'Don't think in your head, think aloud': ICT and exploratory talk in the primary school mathematics classroom

‘DON’T THINK IN YOUR HEAD, THINK ALOUD’: ICT AND EXPLORATORY TALK IN THE PRIMARY SCHOOL MATHEMATICS CLASSROOM

Frank Monaghan, Centre for Language and Communications, The Open University

This paper arises out of research into classroom activities conducted with Year 5 and Year 6 primary school students (9-10 year-olds). The study applied the ‘Thinking Together’ approach developed by Mercer and colleagues at the Open University in mathematics lessons involving the use of ICT. The study describes the use of mathematics software to promote collaborative thinking and exploratory talk in the mathematics classroom. Teachers were given training in the Thinking Together approach. They then conducted a series of lessons with students and explicitly taught them how to work and talk collaboratively to solve mathematical problems at the computer. These lessons were video-recorded and the transcripts analysed for evidence of ‘exploratory talk’. This paper reports on the role of the teacher, the students and the computer in developing exploratory talk.

DISCUSSION IN MATHEMATICS CLASSROOMS

The 1980s saw a shift away from a view of mathematics as a teacher-directed activity where students learned algorithmic routines that they then practised in isolation from one another towards a more investigative, problem-solving approach. This shift grew out of work by theorists such as Polya (1954; 1973) and Lakatos (1976), which emphasised the role of conjecture in mathematical proof. This work was a reaction to strictly formalist approaches that suggested that mathematics emerged perfectly formed from its ancient axioms without any of the messiness found in, say, the science laboratory. Lakatos and Polya both sought to understand the process of mathematical thinking and considered it in its social and historical context. Lakatos (1976), for example, argued that:

> … mathematics does not grow through a monotonous increase of the number of indubitably established theorems but through the incessant improvement of guesses by speculation and criticisms, by the logic of proofs and refutations (p. 5).

Such thinking subsequently influenced key documents on the teaching of mathematics in schools such as *An agenda for action* (NCTM, 1980) in the United States and *The Cockcroft Report* (HMSO, 1982) in the United Kingdom. These ideas have continued to remain integral to subsequent policy statements (e.g. DES, 1991; DfEE, 2000). In all these documents, the role of discussion in developing students’ mathematical abilities is seen as central, as Cockroft (1982), for example, discussed:

> By the term ‘discussion’ we mean more than the short questions and answers which arise during exposition by the teacher. … The ability to ‘say what you mean and

> mean what you say' should be one of the outcomes of good mathematics teaching. This ability develops as a result of opportunities to talk about mathematics, to explain and discuss results which have been obtained, and to test hypotheses. … Pupils need the explicit help, which can only be given by extended discussion, to establish these relationships, even pupils whose mathematical attainment is high do not easily do this for themselves (paragraph 246).

The need for explicit teaching of how to discuss is taken up by (mathematics) educators such as Lyle (1993), Sfard (2001) and Lampert (1990), who argues for a 'culture of disagreement' in the classroom and Krummheuer (1995, p. 247), who similarly describes an 'ethnography of argumentation' in which the aim is 'to convince oneself as well as other participants of the property of one's own reasoning and to win over the other participants of this special kind of 'rational enterprise'. Gordon Calvert (2001, p. 17) discusses this move away from school mathematics being conceived as a solitary practice to one in which it becomes a group activity in which the focus is less on finding the 'right' answer than on providing an agreed explanation and justification for a particular strategy and solution and where the 'responsibility for determining correct or acceptable answers shifts from teachers and textbooks to the classroom members as a community of learners.'

The first key issue that emerges from the literature in this context are the potential benefits for individual learners that can accrue from participating in effective group work, not only in terms of gaining insights from the contributions of others but also through having an opportunity to externalise and make explicit their own thinking to their partners and, crucially, to themselves. The second issue is the role of teachers in mediating a 'culture of disagreement' that leads to successful collaborative talk. In this paper, these two issues will be addressed in the context of a model for such practice known as the *Thinking Together* approach.

THE THINKING TOGETHER APPROACH

Thinking Together is a project that began in the mid 1990s at the Open University growing out of research in applied linguistics and taking a sociocultural perspective (e.g. Vygotsky, 1978, 1986; Rogoff, 1990). Vygotsky (1986) showed that children need to rehearse language in different contexts and that through collaboration with and feedback from their peers and others they will learn to modify their ideas and refine their expression of them. The research is thus founded on 'a sociocultural conception and analysis of education, which focuses on the ways that children can be induced into the communicative and intellectual activities of the classroom as a community of enquiry' (Rojas-Drummond and Mercer, 2003, p. 99). Its fundamental premise is that the ability to communicate effectively is a key skill that children need to develop in every aspect of their lives and one that lies at the heart of educational success. Central to the *Thinking Together* approach is the belief that such discourse skills can and should be explicitly taught. A goal arising from this belief is to enable teachers and children to conceptualise talk as, in Neil Mercer's phrase, 'interthinking', which he defines as 'our use of language for thinking together, for collectively making sense of experience and solving problems' (Mercer, 2000, p. 1)

Vygotsky (1978) conceives of language as both a psychological and a cultural tool used for developing shared knowledge within a community and for structuring the process and content of thought within an individual mind. He proposes that engagement in *intermental* activity (social interaction) fosters the development of *intramental* (individual) cognitive abilities. The *Thinking Together* project has sought to investigate and apply these insights in classroom settings and has led to a number of research studies (Mercer, 1994; Mercer, Wegerif and Dawes, 1999; Wegerif, Rojas-Drummond and Mercer, 1999) and books aimed at teachers (Mercer, 1995, 2000; Littleton and Light, 1999; Dawes, Mercer and Wegerif, 2003; Wegerif and Dawes, 2004). This work has influenced educational policy and practice in the UK, having been incorporated into the teacher guidance and training materials for the *National Literacy Strategy* and the *National Strategy for Teaching and Learning in the Foundation Subjects* (QCA, 2001; DfES, 2002, 2003).

The research and classroom experience of the *Thinking Together* team and the teachers involved in its various projects has shown that the key identifying conditions and features of effective talk are that:

- everyone is encouraged to contribute
- everyone listens actively
- ideas and opinions are treated with respect
- information is shared
- challenges are welcomed; reasons are required
- contributions build on what has gone before
- alternatives are discussed before decisions are taken
- groups work towards agreement before an action is taken
- it is possible for participants to change their mind
- discussion is understood to be a way of learning

Not all discussion displays these features, however. This observation has led to the identification of three types of talk commonly found in the classroom when students are engaged in group work (Wegerif and Mercer, 1997).

Disputational talk

Disputational talk is characterised by assertions, disagreement and short exchanges between participants in which there is little evidence of any explicit reasoning. Typical of this sort of talk will be the proliferation of utterances such as, 'That's wrong, it goes there, stupid', 'It's number 2, it's number 2', 'You're wrong, I'm right, end of story'.

Cumulative talk

Cumulative talk is characterised by self-repetition and elaboration leading to uncritical agreement, again with little evidence of shared meanings being created. Such talk is usually calm and unaggressive. It often arises when groups are organised on the basis of friendship. Typical utterances would be, ‘Okay, well I suppose we might as well…’ or ‘That’s fine, whatever, so long as you put in what I said as well…’

Exploratory talk

As defined by Wegerif and Mercer (1997), exploratory talk occurs when:

> Partners engage critically but constructively with each other’s ideas. Statements and suggestions are offered for joint consideration. These may be challenged and counter-challenged, but challenges are justified and alternative hypotheses are offered. Compared with the other two types, in exploratory talk knowledge is made more publicly accountable and reasoning is more visible in the talk (p. 54).

Typical utterances will be, ‘What do you think?’, ‘Why do you think that?, ‘I think x because…’, ‘Is there another way of looking at it?’.

Exploratory talk is the most likely to result in the features of effective talk described earlier. Students are, however, rarely explicitly taught how to engage in this kind of talk. A more typical pattern is one in which teachers ask a question, the students respond and the teacher gives evaluative feedback. This form of ‘triadic dialogue’ (Sinclair and Coulthard, 1975; Lemke, 1990; Wells, 1999, p. 498) has been described by Wells (1999, p. 145) as one of ‘the chief impediments to truly dialogic interchange in the classroom’. A fascinating and honest account of how this pattern can occur is given by McVittie (2004). She reports her experience as a researcher working in a classroom with two eight-year olds when she found herself setting up triadic dialogue patterns:

> I posed a question, one of the students answered, and then I probed from the answer, giving the impression that the answer was yet incomplete. I did this because I was looking for a specific answer, a strategy I have heard called ‘Guess what is in the teacher’s head’ (p 498).

In order to promote the development of exploratory talk, a series of lessons have been devised with teachers as part of the approach in order to provide a framework for both them and their students. Studies (e.g. Mercer et al., 1999; Wegerif et al., 1999 and Rojas-Drummond and Mercer, 2003) have repeatedly demonstrated that exploratory talk can be successfully developed in primary school children, that this training improves students’ capacity to reason and solve problems both individually and in groups, and that this training also has positive impacts on knowledge and abilities in a range of curriculum areas.

Whilst the *Thinking Together* approach was initially applied in literacy and PSHE settings in Key Stage 2, it has now been applied across the age range and in a number of curriculum areas, including mathematics. As Wegerif and Dawes (2004) point out:

> Maths is not only a way of thinking inside an individual mind; it is also a kind of language. That is, maths can offer a form of social communication between people. To become fluent in that language, as with any language, children need guidance and opportunities to practice (p. 102).

This principle has guided the work of the project team in a number of ways. In collaboration with the SMILE Centre (a mathematics education publisher that produces a range of mathematics software used in schools), the aim was to develop pedagogical approaches that develop pupils' skills in talking and thinking in the mathematics classroom. This aim has led to the publication of a set of guidelines, lesson plans and a professional development pack for use with a variety of SMILE software activities at Key Stage 2 (Sams, Wegerif, Dawes and Mercer, 2004).

THE STUDY

The study reported in this paper was conducted in six primary school classes across four schools, two located in London and two in Milton Keynes[1]. Two of the teachers in the Milton Keynes schools had previous experience of working on a *Thinking Together* project, the others were all new to the approach. The study involved the use of computer software programs developed by SMILE Mathematics with which the teachers were not previously familiar.

We held two training sessions for the teachers to introduce them to the SMILE software and the *Thinking Together* approach and then developed a series of lesson plans in collaboration with the teachers aimed at introducing their students to the approach and leading in to the mathematics lessons in which it would be applied. This consisted of three lessons of *circa* 60 minutes duration, each including activities aimed at developing the skills needed to work and learn together effectively using ICT.

Twelve lessons were video-recorded including a sequence of three lessons entitled 'Introduction to *Thinking Together* around ICT in mathematics lessons, described below. We also recorded children working with the SMILE programs *Co-ordinates , 3 in a Line*, *Lines* and *Rhino* and *Tenners*. The work reported here was based on sessions in which *3 in a Line* and *Lines* were used. These programs are a computer version of the popular strategy game *Connect 4* and requires the students to play as a team against the computer.

In the current climate, teachers needed some persuading to take time out of their Year 6 mathematics lessons in order to 'talk about talk'. The fact that they were willing to do so (sometimes in the face of concern from their head teachers about preparation for the next set of national tests) spoke volumes about their commitment to the project.

Lesson one: talking about talk

The objective for this lesson, which is shared with the students, is to raise awareness of talk: ‘We are learning to talk about talk.’ In this lesson students discuss such questions as:

- Who thinks they are a talkative person?
- Who thinks they are a quiet person?
- Who do you like talking to? Why?
- When are you asked not to talk? Why?
- Why is it really helpful to be able to talk?
- What sort of things can we do by talking together?

The students work in groups of 3 and are given a set of picture cards showing people engaged in various types of talk activities. They are asked for their ideas about what sort of communication is taking place and to describe the talk. They feed this back to the whole class. They then practise talking and listening to each other in pairs about a topic of their choice and again feedback to the whole class. In groups, they discuss a set of words related to talk such as, *decide, remember, persuade*, *interrupt*, *discuss, listen, share*, *argue, reason*, etc. The lesson ends with a plenary discussion on what makes a good talker and listener and how these skills might be useful. They are then asked to consider these points and the word list in the context of working at the computer. The lesson ends with a discussion of whether they think they have met the lesson objective.

Lesson two: agreeing the ground rules for talk

The objective for this lesson is to establish a set of ‘ground rules’ for talk: ‘We are learning to agree a set of ground rules for talking to each other.’ The lesson begins with an introduction to the idea of ‘ground rules’ as basic rules everyone can agree to. There is a discussion of other kinds of rules, such as those used in a board game, and of what would happen if the rules were ignored or arbitrarily changed. At this point, the students consider what sort of rules might apply for talk in the classroom. They then work in groups of three and are given a set of cards with possible rules on them and have to decide whether they are good, bad or uncertain. They are asked to decide on the four they think are most important and then to devise a further two of their own. The outcomes are shared with the class and they agree on their set of ground rules. They are then asked to discuss in their groups a final rule that would be particularly important when working at the computer. Again, one rule is agreed from the whole class. The session ends with an evaluation of the lesson in terms of the objective. Here, as an example, is a set of ground rules produced by a class in one of the previous studies:

Class 5D Rules for Talk

- Everyone should have a chance to talk
- Everyone's ideas should be listened to
- Each member of the group should be asked
    - What do you think?
    - Why do you think that?
- Look at and listen to the person talking
- After discussion, the group should agree on a group idea

It is interesting to note how well these rules accord with the features of effective talk identified previously. The rules developed in each class in this study were all similar to this example.

Lesson three: practising the ground rules

The objectives for this lesson are to use the ground rules for talk on mathematical problems designed to address statements from the National Numeracy Strategy (NNS); to use known number facts to add/subtract a pair of numbers mentally (NNS 47); to add several numbers mentally (NNS 43); and to solve mathematical problems or puzzles (NNS 79).

The lesson begins with a whole class session in which the children are asked to recall the ground rules for talk they have established. The lesson objectives are shared with the students with an emphasis placed on applying the ground rules for talk in a mathematical context. The students are then introduced to or revise the idea of 'magic squares' – typically a 3x3 grid containing the digits 1-9 which students have to arrange in such a way that all rows, columns and diagonals have the same sum. We used a simple Word table to demonstrate this idea and the students then worked in groups of three on the task of completing the magic grid. The teacher's role was to monitor and intervene in their activity, always keeping the focus on using the ground rules for talk. The plenary required the students to report back on how they had solved the problems and how they had organised their group work. They were also asked to comment on how well they had used the ground rules.

Subsequent lessons followed a similar pattern, starting with a review of the ground rules; an introduction to the objectives (which always included a 'talk' objective) and the activities; group work around the computer; and a plenary to discuss the outcomes. In these lessons, students worked on SMILE programs from their 'Co-ordinates' suite (e.g. *3 in a Line* and *Rhino*) and from their 'Numeracy' suite (e.g. *Tenners*). These activities were chosen for their mathematical appropriacy and because, being strategy games, they made reasoned discussion essential and also allowed the students to play against the computer rather than each other, an aspect of the programme that will be discussed in further detail later.

OUTCOMES

Previous studies (e.g. Fernandez, Wegerif, Mercer and Rojas-Drummond, 2002) have established the benefits of the *Thinking Together* approach on a variety of measures (including the *Raven's Progressive Matrices*, a test of non-verbal reasoning, taken as pre- and post-tests) and on our own measures of change in language use by the children. In one study (Mercer, Wegerif and Dawes, 1999) students were recorded doing one of the Raven's non-verbal tests prior to the *Thinking Together* lessons and again afterwards. The following table emerged indicating significant changes in the use of key words associated with collaborative thinking:

Key word	Pre	Post
Because	25	100
Agree	7	87
I think	7	87
Would	1	15
Could	2	14

This demonstrates how the children's use of such markers of exploratory talk as logical connectives and use of conditional verb forms increased significantly as a result of the intervention. In this project, however, we were more interested in examining the kinds of effective interactions and strategies that were developed by the teachers and students. To this end, we filmed three lessons each of six classes of 8-10 year-old students, including initial lessons on developing the ground rules for talk and work on the mathematical activities around the computer. Our initial analysis of the transcripts of the lessons revealed some interesting insights into the role of the teacher in scaffolding effective collaborative talk, how a community of practice (Lave and Wenger, 1991) was developed, and into the students' conceptualisations of the computer as a partner in their activity. These insights are discussed below.

The role of the teacher

Teachers provide a key role in modelling appropriate language and behaviour to the students. In the following extract, which, incidentally, demonstrates an effective use of triadic discourse, the teacher both models and rehearses the sort of language and conduct that is expected:

Extract 1

1	Teacher	Anything else I might hear?
2	Students	I disagree because.
3	Teacher	'I disagree with you because,' good, well done. Esme?
4	Student 1	Have we got any more ideas to share?
5	Teacher	'Have we got any more ideas?' Maybe they're not the

	only moves we can do. Maybe there are different ideas?
Student 2	Don’t think in your head, think aloud.

The teacher here requires the students to make explicit the kind of language that will be needed and models its use herself by reflecting aloud on alternatives (lines 5-6), focussing on the need to explore and ‘share’ alternatives. Her own use of positive reinforcement to Esme (line 3) also serves as a model to the students of the social relations that she is seeking to inculcate in the children.

Another crucial role for the teacher is that of monitor. Moving around the classroom, the teacher is able to observe points at which an intervention would help, e.g. to check the students’ understanding and probe for shifts in thinking, as in this extract:

Extract 2

Teacher	Can I ask you a question? Did you place your counter in the middle?
J,T&C	Yes.
Teacher	Brian was the only one of you three who said you should … Have you changed your idea about that?
J	Yes.
Teacher	Why?
J	Because then you can anywhere. You can go there, there and there…
Teacher	What do you think Claire?
C	If you do it (4,4) you’ve got more chance. You can do it anyway. You can block the computer too.

The teacher here is not only checking their mathematical strategies and ability to justify their reasoning, she is also making explicit the advantages of thinking together. By bringing her students to acknowledge that Brian had been right to pose an initially unpopular alternative, she creates space for the ‘outsider’ to be included and makes being able to change one’s mind a sign of strength rather than weakness when persuaded of the advantages of a different strategy. Her question to Claire (line 9) also models the desirability of including all participants and allows Claire to externalise her understanding to the group.

In addition to this sort of direct intervention, teachers have also found other ways to support the *Thinking Together* approach by providing students with cue-cards on post-it notes stuck to the computers so that the children can refer to the ground-rules during the lesson. This strategy has the positive effect of providing an *aide-memoire* for students during the activity which has also helped students with challenging behaviour by giving them a structure to work within as they develop a new ‘self’ as an effective member of the mathematics discourse community.

Shaping a reflective community of practice

A further important feature of the approach is the use of the plenary to consider explicitly what has taken place during the lesson and how it reflects the aims for the session. The plenary allows the teacher to foreground the talk targets and to review how successfully they have featured in the day's work. The teacher is able to celebrate the good practice that has occurred, enable students to hear from their peers the sorts of behaviours that constitute the targeted discourse, and assess what more needs to be done. This is useful in shaping the community of practice in that it allows the students to come together and reflect jointly on what they have been doing and what they have learned from it, not just in terms of the mathematics but how the mathematics is explored through language and social behaviour. The following extract is taken from the end of a lesson. The teacher has gathered the students in a circle on the mat:

Extract 3

Teacher	Do you want to sit yourself down, A? S, we're just waiting for you to come and join us on the carpet. Now I had four secret spies amongst you. S, who was kind of my monitor. Can you explain to people what you were doing this afternoon G?
G	We were going round visiting the people and seeing what we heard.
Teacher	Right. So I had four people who were going round and they are going to help me judge whether or not we gave good explanations because they have been gathering evidence all through this afternoon's session. They have been looking for all these phrases to see if we are using them and from the looks of their sheets I think I'm going to have a really big smile on my face the same as everybody else. Can you explain what you found out? What sorts of things are we seeing? Those people who have been monitoring?
H	'That would be good because.'
Teacher	'That would be good because'. That's one we didn't even come up with here but which some people were using really effectively to give reasons and back people up. Thank you very much. A, what did you find out? What was the most popular way of giving an explanation?
A	'Because'.
Teacher	Simply 'because'. Okay. How many times did you hear that this afternoon?
A	Eight times.
Teacher	Eight different times in just the groups that you were

29 listening to.

The teacher here has apparently handed over a level of control to the students by having them monitor each other's performance and gather evidence of how it conforms to expectations of their role as collaborative thinkers and mathematicians. The message is that the language they use is an important constituent of this community of practice. The teacher locates this use of language not just in its function as a medium of thought but also in its interpersonal, affective functions in sustaining solidarity within the group, as seen in her evaluation of one of the phrases used by the children to: '…give reasons and *back people up*' (lines 19-22, my emphasis). Her use of monitors to gather examples of exploratory talk (lines 8-15) might also serve to remind the children of the need to monitor their own use of such language.

Students were also involved in reviewing the use of the ground rules so that they become conscious and reflective about their own practices. In the following extract taken from the very end of a lesson, the teacher has reviewed their mathematical strategies and the class have discussed what did and did not work. The teacher continues with a discussion of how effectively the students have used the ground rules:

Extract 4

T Let's finish off. Let's go back to our rules. We're looking to apply our ground rules for talk. I'm going to be very interested to look at [the] footage to see how well we've done there, but what's your assessment? Let's see the thumb vote. Compare it to this time last week when we tried somewhat unsuccessfully to apply those ground rules. Think of that last session. Think of how you interacted with your partners. Yes, [thumb up] I applied the rules as well. Okay [thumb horizontal], but definitely room for improvement. Let's have a thumb vote. Okay, [addressing one pair] you're not happy with the ground rules but your partner is. That's interesting. Maybe we need to clarify that. We've got a lot of thumbs up, the majority. Okay, thank you. I'd generally agree. I think we're getting better at the ground rules. There was a lot of conversation there, there was a lot of people listening to each other's ideas and also giving reasons for those ideas.

This sends out a very different and far more engaging message about how the teacher sees their students' role in becoming members of this particular community of practice than one finds in Auden's: 'Minus times minus is plus, the reason for this we need not discuss' or von Neumann's icy put-down to an inexperienced journalist: 'One does not understand mathematics, young man, one just gets used to it' (cited in Sfard, 2001). The students are expected to reflect not only on the day's performance but also to see it as part of a continuous process of conscious learning and adaptation.

The students and the computer

Although computers (like teachers) prompt, respond and frame the dialogues with the students, their infinite patience, non-judgmental (inter)face and absence of expectations of the students enables discussion to become a powerful space in which students can talk and think their way to a solution of the problem they face. Another advantage is that by setting the students to ‘play’ against the computer, their group work has a clear focus and provides the group with an external opponent rather than producing additional personal tensions within the group itself. We discovered some interesting insights into the students’ view of the computer. For example, students tend to personify the computer as male, as in this extract:

Extract 5

B	I think five four because he’ll try making another diagonal and we’ll go there and he’ll try again and we’ll go there.
C	Yeah, but I think we should do two-six because then we’re stopping him and we can get on with our lines.
J	No, but then we’re thinking of stopping him instead.

They consistently refer to the computer using masculine pronouns (‘he’ and ‘him’, lines 1, 2, and 5) attach notions of human persistence to it (‘he’ll try again’, line 2).

Similarly, in another exchange, a student commented, ‘He’ll probably go there and we’ll have to go either side to block him. He does remind me of my computer. A lot.’ (this pattern will be seen again in extract 8). Not even the teacher is immune from such personification:

Extract 6

Teacher	We can’t win, he’s going to go there and then we’re stuck, aren’t we? Because then he can go either side of us. Assuming the computer is a He. I think it might be a She.
Student	I think three-three, because then he’ll try getting it to four-Four and we can still block him.
Teacher	Hang on a minute. If we go to three-three he can go there.

The teacher is initially following the student’s use of masculine pronouns and then immediately checks herself in lines 2-3 to suggest that the computer might be female. It’s interesting to note that she does not seek to de-humanise the machine by using the neutral pronoun ‘it’ and in line 6, apparently caught up again in the immediacy of the developing strategy, reverts to referring to it as male.

Outsmarting the computer

The following transcript is taken from a group of students, still relatively inexperienced in using the ground rules, working on a program called ‘Lines’, which involves using co-ordinates to place counters on a grid and attempting to win by getting four counters in a line:

Extract 7

B	I knew he'd do that.
J	I agree with (3,3) because then you can go there.
B	Exactly. He'll go there.
C	Doesn't really matter.
J	But then we can block him. (3,6) I agree with (3,6).
B	I agree definitely with (3,6).
C	I agree because then you're blocking him all the way down there and then he'll have to start something new.
B	Exactly. And then we can go on with our line. Exactly. I agree.

There are a number of interesting features to note here. First, the opening statement, 'I knew he'd do that', positions the computer as a cunning adversary. In another exchange, for example, two girls share a rather philosophical exchange:

Extract 8

M	It's mean he keeps winning. isn't it?
C	Yeah but it's doing its job isn't it?

The pattern of positioning the computer as an adversary occurs over and over again in the data, perhaps the result of students' familiarity with adventure games. A second interesting feature is that J, who is learning English as an additional language, seems to use 'agree' to mean 'suggest'. His partners don't correct him on this but use the word correctly, providing him with a model of how it should be used. Thirdly, J and C show very few signs of 'inter-thinking' but C's final utterance, in which she sums up the advantages of the (3,6) move, leads to B acknowledging the rationale. Their use of the pronouns 'you' and 'we' emphasise both the individual contributions their partners are making and their collective identity as a team. At this point they are beginning to feel their way into a new discourse community, marked by their evidently 'novice' use of the language forms they have been newly introduced to as constituting 'expert' use. This use of new and different language patterns allows them to construct a new 'self' through dialogue with others (Barnes and Todd, 1995; Wegerif and Mercer, 1997; McVittie, 2004). Later in the same transcript, however, there is a good example of the ground rules in action, inter-thinking and a creative use of terminology taken from chess:

Extract 9

J	Wait there.
B	We've checkmated him. Then go there (2,2).
J	I agree with (2,2).

C	Why?
B	Because we checkmated him.
J	Because we’ll checkmate him and then he’ll have no chance of winning.
C	Oh yeah, yeah, yeah, yeah. Now I’m getting it. Yeah, (2,2).
J	Then we’ll obviously win.
C	No, not obviously.

‘Checkmate’ is used here to mean block and this linguistic creativity to describe strategies is a common feature in the transcripts. Other examples include ‘the two-way trick’, which was coined by one of the students to describe the placing of a counter in such a way as to leave a winning line open at two ends, thus ensuring victory. J has now used ‘agree’ correctly (line 3) and both he and B give reasons for their suggested move. In lines 8 and 10, C indicates that, whilst she now understands their reasoning, she does not necessarily agree with their conclusions. This extract, then is a good example of *exploratory talk* (as opposed to *cumulative talk*) as it shows that the prime focus is on the development of the reasoning, rather on the maintenance of social relations. Lines 4-8 are, perhaps, also a good instantiation of Lampert’s (1990) ‘culture of disagreement’ in that C is evidently confident about challenging B and J’s strategy just as they are about being able to justify their reasoning. C’s somewhat sceptical comment in line 10 might also suggest that Lakatos’s (1976) claim that mathematics grows through ‘incessant improvement of guesses by speculation and criticisms’ would also find favour with C.

In the following exchange between two boys (one of whom, ‘R’, is learning English as an additional language), it is possible to see how a student is forced to shift their position:

Extract 10

A	So we move this one to here.
R	Yeah. Move that one to there.
A	Wait. Why do you think that?
R	Because the feeling’s right. The computer hasn’t gone nowhere yet so we can move there and there. All you can do is move them there and there so we might as well move that one.
A	So you’re saying if we can move that one there we can move that one as well.
R	No. I saying if we move that there and move that there, first move that, then move this here.
A	But what if the computer moves that?
R	We’ve still got a chance. This one can move, that one can…
A	I agree now. I get what you’re saying.

R shifts from a position where he initially appears to be relying solely on an unarticulated, instinctive response (‘the feeling’s right’ line 2) to one where, in the face of persistent requests from A for clarification, (‘So you’re saying..’ line 5, ‘But what if…’ line 9) he is able to explain his reasoning and convince A to follow it. A’s challenge in lines 7-8 as to the motivation behind the suggested move leads R to make his thinking visible to A and possibly also to himself. This then allows A to rehearse alternative scenarios (line 11) which R responds to (line 12), demonstrating that he has thought through his strategy and its possible outcomes.

Discussion

The purpose of this research was to explore the applicability of the *Thinking Together* approach to the primary mathematics classroom. The analysis of the data reported in this paper provides evidence to support our hypothesis that the explicit teaching, agreement and practice of ground rules for talk would lead to effective group work in the primary mathematics classroom. The extracts have provided evidence about the contribution that the *Thinking Together* approach can make to students’ abilities to articulate their mathematical thinking (extracts 9 and 10) to make it visible to both their partners and themselves. It has also shown how, through the explicit teaching and agreement of ‘ground rules’ for talk, teachers can provide a solid basis for effective group work (extract 1, 2 and 3) and support the development of reflective practice in their students (extract 4).

Unexpected findings also emerged on the students’ conception of the computer as a *quasi* human agent This point can be used to support the students in developing solidarity within their group as they seek to outsmart ‘him’ (extracts 5-8). This conceptualisation of the computer as a third thing (neither human nor entirely un-human) allows the students to avoid the interpersonal tensions that frequently thwart effective group work in classrooms by allowing them to posit the computer as the ‘enemy’ rather than each other.

Further research is needed to flesh out these themes further and to investigate the advantages of the *Thinking Together* approach in the development of collaborative learning in mathematics classrooms, particularly in the creative use of computer technology. Whilst the linguistic development of students learning English as an additional language was not a focus of this research, some evidence has emerged from the data (extracts 7 and 9) that this approach may also have advantages for them by exposing them to models of collaborative talk and thinking in a socially supportive and linguistically scaffolded context.

Given the above findings we are confident that future research in this area will bear out the following observation from Wegerif and Dawes (2004, p. 102):

> Children working in groups can offer one another chances to explore their conceptions, to employ their new vocabulary, and an audience for

> explanation, planning, suggestion and decision-making. In this way children learn to speak the language of maths. Challenges and explanations in groups, guided by teachers, can lead children to learn more expert ways of talking …. [The] combination of talk and computers is a powerful way of helping children to develop their thinking.

Notes

1. This work forms part of an ongoing *Thinking Together* project on the development of collaborative thinking across a range of curriculum areas project funded by the Nuffield Foundation and follows on from the Language, Thinking and ICT in the Primary Curriculum project (EDU/00169/G).

Acknowledgements

I would like to thank Claire Sams, Rupert Wegerif, Jenny Houssart, Neil Mercer, Karen Littleton (OU), Jacqui Bowers, Mike Quigley, and Nathalie Manners (SMILE) for all their work on this project. Thanks also to the teachers and students in London and Milton Keynes who made it come alive and to Richard Barwell for his heroic editorial efforts in getting this paper to its final state. The failings I claim entirely as my own.

References

Barnes, D., Britton, J. and Torbe, M.: 1990 (4th edn.), *Language, the Learner and the School*, Portsmouth, NH., Boynton/Cook.

Barnes, D. and Todd, F.: 1995, *Communication and Learning Revisited: Making Meaning through Talk*, Portsmouth, NH., Boynton/Cook.

Cockroft, W. (1982) Mathematics Counts: Report of the Committee of Inquiry into the Teaching of Mathematics in Schools, London, HMSO.

Dawes, L., Mercer, N., and Wegerif, R.: 2003, *Thinking Together: A Programme of Activities for Developing Thinking Skills at KS2*, Birmingham, Questions Publishing Company.

DES (Department of Education and Science): 1991, *Mathematics in the National Curriculum*, London, HMSO.

DfEE (Department for Education and Employment): 2000, *The National Curriculum*, London, DfEE.

DfES (Department for Education and Skills): 2002, *Key Stage 3 National Strategies: Teaching and Learning in the Foundation Subjects. Unit 12: Thinking Together*, London, DfES.

DfES (Department for Education and Skills): 2003, *Speaking, Listening, Learning: Working with Children in KS1 and KS2*, London, DfES.

Fernandez, M., Wegerif, R., Mercer, N. and Rojas-Drummond, S.: 2002, 'Reconceptualising "scaffolding" and the zone of proximal development in the context of symmetrical collaborative learning', *Journal of Classroom Interaction*, 36(2), 40-54.

Gordon Calvert, L. M.: 2001, *Mathematical Conversations within the Practice of Mathematics*, New York, NY., Peter Lang.

Krummheuer, G.: 1995, 'The ethnography of argumentation', in Cobb, P. and Bauersfeld, H. (eds.), *The Emergence of Mathematical Meaning: Interaction in the classroom cultures*, Hillsdale, NJ., Lawrence Erlbaum Associates, pp. 229-269.

Lakatos, I.: 1976, *Proofs and Refutations: The Logic of Mathematical Discovery*, Cambridge, Cambridge University Press.

Lampert, M.: 1990, 'When the problem is not the question and the solution is not the answer: mathematical knowing and teaching', *American Educational Research Journal*, 27(1) 29-63.

Lave, J. and Wenger, E.: 1991, *Situated Learning: Legitimate Peripheral Participation*, Cambridge, Cambridge University Press.

Lemke, J.: 1990, *Talking Science: Language, Learning, and Values*, Norwood, NJ., Ablex.

Littleton, K. and Light, P.: 1999, *Learning with Computers: Analyzing Productive Interaction*, London, Routledge.

Lyle, S.: 1993, 'An investigation into ways in which children talk themselves into meaning', *Language and Education*, 7(3) 181-198.

McVittie, J.: 2004, 'Discourse communities, student selves and learning', *Language and Education*, 18(6) 488-503.

Mercer, N.: 1994, 'The quality of talk in children's joint activity at the computer', *Journal of Computer Assisted Learning*, 10, 24-32.

Mercer, N.: 1995, *The Guided Construction of Knowledge: Talk Amongst Teachers and Learners*, Clevedon, Multilingual Matters.

Mercer, N.: 2000: *Words and Minds: How We Use Language to Think Together*, London, Routledge.

Mercer, N., Wegerif, R. and Dawes, L.: 1999, 'Children's talk and development of reasoning in the classroom', *British Educational Research Journal*, 25(1) 95-111.

NCTM: 1980, *An Agenda for Action*, Virginia, NCTM

Polya, G.: 1954, *Mathematics and Plausible Reasoning: Induction and Analogy in Mathematics*, Princeton, NJ, Princeton University Press.

Polya, G.: 1973 (2nd edn.), *How to Solve It: A New Aspect of Mathematical Method*, Princeton, NJ., Princeton University Press.

QCA (Qualifications and Curriculum Authority) (2001): *Language at Work in Lessons: Literacy Across the Curriculum at Key Stage 3*, London, QCA.

Rogoff, B.: 1990, *Apprenticeship in Thinking: Cognitive Development in Social Context*, Oxford, Oxford University Press.

Rojas-Drummond, S. and Mercer, N.: 2003, 'Scaffolding the development of effective collaboration and learning', *International Journal of Educational Research*, 39(1-2) 99-111.

Sams, C., Wegerif, R., Dawes, L. and Mercer, N.: 2004, *Thinking Together with ICT & Primary Mathematics: A Continuing Professional Development Pack*, London, SMILE Mathematics.

Sfard, A.: 2001, 'Learning mathematics as developing a discourse', in Speiser, R., Maher, C., and Walter C. (eds.), *Proceedings of 21st Conference of PME-NA*, Columbus, OH., Clearing house for science, mathematics, and Environmental Education, pp. 23-44.

Sinclair, J. and Coulthard, M.: 1975, *Towards an Analysis of Discourse*, Oxford, Oxford University Press.

Vygotsky, L.S.: 1978, *Mind in Society: The Development of Higher Psychological Processes*, Cambridge, MA., Harvard University Press.

Vygotsky, L.S.: 1986, *Thought and Language*, Cambridge, MA., MIT Press.

Wegerif, R. and Mercer, N.: 1997, 'A dialogical framework for researching peer talk', in Wegerif, R. and Scrimshaw, P. (eds.), *Computers and Talk in the Primary Classroom*, Clevedon, Multilingual Maters, pp. 49-61.

Wegerif, R. and Dawes, L.: 2004, *Thinking and Learning with ICT: Raising Achievement in Primary Classrooms*, London, Routledge.

Wegerif, R., Rojas-Drummond, S., and Mercer, N.: 1999, 'Language for the social construction of knowledge: comparing classroom talk in Mexican preschools', *Language and Education*, 13(2) 133-150.

Wells, G.: 1999, 'Language as education: reconceptualizing education as dialogue', *Annual Review of Linguistics*, 19, 135-55.