining why it is relevant	'I think the Brit came first'	Veldhuis-Diermanse and Artz & Armour-Thomas *Exploring (cognitive)*
Agrees without explanation	A pupil agrees with a previous suggestion but doesn't explain why		Veldhuis-Diermanse
Disagrees without explanation	A pupil disagrees with a previous suggestion but doesn't explain why	"nah, nah, nah, nah, nah. No"	Veldhuis-Diermanse

Reading	Pupil reads the problem from the sheet provided	"the Canadian jumped twice as long as the American"	Artz Armour-Thomas *Reading*
Content directed question	A pupil asks another pupil a question related to the content of the problem		Veldhuis-Diermanse
Evaluating	A pupil gives an evaluation of their progress without reasoning.		I am using this because there is a difference between metacognitive evaluation and reflection and a quick one word answer!

Metacognitive

Code	Description	Example	Reference
Monitoring Instructions or plans	It will be clear that a pupil is monitoring what is being said or done in relation to the solution of the problem or instructions they have received	No, you said three and a half. The Swiss jumped two and a half	Artz Armour-Thomas *exploring* (monitoring) Veldhuis-Diermanse Hurme, Palonen & Jarvela *Metacognitive Skills, monitoring*
Presenting a strategy or approach	A pupil will provide a strategy which could be used to solve the problem.	“well, what you could do…. Get a ruler, check if they’re the same.”	Artz Armour-Thomas *planning* Veldhuis-Diermanse Hurme, Palonen & Jarvela *Metacognitive knowledge, strategy variable*

Refocussing attention	A pupil will draw others back, or give instructions as to what they are supposed to be doing	“yes but that’s not the problem is it?”	Artz and Armour-Thomas *exploring* (monitoring) Hurme, Palonen & Jarvela *Metacognitive Skills, monitoring*
Evaluating	A pupil gives an evaluation of their progress with an explanation.		Goos, Galbraith and Renshaw, 2002 *Assessing*
Clarifying or understanding	Pupils answer the teacher or question the teacher about the problem in order to aid their understanding (this is more of a questioning but shows their understanding through it)	“Do you, is it like, do you have to draw a line in the middle of the ruler to em figure out what side to do the halves and quarters on?”	Artz & Armour-Thomas *analyzing* Goos, Galbraith & Renshaw *New Idea or Assessment*
Disagreement with explanation	A pupil is able to critique another’s suggestion and provide a reason for it		Goos, Galbraith & Renshaw *Assessment*

Teacher Talk – Individual Groups

Cognitive

Code	Description	Example	Reference
Content directed questioning	The teacher or a pupil asks a question directly related to the content of the problem	“so how did you work that out?”	Anderson et al (direct instruction) Veldhuis-Diermanse
Non-content directed questioning	A pupil asks a question relevant to completing the task but not directed to the content of the task	“can we write on this?”	**Might just come under a general rules/guidelines clarification**
Step or solution without explanation	A pupil provides a step towards the solution or a possible solution without explaining why it is relevant	“we’d have to do all the millimetres and all the right lengths of the ruler”	Veldhuis-Diermanse and Artz & Armour-Thomas *Exploring (cognitive)*
Focussing discussion	The teacher focuses attention on a specific aspect of the problem	“Repeat back to me what you think I said to you. What have I asked you to do?”	Anderson et al (direct instruction)

Evaluating	Pupils evaluate their performance without explanation	"we did quite good"	I am using this because there is a difference between metacognitive evaluation and reflection and a quick one word answer!
Agreement without explanation	A pupil agrees with a previous suggestion but doesn't explain why		Veldhuis-Diermanse
Disagrees without explanation	A pupil disagrees with a previous suggestion but doesn't explain why	"nah, nah, nah, nah, nah. No"	Veldhuis-Diermanse
Reading	Pupil reads the problem from the sheet provided	"the Canadian jumped twice as long as the American"	Artz Armour-Thomas *Reading*
Instruction relevant to solution	Pupil gives another an instruction to do something which is directly linked to solving the problem	'Now we've got to discuss'	Artz & Armour-Thomas *implementing* AND Veldhuis-Diermanse
Instruction not relevant to solution	Pupil gives another an instruction to do something which is not directly linked to solving the problem	'talk'	

Metacognitive

Code	Description	Example	Reference
Clarifying or understanding	Pupils answer the teacher or question the teacher about the problem in order to aid their understanding (this is more of a questioning but shows their understanding through it)	"Do you, is it like, do you have to draw a line in the middle of the ruler to em figure out what side to do the halves and quarters on?"	Artz & Armour-Thomas *analyzing* Goos, Galbraith & Renshaw *New Idea or Assessment*
Presenting a strategy or approach	A pupil will provide a strategy which could be used to solve the problem.	(what would be easier?) "That (pointing to the ruler) because we don't have to draw."	Artz Armour-Thomas *planning* Veldhuis-Diermanse
Disagreement with explanation	A pupil is able to critique another's suggestion and provide a reason for it		Goos, Galbraith & Renshaw *Assessment*
Evaluating	A pupil gives an evaluation of their progress with an explanation.		Goos, Galbraith and Renshaw, 2002 *Assessing*

Monitoring Instructions or plans	It will be clear that a pupil is monitoring what is being said or done in relation to the solution of the problem or instructions they have received	No, you said three and a half. The Swiss jumped two and a half	Artz Armour-Thomas *exploring* (monitoring) Veldhuis-Diermanse Hurme, Palonen & Jarvela *Metacognitive Skills, monitoring*
Refocussing attention	A pupil will draw others back, or give instructions as to what they are supposed to be doing	“yes but that’s not the problem is it?”	Artz and Armour-Thomas *exploring* (monitoring) Hurme, Palonen & Jarvela *Metacognitive Skills, monitoring*

Teaching

Code	Description	Example	Reference

Facilitating discourse	Teacher draws pupils into a discussion	"what do you think the problem's about?"	Anderson et al *facilitating discourse*
Giving instructions	Teacher gives specific instructions regarding the task	"uh uh (taking ruler away) those aren't your tools"	Anderson et al *instructional design*
Encouraging or Reinforcing student contributions	Teacher gives positive feedback to a contribution by a pupil	"Brilliant""	Anderson et al *facilitating discourse*
Seeking clarification or understanding	Teacher asks pupils if they all agree or understand	"So there was a specific order that you had to follow? And did you all agree?"	Anderson et al *facilitating discourse*
Instructions not related	Teacher gives instructions not directly related to the task	"you'll need to speak up because they can't hear you on.."	

Affective

Code	Description	Example	Reference
On task	Pupils display emotional reactions about the task or their involvement in it	"I would hate to draw rulers like them"	Veldhuis-Diermanse
Off task	Pupils display emotional reactions not relating to the task	"They crayons reek!"	Veldhuis-Diermanse

Social

This relies heavily on my interpretation of positive and negative in view of what I know of the pupils

Code	Description	Example	Reference
Negative about other group members	Pupils interact in a negative way towards one another	"I'll scream in your ear again when we go out to break"	These codes are general headings which are derived from the data.
Negative to other people/things	Pupils talk negatively about other things or people outwith the group	(Do you like her?) "No. She's a show off"	
Positive/neutral about other group members	Pupils interact in a positive or neutral way towards one another	"So if you draw that you'll get a tan?"	
Positive / neutral to other people/things	Pupils talk positively or in a neutral way about other things or people outwith the group	Do you know Donald in the other class? He sent Ben a picture from facebook and I was round at Ben's house.	

Unclassified

Code	Description	Example	Reference
Indistinguishable talk	Talk which can’t be made out because it is cross talk or because of unclear speech by an individual		
Silly noises or singing			
Nonsensical utterances	When an utterance cannot be classified as making sense on its own.	“two, twelve, right wait right”	

Appendix B Problems

Week One – Length

There were two sections to the problem solving task. Firstly, to remind students about halves and quarters, they were asked to create a ruler. The teacher gave the following instructions:

I want you in your groups of four to use two colours of crayon. You are going to use one colour of crayon to put halves on a ruler and the other to put in quarters on the ruler.

In the second section, the students were provided with a scenario for which they had to find the correct solution. The scenario was based at the winter Olympics and the event was the ski jump. Measurements were in centimetres as those were what the students had been using in class:

The American skier jumped 2 cms. The Canadian jumped twice as long as the American. The Brit jumped 3 times as long as the American. The Australian jumped one and a half times as long as the American, the Swiss jumped two and a half times as long as the American.

1. Can you find out how far each of the skiers jumped?
2. Who won gold, silver and bronze medals?

Week Two – Area

The groups were given a scenario concerning the area of rectangular fish pond:

Ian had made a new fish pond in his garden but he needed some rope to go round the outside. He phoned his friend Elliot and asked him to bring some rope. Ian told Elliot that the fish pond was rectangular and it was $36m^2$. Elliot arrived with four pieces of rope to go round the pond. Two pieces were 9 metres long and two pieces were four metres long. However, these did not fit the pond.

Why did these pieces not fit the pond? What other lengths of rope might fit?

Week Three – Sequencing

Hedgehogs and Rabbits
This problem required the students to apply rules in order to change the sequencing of objects. They also had to discover that *recording* the sequencing moves would aid them in their final solution.

Two hedgehogs and two rabbits were sitting on chairs in the following order:

Hedgehog	Hedgehog	BLANK	Rabbit	Rabbit

The task was to move the hedgehogs and rabbits so that they were sitting in the following order:

Rabbit	Rabbit	BLANK	Hedgehog	Hedgehog

Rules:

Hedgehogs can move one space at a time but only to the right.
Hedgehogs can jump over rabbits.
Rabbits can move the same way as hedgehogs but to the left.

What is the least number of moves in which the sequence can be changed?
What were these moves?