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# Contingent scaffolding: analysis of teacher utterances and group success in collaborative mathematics tasks using multi-touch tables

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**Biography:** Andrew is a former primary school teacher whose research focuses on computer supported collaborative learning in a primary classroom. He also researches teacher education in low and middle income countries.

**Abstract:** This study explores teacher utterances during interactions with groups of participants (10-11 years old, n=96 from six schools in England) engaged in collaborative text-based mathematics tasks using multi-touch tables. Utterances were coded using a modified version of Engle and Conant's framework for fostering productive disciplinary engagement (2002). The results explore the association between the frequency and categories of utterance made by the teacher and subsequent degree of group success. Interactions with successful groups changed in focus from holding students accountable to disciplinary norms towards problematizing towards the solution. Evidence suggests that successful groups take note of the unvoiced proleptic connotations of teacher utterances intended to scaffold productive working practices. Less successful groups do this less effectively.

**Keywords** Collaboration \* Multi-touch computer \* Scaffolding \* Elementary School \* Mathematics \* CSCL

**Word count: 7855**

## Introduction

Contingent scaffolding, ad hoc interventions by teachers during learning activities based upon their on-the-spot assessment of the needs of one or more learner, in technology rich environments has been shown to have been effective in supporting communication and discussion (Major, *et al.*, 2018). However, of the many studies exploring scaffolding processes in the classroom the majority are descriptive studies. Few focus on the effectiveness of the strategy (Bakker, Smit and Wegerif, 2015). This study explores the impact on success of contingent scaffolding, in the form of teacher interactions, with groups of four learners each engaged in Mathematics tasks. The utterances made by the teacher were coded using an adapted form of the Engle and Conant (2002) framework for fostering productive disciplinary engagement.

The evidence presented in this study indicates teacher utterances made to groups which met with more success differed compared to those made to groups which met with less success. These utterances were unscripted and *proleptic* in nature - the teacher projects an unattained level of understanding onto the participants who enact the role of having achieved this level (Van Lier, 2004). Quantitative analysis indicated that utterances made to more successful groups in the First task focused on supporting groups in establishing successful collaborative working practices. In the final task utterances made to more successful groups focused on problematization in reasoning and task completion. To give a better understanding of the quality of interactions, two vignettes are offered which focus on interactions by the

same teacher during the same activity with two different groups. In the first the teacher makes a successful assessment of learner needs. They then initiate an appropriate contingent scaffolding strategy. In the second, the same teacher makes an inappropriate assessment of learner needs where the progress of the group in question was adversely affected by the subsequent contingent scaffolding strategy.

The metaphor of scaffolding learning was originally used to describe play-learning interactions between mothers and babies (Wood, Bruner and Ross, 1976). Quality of scaffolding being more important than quantity in driving success (Griffin and Cole, 1984). Teaching is a process of ‘assisted performance’ of activity within a socio-cultural context (Tharp and Gallimore, 1998). The features of contingent scaffolding strategies are embodied and socially situated dynamic processes (van Geert and van Steenbeek, 2005). These features have to be understood, like any skills or information acquired by learners evolves within the wider socio-cultural context in which it is encountered (Greeno and Engeström, 2014).

There are three principal features in a scaffolded process: contingency, fading and transfer of responsibility (Van der Pol, Volman and Beishuizen, 2010). To be *contingent*, scaffolded support requires an initial and accurate diagnosis of the learner’s needs by the teacher. Gradually that which could only be achieved with support through inter-mental activity is internalised as, ultimately, processes become automated (Tharp and Gallimore, 1998). As learner internalization progresses, the teacher *fades* the level of support available *transferring* responsibility to the learner for this aspect of their development. Thus, processes which once required inter-mental interactions between learner and teacher can be completed by the individual relying on their own intra-mental processes (O’Donnell & Hmelo-Silver, 2013). Three key activities have been identified which contribute to the internalization of knowledge and skills by the learner: appropriation, prolepsis and revoicing (Moschkovich, 2015). It is these key activities, particularly prolepsis, which this study will explore in relation to group success in collaborative Mathematics tasks.

#### *Strategies for contingent scaffolding: Appropriation, Prolepsis and Revoicing*

Learners appropriate new competencies or knowledge which were previously unavailable to them gradually. Through participation in activities supported by a teacher, learners can participate in cognitive processes which may be otherwise implicit and difficult to either explain or observe. During their participation, that which is appropriated by the learner is transformed into something of unique significance to them (Rogoff, 1990). They take what others have created and they are able to redeploy it in subsequent productive activity. In doing so the *appropriated* competency can either develop further meaning, a new application or becomes more nuanced (Moschkovich, 2004). This characterization of appropriation implies dialogic fluidity; meaning is negotiated by the participants depending on their previous experiences and the context in which the dialogue takes place (Bakker, Smit and Wegerif, 2015).

*Prolepsis* is the process by which the teacher projects mature psychological capacities onto learners who have not yet reached this stage of development (Bakhurst, 1991, p.67; van Lier, 2004). Proleptic interactions between teachers and learners presume a level of shared understanding which is the goal rather than the starting point. Frequently proleptic utterances take the form of questions. The teacher asks a question (to which they already know the answer) in such a manner that implies that the learner also knows the answer. Moschkovich (2015) gives the example of a teacher asking “Now, does that look like the right number?” when the task was to check computation matched expectation. The implication was that both

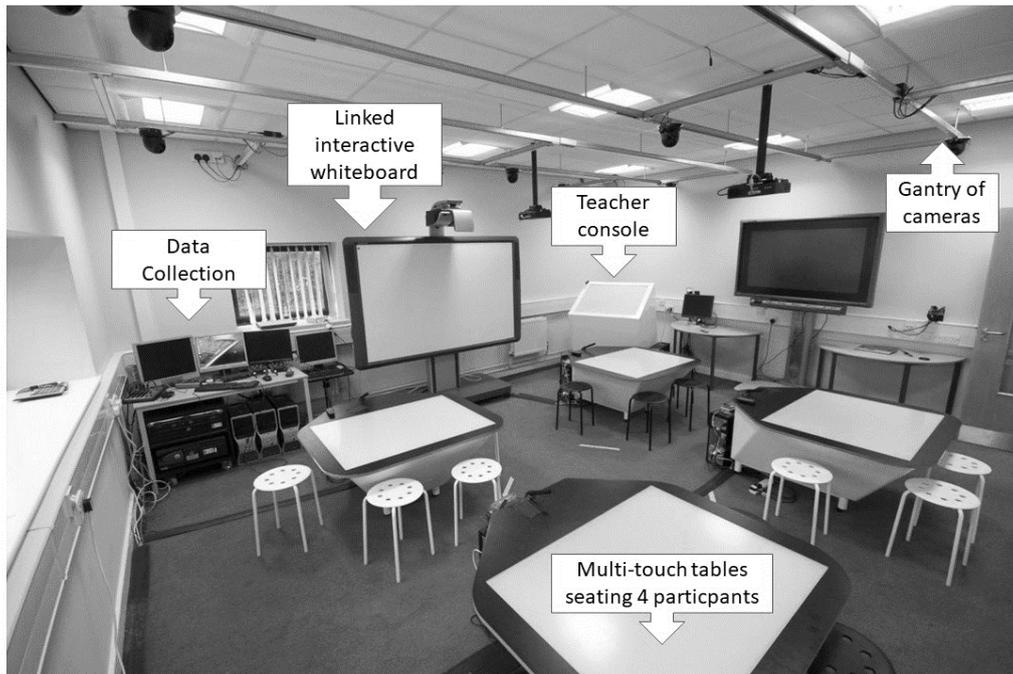
learner and teacher knew what the correct number should have been. The proleptic question predicted a process (checking the calculation) which the learner had not yet undertaken. Over time, the need to presume a particular capacity fades as the actual capacity itself develops (Reiser and Tabak, 2014).

Revoicing by an adult, typically a teacher, occurs when the student's contribution is rephrased or expanded upon. Revoicing in whole class discussion can support scaffolding of mathematical practices by allowing students to claim or disclaim ownership of the revoiced idea (O'Connor and Michaels, 1996). Revoicing combines elements of both appropriation and prolepsis. The teacher tries to structure learner's thinking by presenting their ideas back to them and thereby allowing them to access new uses for language. In doing so they invite them to participate in proleptic dialogue for which, initially, the learner's vocabulary may be inadequate to express the concepts which they are wishing to explore. Revoicing is a means by which the teacher can negotiate the tension between providing appropriate support without resorting to direct instruction, thus maximising the opportunities for participation from students at a range of ability levels (Moschkovich, 2015).

Putting the theory of collaborative learning into practice is not always successful (Webb, 2013). Scaffolding effective collaborative activity requires a great deal of skill and preparation by the teacher. Over the past two decades there has been an increasing interest in the role technology might play in scaffolding activities in the classroom (Reiser and Tabak, 2014). Some has been used effectively to scaffold both general and discipline specific argumentation activities (Baker and Andriessen, 2014). The challenge for developers of educational technology is to make available tools which are as learner centred and accessible as possible. SynergyNet uses large screen multi-touch tables to enable equal participation by groups of up to four learners. It also uses the affordances of multi-touch screens to present learners with novel and engaging tasks in a classroom environment. Yet it still requires teachers to scaffold learning in natural classroom environment through pedagogical monitoring and interaction.

### *SynergyNet*

Technological innovation, unsupported by appropriate pedagogical innovation can negatively impact learning and waste money (Kyriakou & Higgins, 2016; Smith & Higgins, 2006). Therefore, the SynergyNet project aimed to innovate technologically and pedagogically to deliver new tools and tasks which enabled teachers to effectively support collaborative learning through task design and contingent scaffolding as well as to facilitate increased engagement from participants. The design of the tasks and software was one of iterative design, as this evolved so did the research questions the team were able to explore. Later iterations of the lab-classroom using larger, flatter screens than previous studies in the project (see Figure 1), allowed the team to explore the nature of successful collaboration *and* collaboration for task success.



**Figure 1: The layout of the SynergyNet Lab Classroom**

Figure 1 shows the lay out of the SynergyNet lab-classroom, with four multi-touch tables, each able to seat 4 participants, a teacher orchestration console, an interactive whiteboard which was integrated with the participants' tables and an array of audio-visual data collection tools, including 10 ceiling mounted cameras.

Multi-touch tables are distinguished from other tablets primarily by their size and the number of touches they can support. Those designed by the SynergyNet project could support over 200 simultaneous touches which is far higher than many capacitive touch screens. They are also far larger and more durable than most screens used in primary schools.

The tasks used were adapted from paper-based equivalents which had been extensively used in classrooms (Leat & Nichols, 2000). These 'mystery' tasks were designed to overload any individual student with information and thus required groups to work together to share a large number of clues (Leat & Higgins, 2002). The clues for these mysteries were movable and resizable using the multi-touch screen. Figure 2 shows a screenshot of a group engaged in shared reading – with a clue enlarged and placed centrally.



RQ1: What relationship is there between the categories of utterances by teachers and the subsequent levels of success for groups?

RQ2: Is there a relationship between the categories of utterances made during teacher interaction with a group and the subsequent level of success that this group then achieved in a task?

RQ3: Is there a change over time between the categories of utterances made during teacher interaction with a group and the subsequent level of success that this group then achieved?

## 2. Method

### *Data Collection*

The SynergyNet lab classroom was equipped with multiple cameras and microphones. Cameras recorded teacher movement and interaction from multiple angles. Teacher speech was recorded using a clip-on microphone. Microphones mounted on the tables recorded speech from participants on that table. Cameras mounted on a gantry recorded interaction between members of each group from two angles. The cameras were mounted to reduce intrusion, reducing participant self-consciousness (Smith & Higgins, 2006; Stephen & Plowman, 2008).

Ninety-six students (aged between 10 and 11 years, even gender balance) from six schools in England (school names have been anonymized); all participants were considered by their schools to be working at an age-appropriate level in English and Mathematics. The schools varied in size and socio-economic circumstances. There were 16 participants from each school. Participants were seated in groups of four. Four schools had mixed-gender groups and two had single gender groups. Table 1 shows a summary of the conditions under which the study was run. The project received ethical approval from the university ethics committee. All data was anonymised. Informed consent for sought from the parents or carers of all participants. Informed assent was sought from all participants themselves using a range of age-appropriate forms and information materials.

<b>School</b>	<b>Room orientation</b>	<b>Gender organization</b>	<b>Teacher</b>
Benbrook	Centered	Single	David
Dunhulme	Traditional	Single	Michael
Easterburn	Traditional	Mixed	David
Seacrest	Traditional	Mixed	Michael
Shadbrook	Centered	Single	David
Yadstone	Centered	Single	Michael

Table 1: Study conditions

Two male members of the research team, both experienced former primary school teachers, facilitated the activities for the groups. The use of researchers as teachers ensured consistency in delivery of instructions and technical across all schools. The identities of both teachers have been anonymised.

The tasks required the students to sift information, decide relevance and use inductive reasoning to arrive at the correct answer (Leat & Nichols, 2000). The first task, required students to reason about the properties of number. Successful completion required learners to select and use six pieces of information (out of a total of twelve). The later task, focused on deductive reasoning to logically sequence a chain of events using six pieces of information.

The tasks were presented as a number of individual clues, projected on to the surface of the multi-touch tables. These clues could be manipulated by the participants' touch (with one touch the clue

could be moved around the screen, with two it could be resized or rotated). The number of clues (over 10 in both cases) was designed to cognitively overload any individual team. Rather groups would have to read and discuss clues employing a strategy of distributed cognition among group members (Mercier and Higgins, 2014).

### *Coding and Analysis*

The extent to which each group was successful in completing each task was coded from 1-3. Inter-coder reliability on a 10% sample of this coding was 86%. Table 2 shows the criteria for success coding (Joyce-Gibbons, 2016).

Table 2: Criteria for success

Value	Title	Description
1	Some progress	Two or more group members read clues. Little structure when sharing clues e.g. turn-taking. Calculations based on erroneous reasoning (such as taking numbers in clues out of context and using them in calculations). Only single step relevant calculations.
2	Good progress	Coherent attempts by two or more group members to read and use clues. Multi-step calculations and reasoning to try and solve the problem but final solution are not reached.
3	Successful	Two or more group members solve problem.

When analysing interactions with the teacher, the unit of analysis was the utterance. This was determined to be a word or series of words bounded by the start and end either by a pause of over one second or by a student's utterance or by the end of that phase of the activity for the class. Some utterances lasted for more than 60 seconds, some lasted less than a second. There were four categories of utterance based on adaptation of the principles of the Engle and Conant framework (2002): problematizing, giving authority, holding students accountable and relevant resources. These are defined and exemplified in Table 3.

Chi-square tests explored possible statistical association between the conditions of the study and the categories of utterances made by the teachers (Puntambekar, 2013). The quantitative analysis provided a rationale for subsequent qualitative exploration of groups who represented either typical and atypical features of the data. These were studied in greater detail and vignettes of both kinds are presented below (Barron, Pea and Engle, 2013).

Table 3: Categories of utterances in the Engle and Conant (2002) Framework

Category	Description	Exemplification
Problematizing	The teacher encourages students to challenge and evaluate the content, developing their understanding of the task. Questions focus group attention on aspects of content which have not been sufficiently considered.	Benbrook, Reasoning Task: <i>T2: You've got some statements about the different room numbers and you've got to work out which room the statue is hidden in. So can you give me an example of a clue that tells you something?</i> <i>r30: There are a hundred rooms in the Grand Hotel.</i> <i>T2: So you know there are 100 rooms so it'll be from 1 to 100.</i>
Giving Authority	Teachers affirm student agency to complete the task, by recognizing that they have already developed a certain level of knowledge and procedural expertise. This may be a very brief utterance indicating that the teacher wants them to speak. Questions are open and indicate the teacher does not have a preconceived answer in mind.	Benbrook, Reasoning: <i>T2: Okay, these two groups were really quick. Can you explain your thinking?</i> <i>b27: We broke it down like, we started with 100 then 50, then 25 then it said the multiple has to be...</i> <i>b28: is not even</i> <i>b27: is not even and it has to be in five and it says it's not 25 so the only answer it could be is</i> <i>b28: and it can't be three either</i> <i>T2: And what do you mean by it can't be three?</i> <i>b28: it can't contain the digit 3</i>
Hold Students Accountable	The teacher directs the the group towards completing the task, reminding students of their obligation to each other to work equitably to solve the task. Questions are closed or indicate that the teacher already has a predetermined answer to the questions in mind..	Benbrook, Reasoning task: <i>T2: [To whole class] Okay. We've got two tables. If you know, just keep quiet for the moment. Let's let the other two tables work it out.</i> <i>T2: [Goes to group still finishing] Are you somewhere near ready to...? Do you think you know what it is? Have you worked it out yet?</i>
Relevant Resources	The teacher gives guidance on how to use the multi-touch tables to complete the task.	Benbrook, Reasoning task: <i>g34: Oh man! It keeps moving every time I try to do it.</i> <i>T2: So, one finger first but remember like your spider, not with your hand flat, because if you try and do that it doesn't work very well.</i>

### 3. Results

*RQ1: Do statistically significant differences exist between the kinds of utterances used and the conditions under which the study was run?*

A chi-square test indicated a statistically significant association ( $p < .05$ ) between the categories of utterance and the task:  $\chi^2(3, n=222)=26.092, p < .01$ . Table 4 shows kinds of utterances the teachers made were different in the first task compared to the final task.

Table 4: Association between teacher utterances and the conditions of the study

Condition	Categories of utterance (First task)	Categories of utterance (Final task)
School	$\chi^2(15, n=88)=18.138, p=0.255$	$\chi^2(15, n=134)=24.080, p=.064$
Room orientation	$\chi^2(3, n=88)=8.26, p=.834$	$\chi^2(3, n=134)=11.933, p=.008$
Gender organization	$\chi^2(6, n=88)=3.394, p=.798$	$\chi^2(6, n=134)=6.372, p=.383$
Teacher	$\chi^2(3, n=88)=7.035, p=.071$	$\chi^2(3, n=134)=3.360, p=.339$

Except for the room orientation in the final task, the Chi-Square tests did not indicate any statistically significant associations at a  $p < .05$  level between the conditions under which the study was run and the kinds of utterances made by teachers in their interaction with participants. Teachers' chose how to interact differently in each task based non-contextual factors.

*RQ2: Is there a relationship between the categories of utterances made during teacher interaction with a group and the subsequent level of success that this group then achieved in a task?*

Chi-square tests indicated that the kinds of utterance made by teachers to groups that achieved a successful outcome in the first task was different from the kinds of utterances they made to groups that were successful in the final task. The same is true of groups which made good progress towards completion (see Table 5).

Table 5: Chi-square tests for association between level of group success and the categories of utterances used by the teacher in the both the First and the Final task.

Level of success	Result
Some progress	$\chi^2(df3, n=79)= 22.87, p=0.52$
Good progress	$\chi^2(df3, n=34)= 9.79, p=0.02$
Successful	$\chi^2(df3, n=109)= 21.30, p < 0.01$

These findings may relate to the result presented in RQ1 that a statistically significant association is present between the number of utterances in each category used by teachers in the first and final tasks. Given that an association exists between the kinds of utterances made by teachers during their interactions with groups successful in the first task and groups successful in the final task, the final question explores this association in greater detail, looking at the trajectory of group success and teacher utterances.

*RQ3: Is there a change over time between the categories of utterances made during teacher interaction with a group and the subsequent level of success that this group then achieved?*

To try and establish if teacher utterances made a difference to the success of a group over time, a new variable, *trajectory*, was created. There were four sub-categories in this variable:

i) groups successful in both tasks; ii) groups that did not complete the first task but completed the second task; iii) groups that completed the first task but did not complete the second task,

Decline (3)	Stay the same (3)	Improve (2)	Success (4)
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and; iv) groups that did not complete either task.

Table 6: Chi-square tests for association between categories of utterances made by the teacher and the success trajectory of groups

Trajectory	Number of groups	
Successful in both tasks	7	$\chi^2$ (df3, N=59)= 7.97, p=0.04
Improved between tasks	6	$\chi^2$ (df3, N=83)= 10.79, p=0.01
Declined between the tasks	7	$\chi^2$ (df3, N=59)= 2.44, p=0.49
Stayed the same in both tasks (but never successful)	4	$\chi^2$ (df3, N=21)= 6.23, p=0.22

Table 6 shows the number of groups in each category and the results of chi-square tests for statistical association between group *trajectory* and the categories of utterances the teacher used during interactions with those groups. The results indicate that for each group there was a clear statistically significant association at the  $p < .05$  level between the trajectory of each group and the categories of utterances which the teachers.

Teachers talked differently to groups depending on how successful they were as the activities progressed. Table 7 presents the frequencies of utterances used by the two teachers to groups in the four different trajectories.

Table 7: Frequency of categories of utterance by task and group success trajectory (number of groups)

		First task	Final task	First task	Final task	First task	Final task	First task	Final task	Total
David	Problematization	6	3	0	5	6	17	1	4	42
	Give students authority	4	4	2	4	4	1	5	2	26
	Hold students accountable	4	4	3	3	4	4	2	2	26
	Relevant resources	4	0	0	1	0	1	4	0	10
	Total	18	11	5	13	14	23	12	8	104
		Decline (4)		Stay the same (1)		Improve (4)		Success (3)		
		First task	Final task	First task	Final task	First task	Final task	First task	Final task	Total
Michael	Problematization	1	7	0	1	4	17	2	23	55
	Give students authority	4	1	1	1	5	5	1	3	21
	Hold students accountable	9	5	0	0	8	4	2	5	33
	Relevant resources	1	2	0	0	1	2	0	3	9
	Total	15	15	1	2	18	28	5	34	118

Teachers said less to groups which did not improve than they did either to those whose success declined or who were more successful. With groups who improved or who were consistently successful, teachers focused more on problematization in the final task compared to the first task.

To explore the relationship between the categories of utterances and the trajectories of groups in more detail, specific interactions between teachers and students will be presented. The first of these will show instances of teacher utterances focused on to collaborative working practices (holding students accountable). The second will present a teacher interaction with the same group in the final task where the focus is successful task completion (problematization). A third and final interaction will present a situation where a teacher makes an unproductive intervention which may prevent a group from fulfilling their potential on a particular task.

Scaffolding to develop of positive collaborative working practices  
The following two examples are groups from the same class, taught by *Michael*. Both groups improve the level of success they achieve between the first and the final task. The school was chosen because the groups experienced the greatest change in the number of utterances categorised as 'problematization' between the first and the final task. Table 8 shows the frequency of the different categories of utterances during teacher interactions with Seacrest groups during the two tasks.

Table 8: Frequency of each category of utterance by task for Seacrest

Task	Problematization	Give authority	Hold students accountable	Relevant resources	Total
First	1	3	10	1	15
Final	32	7	4	5	48

The first task requires students to find the location of a stolen statue in a hotel by reading clues about the room number in which it is hidden. The teacher observes that the group are engaged in an avoidance strategy, only moving the clues around the table rather than using them to reason towards solving the problem.

- Michael:* *How are we doing here? [Hold students accountable]*
- R63:* *Good, if we could get that smaller.*
- Michael:* *I'll do it. [Relevant resources]*
- R62:* *Oh, we kept them.*
- R62:* *Ohhhhhhhh.*
- R61:* *What's wrong? [directed at r64]*
- Michael:* *Right, are you guys all right here? There doesn't seem to be a lot of people talking about it. Do you know what the answer is yet? [Hold students accountable]*
- R64:* *No.*
- Michael:* *So, do you think maybe you're spending a bit too much time organising the clues and not enough time actually reading them out and thinking about it? [Hold students accountable]*
- R63:* *A bit.*
- Michael:* *Yes - I think, you know, you're going to have to think about how to make sure everyone can see it, but also, remember, you've got to work out what the answer is to this question. Which room is the statue hidden in. [Hold students accountable]*
- Michael:* *Okay?*
- R61:* *The bedroom?*
- Michael:* *Well yes, it's a bedroom, but which one? It's in a hotel. [Problematization]*
- R64:* *The room number the statue is in is not less than 25.*
- Michael:* *All right, so, that's helpful. [Give students authority]*

During the period of silent observation, Michael monitors the group, making a contingent assessment of their progress towards task completion and diagnosing how this can be supported. In this case they need support to achieve greater group focus and develop better working practices.

His questioning is proleptic in that the superficial meaning suggests that he is encouraging them as they engage intellectually with the task, yet the question exposes the gulf between his superficial expectations and the reality that they were not engaged with the task at all. The subtext to the question being to expose this gap between the aspirational narrative implied by the teacher's words and the reality of the group's lack of focus.

The response of the group is positive. They engage with unspoken meaning of the teacher's words (R65) and acknowledge that they need to focus (R63). Before the question ends they are engaging with the challenge in the task (R61 and R64). By giving the students authority to continue, the scaffolding is faded by the as they shift their attention away to other groups.

During the final task; the teacher once again interacts with this group after a period of observation:

- R63: *Yeah, but we're on about Mike, not Jack.*  
R62: *Oh.*  
R62: *YUCK, cried Ruby, making a face at the slice...ah, I can't read.*  
Michael: *So she can't have pizza - she doesn't like pepperoni pizza does she? [Problematization]*  
R63: *And he doesn't like cheese. Well...*  
Michael: *Is there anyone we know for sure... [Problematization]*  
R61: *And he...he's...*  
R61: *He's allergic to emmm yogurt.*  
Michael: *Right, what does Mike have? [Problematization]*  
Michael: *Mike can't have the yoghurt can he? Is there anyone who likes yoghurt? [Problematization]*  
Michael: *[Student puts hand up] No I mean here. [Problematization]*  
R63: *Tanya.*  
Michael: *So Tanya gets Mike's yoghurt so what does Tanya have? [Problematization]*  
R64: *Salad. Salad!*  
R63: *Salad.*  
Michael: *So is there anyone who might like a salad? [Problematization]*

Michael opens with a proleptic question to support a learner (R62) struggling to read the clue. He finishes reading the clue for them and immediately asks a question to focus the group on the clue. His subsequent utterances all focus on modelling the reasoning processes the group needed to complete the task. He revoices a student (R63) utterance, expanding on it and presenting an additional step in the reasoning process; which could itself be regarded as having a proleptic element, (O'Connor and Michaels, 1996). This time there is a non-verbal transfer of authority, Michael stepped back and fades the physical scaffolding of their presence though discrete observation before shifting their attention and moving on

The above group, school improved their level of success across both tasks. The teacher's utterances to the group in the first task focused around developing successful collaborative practices. By the third task they group were apparently engaged and focused on task completion, needing support from the teacher with reasoning using the clues. The contingent scaffolding strategies, prolepsis and revoicing, implicitly invited learners to adopt the reasoning modelled by the teacher.

While this is an example of an improving group whose interactions with the teacher positively supported their reasoning processes, not all teacher interactions with groups were as potentially positive in their outcome.

#### *Contingent scaffolding: teacher gets it wrong*

This group, from the same school and working with the same teacher, has a very different experience which highlights the difficulty for teachers of scaffolding collaborative group activity.

On this occasion, the teacher did not spend long monitoring the group prior to the interaction. He focused on holding the students accountable to the norms of classroom practice and each

other. Yet this was to misunderstand the needs of the group and how they were engaging with the task. Rather than effective contingent scaffolding, his interactions were a distraction:

- Y49: *It's not that one, it's not that one. The room number which Sydney has hidden the...*
- Y52: *There! The room number he has hidden it in is...is not less than 25.*
- Y49: *Not less than 25.*
- Y51: *It doesn't end with 3.*
- Michael: *Do you think it might be helpful if you had them so everyone could see them even though, you know, it's not the one that's being read, just thinking, because you might have to go back to some of the clues, you know. [Hold students accountable]*

The students in this group had their gaze physically focused on the task and in the 30 seconds prior to the interaction with the teacher; three of them had participated in a discussion of the clues. This suggests that the teacher's concern that not all the students could see the clues was misplaced. It also suggests that the group had established a joint attention on one clue rather than looking at clues individually prior to discussion.

In the final task the students are engaged with reading the tasks separately and then sharing them. This time the teacher appeared to pick up the utterance of pupil y50 and interpret it as part of an avoidance strategy (such as he had dealt with earlier in the Red group during the first task). He used humour to soften his intervention but he was clearly concerned that the group remain on task.

- Y51: *This one's mine.*
- Y52: *Hey, anybody want these chicken wings? Asked Grace. I don't like anything with meat in it.*
- Y49: *YUCK! Cried Ruby...*
- Y51: *Don't look at me, moaned Jack. I hate any food with cheese...with cheese in it, on it. At that, he pushed away his cheeseburger.*
- Y50: *Ey, the Table's not working.*
- Michael: *Right, see, now that's not going to be helpful, is it, if you - I bet you're the sort of person who hides jigsaw pieces just to put in at the last one. [Hold students accountable]*

After this the teacher pulls back and observes intermittently (casting their eyes about at the other groups but returning to Yellow group). After a 45 second silence he returns to the group, expressing concerns at the apparent lack of progress which they seem to be making. The unvoiced meaning of his question is that is a focus on procedural rather than solution focused talk:

- Y49: *Nah, we've read that one.*
- Y52: *They're going out of the screen!*
- Y49: *Put them where everyone can see them.*
- Y52: *Do you think this one'll be...?*
- Michael: *So what's happening here - why are we - you're not making much progress on this one what's the problem? I think you're spending a wee bit too much time just organising them here. [Hold students accountable]*

Y52: *Yeah.*  
Michael: *So, you see this - you need to be reading the questions, you need to be reading the clues and you need to be trying to work it out together, okay, because if we all just push these around it's not going to work, right? [Hold students accountable]*

The final interaction here is almost inevitable given the teacher's incorrect diagnosis of the needs of the group prior to the previous interaction. The proleptic implication underpinning this interaction was that whatever the students had been engaged in prior to that time was not the desired kind of talk. It was natural for them to then shift to a different focus for their talk, procedure (an indication that they had taken up misplaced instruction). The teacher makes two utterances, both hold students accountable to classroom norms. In presenting his concerns as a question the teacher is inviting the group to participate in a process to correct the behaviour they have engaged in (appropriation and prolepsis). One student appears to take this on board but without much enthusiasm (Y52).

## **Discussion**

Earlier SynergyNet research showed that student collaborative practices and reasoning were related to the resources used, be they paper-based or digital (Higgins *et al.* 2012). The multi-touch tables provided a platform for the group working with which the teachers chose to interact in contingent scaffolding processes. As such the multi-touch tables were not simply a tool for exploring mathematics problems, they were a tool for mediating dialogue (Warwick *et al.*, 2010).

The data presented answered RQ1 inconclusively. No statistically significant associations were shown to be present between the kinds of utterances spoken by the teacher and the school from which the participants came, the gender complexion of the groups or the tasks which they were undertaking. A positive statistically significant association was shown to be present between the room orientation and the kinds of utterances made by the teachers. This would perhaps blend with the finding of an earlier study that task success and on-task talk differed depending on the organisation of the room (Mercier, Higgins & Joyce-Gibbons, 2014). However, given the limitation of the study that the teachers both taught a different number of schools in each room orientation condition, it is not possible to declare an association present with any confidence.

Clear statistically significant associations were present between the kinds of utterances made by the teacher in their interactions and the subsequent level of success achieved by that group over time (RQ2). Again, chi-square analysis indicated that an association does exist between the trajectory of a group's success and the kinds of utterances teachers made to them (RQ3).

The flip-side was the agency of the listener - the ability of the participants to internalise the implications of proleptic utterances made during interactions with the teachers (Tharpe & Gallimore, 1998). The teacher was able to fade the scaffolding support they gave these groups, transferring responsibility to them for maintaining positive collaborative practices which then enabled them to shift the focus of their support to problematization of the task (Van der Pol, Volman and Beishuizen, 2010).

Exploration of the transcripts highlighted the transition the kinds of utterances made to groups whose level of success increased over time. The teachers interacting with these groups employed revoicing, appropriating and proleptic strategies in their contingent scaffolding

interactions with groups (Moschkovich, 2015). During periods of monitoring and evaluating collaborative working in the first task teachers made more utterances holding them accountable to disciplinary norms and to each other (Engle & Conant, 2002;). These utterances contained proleptic implications for the participants: implications which challenged them to develop more effective collaborative practices and provided suggestions on how to do this. By the final task teachers interacting with these groups did not feel the need to focus on working practices but rather used revoicing and appropriating strategies (also containing proleptic implications) to structure the reasoning process through utterances which problematized the clues and the discussion. These interactions were similar to those observed by Mercier (2016) when studying full time teachers working with groups of children from their own classes.

However, to say that improved task success is dependent solely on the uptake of the proleptic implications of teacher utterances is an over simplification. Teacher interactions could have a potentially disruptive effect on group working. The interactions of the Michael with the Seacrest Yellow group show that when a teacher makes an incorrect assessment of the needs of a group (in this case the group had already developed productive collaborative practices but the teacher, unaware of this, concluded that they needed additional scaffolded support to do so). The subsequent issue which the group had, identified by the teacher shortly after the first interaction was not a failure to uptake the proleptic implications of teacher utterances but rather the direct result of doing so.

#### *Limitations of the study*

The evidence in Table 7 suggests that the patterns of utterances changed to groups following different trajectories for both teachers: David and Michael. Here transcript evidence is only presented for Michael's interactions with one class. This decision was taken to illustrate the potentially erratic and widely varying impact of a single teacher's assessment and interactions during contingent scaffolding processes. David and Michael have been shown to have some differences in their approaches to evaluation and interactions at a whole class level (Joyce-Gibbons, 2016). Arguably, the study design which made each teacher deliver to a different number of groups in the two table conditions also may have impacted on the quality and kinds of interaction. However, this was not shown to be the case (Mercier, Higgins, Joyce-Gibbons; 2014). The frequencies of the utterances classified in different categories presented in Table 7 suggests that there was a broad similarity between the two teachers, particularly in relation to the kinds of utterance they made in the first task and the final task to those groups who improved their level of success between the two tasks.

A final weakness of the study was that it did not investigate a specific measure of uptake of teacher utterances by the group to explore in detail what impact teacher interactions may have had on the group's dialogue or behaviour. Scaffolding is a long-term process, layered, distributed and cumulative. Teachers layer multiple sources of evidence to form beliefs about the needs of children. Scaffolding is most effective when conducted as an iterative process where the cycle of diagnosis, design, implementation and evaluation are spread over multiple sessions. Learning through these sessions is cumulative and non-linear with scaffolding strategies deployed or faded as the teacher judges necessary over time (Van der Pol, Volman and Beishuizen, 2010). The lack of familiarity with the researchers who were acting as the 'teachers' on the part of the participants (and vice versa) may have impacted on the accuracy of assessment of learner needs (by the teachers) and on the uptake of the proleptic implications of utterances (by the participants).

## **Conclusion**

This study presents a detailed exploration of a limited number of teacher interactions with groups working on collaborative mathematics tasks using multi-touch tables. The findings of the study indicate that teacher utterances categorised using an adapted form of the Engle and Conant (2002) framework show a change in focus between interactions taking place in the first of a series of three tasks compared to those which took place in the final task. Teachers made utterances with an implied proleptic focus on developing successful collaborative practices to groups who were more successful in the first task (holding students accountable to disciplinary norms or to the norms of the classroom). Teachers tended to make utterances which were focused on reasoning towards successful completion of the task (problematization) to groups which were more successful in the final task.

To explore the impact of utterances teachers made on the collaboration and reasoning processes of groups and the level of success they achieved, future research should focus on: i) whether there was a relationship between contingent scaffolding interactions initiated by the teacher and changes in intellectual or organisational leadership roles in the group (Mercier, Higgins & Da Costa, 2014); and ii) Whether teacher initiated contingent scaffolding interactions led to a change in the representations of reasoning by groups on the multi-touch tables and how this related to the level of success achieved by the group experiencing these interactions (Mercier & Higgins, 2014).

## **Acknowledgements**

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