The Effects of Interaction Techniques on Talk Patterns in Collaborative Peer Learning around Interactive Tables

Izdihar Jamil[*], Kenton O'Hara[‡], Mark Perry[†*#], Abhijit Karnik[*] and Sriram Subramanian[*]

[*]Interaction & Graphics Group
Department of Computer Science
University of Bristol, UK
{jamil, karnik, sriram @cs.bris.ac.uk}

[‡]Microsoft Research
Cambridge, UK
{kenton@gwork.org}

[†]DISC, Brunel University, UK
{mark.perry@brunel.ac.uk}
[#]Mobile Life, Interactive Institute, Sweden

ABSTRACT

This paper presents the findings of a user study investigating conversational patterns across three conditions of table-based interaction (direct touch interactive table, pantograph interactive table and non-digital table) for different types of educational activities. Findings demonstrate that communication style is significantly affected by interaction techniques. The direct touch technique stimulated conversations based around the topic and pedagogical method. The pantograph technique promoted playfulness and had a higher number of directive utterances between participants, with fewer task-based, group-oriented utterances. The non-digital table promoted reflective forms of task-orientated utterance, encouraged group communication and fostered more equitable participation between members. The findings provide insights into the design of interactive tables to support particular forms of social interaction.

Author Keywords

Interaction techniques, tabletop, communication, collaborative learning and children.

ACM Classification Keywords

H5.3. Group and Organisation Interfaces.

General Terms: Human Factors

INTRODUCTION

With advances in interactive tabletop technology and increased levels of affordability in recent years, there has been a growing interest in exploring their use within educational contexts. Central to this interest are arguments relating to demonstrated benefits of peer collaboration in children's learning that have led to such activities to becoming an increasing aspect of children's educational experience [24]. The aim of such experiences is to allow children to jointly explore particular areas, discussing and exchanging ideas and perspective and thereby facilitating their understanding. Key to the success of these peer collaborations from a learning perspective is the extent to which children participate in the collaboration [18]. In particular it is the *extent* to which peers talk and the *nature* of this talk that comprises this participation that is argued to be key to successful learning [22]. For example, successful collaborative learning has been demonstrated to happen when accompanying talk of this equitable participation consists of greater explanations [23], clarifications [5, 12]; and more shared discussion of goals and plans [16].

Given these characteristics of successful peer collaboration in learning, interactive tabletops are argued to have a number of properties that lend themselves to supporting such collaboration in computer mediated learning environments for several reasons [10]. First, tabletops promote particular proxemic arrangement of groups around the shared learning material supporting face-to-face interaction. Second, tabletops provide opportunities for simultaneous input giving participants equal access to interact with the digital objects on the table. Third, there is the role of visibility in observing the action of others in tabletop settings promoting shared awareness for improved coordination and understanding. With these properties in mind, a number of studies in recent years have sought to explore their impact on the dynamics of collaboration [3, 8, 10-11, 15, 17]. These studies have demonstrated some evidence of more equitable participation with interactive tabletops and perhaps more importantly, the impact on task-based talk that accompanies these forms of collaboration.

What is striking from this research on tabletop interaction is that the findings from these studies are more nuanced than we might have initially expected given the high level arguments about tabletop properties for collaboration. That is, the nature of the interaction does not appear to be derived purely from the shareability of the tabletop's interface, but that the *form* of the shareable interface is important in structuring collaborative activity and its accompanying talk. For example, different input technologies (e.g. stylus, vs mouse vs touch) have been shown to impact on levels of awareness, coordination and the nature of talk during collaboration on tabletops [8, 11]. Similarly, different interaction techniques for tabletops afford different levels of reach and awareness and these have been found to impact on the nature of collaboration in tabletops in terms of conflict management, object transfer, reach and territoriality [15]. These differences are dependent upon task structures and the demands that they impose on collaborative activity and coordination.

CHI 2011, May 7–12, 2011, Vancouver, BC, Canada.

Building on these findings, and the arguments that particular types of talk within peer based collaborative learning are important [22], our concerns in this paper are with the impact of particular tabletop interaction techniques on the type of talk during collaborative learning. Surprisingly there is little in the way of empirical research that specifically examines the effects of the tabletop interaction techniques seen in Nacenta et al. [15], on patterns of conversation in collaborative learning scenarios. In a different study, Harris et al. look at single vs multi touch for this scenario but do not explore different interaction techniques within this context [10].

With this in mind, we present a study of 11-13 years old students performing two collaborative learning activities with different tabletop interaction techniques and compare the effects of these techniques on patterns of conversational utterances. In particular, we compare interactive tables using pantograph and direct touch techniques (as used in Nacenta et al. [15]) with an equivalent non-digital table where the objects are physical and moveable.

In exploring the effects of these interaction techniques on utterance patterns, we will be better able to understand their impact on collaborative peer learning. We begin by examining the related work in this area, highlighting key themes and issues informing our study in this paper.

RELATED WORK

There are a number of key studies that help build our understanding of how different interaction techniques impact on tabletop collaboration. Of particular importance here is the work of Nacenta et al. [15], in part because of their study of different tabletop interaction techniques, but also because of the high level framework they provide for thinking about the differences between them. Their work begins by articulating the importance of awareness in group communication and collaboration and how this is maintained by three key mechanisms: *territoriality*, namely how the space of the table surface is divided up into personal and shared regions for interaction (cf. Scott et al. [19]); *feedthrough*, namely the public visibility of artefacts as they are manipulated and interacted with, e.g. the role of object orientation in communication as discussed in Kruger et al. [13]; and consequential communications [21], the embodied actions produced by the hands, arms and bodies of group members as they collaborate. With these awareness mechanisms in mind, their framework then provides dimensions relating to these mechanisms along with which tabletop interaction techniques can be differentiated. Their study showed how various interaction techniques resulted in different levels of conflict, transfer patterns, reach patterns and performance measures. Such differences (due to the different interaction techniques) were explained with reference to the three dimensions of territoriality, feedthrough and consequential communications. The different levels of difficulty and group dynamics suggest that accompanying conversation would also change in response to these issues. For example, a more difficult interface might lead to less learning-related conversation. The pantograph and direct touch offer different levels of reach. The purpose of the pantograph technique is to minimise the need to physically reach into other people's personal space for far objects. Thus coordination is less necessary. When using the pantograph, users are more focused with the actions that occur within the proximity of their pantograph and pantograph area. This might reduce conversation related to passing objects or social organisation. Hence there is the possibility that the users: (1) become less connected with the activities that occur within the group and (2) tend to concentrate more on the object highlighted by their pantograph, causing them to reflect on the key words. The case that interface influences group dynamics still holds here.

Similar kinds of arguments can be found in the work of Ha et al. [8] and Hornecker et al. [11]. While this work compares input technologies (mouse, stylus, direct touch) as opposed to interaction techniques per se, the arguments for direct touch vs. indirect input techniques are informative for the comparisons of interaction techniques explored in our study. For example, Ha et al. argued that direct touch techniques, while offering good visibility of actions, can actually lead to physical collisions and interference that can impact on the territorial arrangements of collaboration [8]. Similar themes are discussed in the work of Hornecker et al. [11]. This work also presents evidence that the differences in awareness offered by mouse vs direct touch leads to differences in terms of conversational utterances such as different levels of verbal shadowing and different levels of supporting action with verbal requests when using direct touch vs mouse.

Another key piece of research that informs our concerns in this paper is that of Rogers et al. [17]. This work is significant in a number of ways, again because of its high level framing of the issues at hand as well as the specifics of the research findings. Of note here is their operationalisation of shareable interaction in terms of different entry points, ie., the multiple ways an interface invites, constrains and enables interaction to occur. Different tabletop configurations, such as size and positioning of the display, single touch vs multi touch, task structures and the presence of other input devices and tangible artefacts can shape the way that collaborators can control, organise and coordinate their activities.

Their study of collaboration compared shareable interface setups with increasing numbers of entry points - single point laptop based interaction vs a muti-touch table vs a combined multi touch table with tangible objects. The study highlights areas where the different conditions impact on the distribution of participation and what factors in these setups contribute to more equitable participation. Significantly for our purposes here, the work considered not just measures of system interaction, but also the impact of interface conditions on the nature and frequency of different types of verbal utterances.

Drawing on the themes and methods from the Rogers et al.

study, Harris et al. present a similar line of research to look specifically at the interactions of young children within collaborative learning contexts using interactive tabletops. Comparing single touch vs multi touch tables, they showed that task centric talk was higher when using multi-touch tables compared with single touch, where turn taking utterances were predominant [10, 17].

Taken together, these studies begin to suggest and help articulate why different tabletop conditions can impact on collaborative talk. To date, there has been no empirical work that looks specifically at the impact of different tabletop interaction techniques, such as direct touch and pantograph, on the nature of talk. In particular, given the significance of conversation style in collaborative peer learning discussed above (most notably by Teasley [22]; Nacenta et al. [15]; Rogers et al. [17]; Harris et al. [10]), there has been no exploration of the impact of different tabletop interaction techniques in this learning context.

The study presented here attempts to address this by measuring how direct touch and pantograph techniques and non-digital tabletop interactions affect the nature of communication during collaborative peer learning activity.

THE STUDY

Method

Participants

We recruited 28 pupils from local secondary schools (14 males and 14 females), aged between 11 and 13 years old. The participants were divided into seven groups of four pupils, which is typical of group-based classroom activities in the UK, suitable for four-sided tabletop conditions and fulfils the criteria for working in "small" groups [6]. The assignment to groups was performed in consultation with the teachers in order to create groups of compatible ability levels. All pupils within the groups were known to each other, being from the same class and familiar with working together in group learning activities.

Apparatus

The interactive table was based on a Frustrated Total Internal Reflection (FTIR) surface [9], with a screen size of 102cm x 101cm. User interaction with the table was captured under the table surface by a Point Grey Dragonfly2 infrared camera. The task applications were created using Adobe Flash and Action Script 3. The height of the interactive table was 76 cm from the floor, and the size of the projection and the interactive precinct on the surface was 72 x 48 cm.

Two different interaction techniques were used for the interactive table. First was the direct touch technique. This was a typical multi touch set up in which multiple users could simultaneously interact by directly touching the digital objects on the surface. The key actions they could perform with were moving, scaling and rotating objects on the surface, and drawing and erasing finger-drawn lines. To erase a line, the user simply touches the line making an eraser appear – touching the eraser then causes the line to disappear. If no interaction occurs after a few seconds of the eraser appearing, it disappears. To rotate or scale objects, users simple place two fingers on the item and size or rotate them accordingly.

Second was the pantograph interaction technique (cf. Nacenta et al. [15]) that allows users to magnify their small touch inputs from their immediate physical interaction space (see figure 1). The user can move his or her finger in the designated pantograph space to reach any objects around the surface without having to reach across the table.

The pantograph area is rectangular and is located in the middle of each side of the surface. Each pantograph is identified with a colour indicating its user. A line that is of the same colour as the pantograph is drawn from the cursor to the tip of the finger to give visual cues (location and movement of the pantograph) to the user. Based on the projection size of our table, a 7x magnification was considered to be the ideal condition.

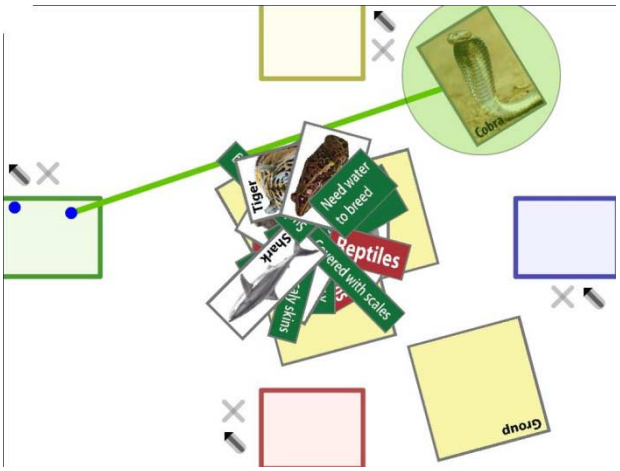

Figure 1. Pantograph interaction technique on a classification task (blue dots in the green pantograph area represent the touch points of the user's fingers)

The same set of key actions was available through this technique, namely moving, scaling and rotating objects and drawing and erasing finger-drawn lines. To draw a line, the user touches the draw button on the left of the pantograph area, then uses the pantograph tool to draw a line between two elements. To erase a line, students use the pantograph tool to hover over the line causing an eraser to appear. When the eraser is visible, the user moves the pantograph over the eraser to delete the line. The eraser will disappear after a few seconds of non-use. Rotation and scaling of objects can be performed by using two fingers in the pantograph area (as shown in Figure 1).

For the non-digital tabletop setup, a horizontal whiteboard with dimensions of 120cm x 90cm was used as the surface. Objects for the task were represented using printed paper cut-outs and were placed on top of the table. The layout of the objects was similar to the interactive table. Objects could be moved and rotated (though not scaled). Non-permanent

whiteboard markers were used to allow hand drawn lines to be drawn and erased using a whiteboard eraser to parallel the possibilities in the digital conditions. The use of such whiteboards for group activities is already prevalent in UK schools and therefore familiar to the pupils as a learning resource.

Activities

Two different types of collaborative learning activities were used. These were (1) spider diagrams and (2) classification tasks. A spider diagram is similar to a mind map, whereby a topic is investigated and explored by visualising associations and relationships between key concepts in the topic. These associations and relationships are created and represented through spatial layout and the drawing of lines between objects. In the task, an image of the key topic was placed in the middle of the table. Four elements were placed at each of the four sides of the table, oriented towards the participants on that side of the table. Five other elements were positioned around the table, scattered around the main topic image. These twenty-two elements included a combination of keywords and images to stimulate the conversation (see Figure 2).

Figure 2. Spider diagram task using a direct touch technique

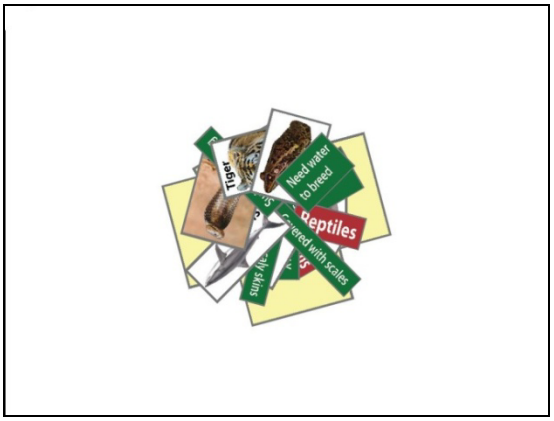

Figure 3. Classification task using a direct touch technique

Two spider diagram activities were designed for the experiment drawing on topics from the UK National Curriculum. The first spider diagram was designed around the topic of *Energy* and the second was designed around the topic of *Food Chains*. The design of these activities was done in conjunction with teachers and support staff from the participating schools to ensure familiarity and the appropriateness of the topics for the pupils. Although this form of group work requires some expertise, spider diagramming is a common learning method used in schools and was familiar to the participating students.

For the classification activities, the objective was to classify twenty elements (images and characteristics of a topic) according to their respective categories. Each category was represented by a square yellow box. The layout of the elements was scattered in a circle around the centre point of the surface, providing equal access to the elements for each participant (as seen in Figure 3).

Participants could use spatial positioning and hand drawn markings in order to visualise and organise their classification scheme. As with the spider diagram we used two different classification activities based around difference topics. The first classification activity was designed around the topic of Animals and the second one was designed around the topic of Genetic Variation. Again, experienced teachers and support staff from the schools were consulted in the development of the activities to ensure familiarity and age appropriateness for the participating pupils.

Experimental Design

The study was designed to explore the effect of two factors on utterance patterns.

The first factor was a table-based *interaction technique* with three different conditions:

(1) DT - interactive table using direct touch interaction
(2) PT - interactive table using pantograph interaction
(3) T - non-digital table

The second factor was an *activity type,* with two conditions:

(1) C – Classification task
(2) S – Spider Diagram task

A within subjects design was employed. Groups performed three different activities, one for each of the tabletop interaction technique conditions. Of these three activities, there would be at least one spider diagram and one classification. To give richness and avoid bias towards a particular activity, the third assignment would either be a spider or classification activity on a topic not already covered. The ordering in which these conditions were experienced was counter-balanced using the Latin Square method.

Procedure

Based on the Latin Square ordering, each group was assigned to an order in which to experience the three different tabletop conditions and two different activities. An experimenter explained the different tabletop and activities conditions before the study began. Time was allowed for the groups to familiarise themselves with the various conditions before beginning the assignment blocks. Participants were given 30

minutes to use and familiarise themselves with the interfaces prior to the task: 15 minutes to explore each interaction technique including 5 minutes to become acquainted with each task type. As mentioned, both tasks are common activities in UK classrooms. As a consequence, the students took very little time to be acquainted and were at ease with the tasks. Participants were told to take as much time a necessary to complete the activities and learning explorations. Video was used to record the physical and verbal behaviour of all the groups performing the activities. These recordings would be the basis of subsequent utterance coding and analysis. Once a group had completed their three activities, an experimenter conducted a debriefing interview with the group to explore their experience with the different activities and tabletop conditions to compliment the video based data.

Coding Scheme

Approximately two hours of video data was collected (average task completion time: (DT) 5.43 minutes, (PT) 6 minutes and (T) 5.43 minutes). Conversations from the video were transcribed and separated into natural units of speech: utterances [1]. Drawing on utterance categories from work in group communication and communication in peer based learning [2, 6, 8, 10, 13, 17, 20], we coded the utterances in the transcripts according to 8 different conversation categories:

(1) *Group identification (GI)* - utterances addressing the whole group or use of plural pronouns (we, us) that identify members as part of a group.
(2) *Interdependence (INT)* - utterances related to the need for teamwork and collaboration.
(3) *Directives (DIR)* - commands, requests as a means to get a listener to perform an action.
(4) *Social organisation (SO)* - utterances that involved planning, managing, organising and coordinating group activities.
(5) *Tasks (TSK)* - utterances related to the activities (classification or spider diagram) and topic (for example Energy and Animals) such as relationships between concepts.
(6) *Reflection (RFL)* - utterances related to broader discussion of the learning topic.
(7) *Interaction methods (IM)* - utterances related to methods of accessing and manipulating objects.
(8) *Playfulness (PLY)* - utterances that relate to playing and fooling around.

These categories are not mutually exclusive; the same utterance may appear in multiple categories. The aim of the different categories is to provide a handle on different types of utterances of relevance to communication in peer collaborative learning that relate to things such as group coordination, group cohesiveness, topic based discussions and off-topic based discussion. Two independent raters coded the transcripts. Inter-rater reliability was measured using Cohen's kappa coefficient (k=0.71).

This level of inter-rater reliability falls somewhere between Fleiss' [7] *good* (k>0.60) and *excellent* (k>0.75). Once the coding was complete, we then calculated the utterances per minute (upm) for each utterance category in the three tabletop interaction conditions and two task conditions.

The reason for measuring conversational patterns in terms of types of utterances was theoretically driven. In the Introduction we highlight arguments from the educational literature that successful outcomes in peer collaboration learning are dependent on the nature of conversation that takes place. This was thus the key motivating factor for focusing on amount of different utterance types. Measuring this in terms of "Utterances per minute" is a well-established approach from the existent literature [10, 17]. "Utterance per minute" allows us to examine the form of conversation taking place regardless of the time taken to complete the tasks. It therefore allowed us to compare utterance types between the different conditions in a way that a simple measure of total utterances would not, allowing us to compensate for variations in task completion times (similar use of UPM in comparable studies [10, 17]).

RESULTS AND DISCUSSION

The mean number of utterances per minute (upm) for the different conversation types under different levels of interaction technique can be seen in Table 1. To investigate whether there were any significant effects of interaction technique or task type, we first conducted a multivariate analysis of variance on all the utterance category upm measures. The results reveal a significant effect of tabletop interaction technique (i.e. T, DT and PT) using Wilks' Lamda ($F(16, 16) = 2.66$, $p=0.029$), Hotelling's trace ($F(16, 14) = 4.50$, $p=0.004$), and Roy's largest root ($F(8, 9) = 11.32$, $p=0.001$). We found no significant multivariate effect of task type for Wilks' Lamda, Hotelling's trace and Roy's largest root ($F(8, 8) = 0.93$, $p=0.54$) and no significant interaction between task and technique. It is possible that with more participations, there may be a significant effect of task on communication patterns. However, such study is beyond the scope of this paper.

	M			SD			TO		
	T	DT	PT	T	DT	PT	T	DT	PT
DIR	2.32	2.92	4.39	0.90	1.55	3.13	94	92	155
GI	2.29	1.81	2.18	1.52	0.68	1.74	108	72	78
INT	12.34	8.32	5.84	2.65	3.03	3.15	465	340	288
TSK	26.06	14.43	9.21	2.93	4.29	4.45	976	559	362
SO	4.97	6.71	9.48	1.48	3.55	5.74	184	208	250
IM	2.22	5.78	10.89	1.55	3.26	6.50	101	211	402
PLY	0.04	1.70	5.44	0.06	2.47	5.18	2	40	189
RFL	10.99	6.54	1.73	3.52	4.74	1.22	442	270	81

Table 1. Mean (M) utterances per minute, standard deviation (SD) and (TO) total utterances per minute with different interaction techniques. Highlighted categories indicate significant differences.

To explore the effects of interaction techniques further, univariate ANOVA was used to compare upm for all the different utterance categories. This revealed a significant effects of interaction technique for *Interdependence*

utterances ($F(2, 15) = 7.71$, $p < 0.05$), *Task* utterances ($F(2, 15) = 43.96$, $p < 0.05$), *Interaction method* utterances ($F(2, 15) = 6.39$, $p < 0.05$), *Playfulness* utterances ($F(2, 15) = 3.96$, $p < 0.05$), and *Reflection* utterances ($F(2, 15) = 10.17$, $p < 0.05$). There were no significant effects for *Directives*, *Group ID* and *Social Organisation* utterances.

For those utterance categories where there was a significant effect we conducted further pairwise comparisons (with Bonferroni adjustment for multiple comparisons) to establish where the differences between interaction techniques lay. We discuss these comparisons alongside qualitative data to facilitate the interpretation of these findings.

Interdependence

Pairwise comparisons showed that there were significantly more interdependence upm in the non-digital table condition ($M = 12.3$, $SD = 2.65$) compared with the pantograph condition ($M = 5.8$, $SD = 3.15$), $p = 0.004$. There were no significant differences between direct touch and pantograph ($p = 0.418$) or between direct touch and non-digital tables ($p > 0.05$). Interdependence relates to the language or words used by members to indicate the need for teamwork and collaboration. According to Engleberg and Wynn [6], the higher the number of interdependence utterances, the more requests for teamwork (invitations for team members to cooperate and collaborate together) are present. Both characteristics indicate a high level of group participation and communication between members; desirable behaviours in collaborative peer learning.

In the video analysis, we looked at utterances that were used to invite cooperation from other group members and any utterances that require feedback. As mentioned earlier, the key to the success of these peer collaborations from a learning perspective is the extent to which children participate in the collaboration [18]. In particular it is the *extent* to which peers talk and the *nature* of this talk that comprises this participation that is argued to be key to successful learning [22].

The conversation style for the groups working around the non-digital table showed more participatory talk patterns between members compared to the other two conditions. Each member was seen contributing towards the discussion at different points of the activities. Team members also valued each other's contribution by inviting each other to participate in the discussion and by using utterances that indicate group identification. The following example illustrates this, beginning with an utterance coded for interdependence (from G1):

```
P3: Where does oil come from?
P1: Oil?
P2: The sea!
P1: Are you sure?
P4: It doesn't come from the sea!
P2: Yeah, you can get it from the sea.
P1: Yes, you can!
```

Here, P3's question about oil by was addressed by all of the team members. In the non-digital table condition we saw that utterances coded for interdependence were often answered by one or more group members, indicating group participation and contribution towards the current discussion. The pantograph technique showed the lowest number of interdependence-coded utterances compared to the other two techniques. This suggests that the pantograph reduces the likelihood of teamwork because there are fewer utterances related to teamwork or collaboration. Also, in the pantograph condition, team members were more focused towards their own pantograph activities (such as moving, rotating, scaling and drawing) and in some instances, even appeared to ignore group discussions when they occurred (from G6):

```
P2: How do you make something bigger?
P3: Oh, a hawk!
P2: How do you make something bigger?
P4: Grass.
P1: You select it and then use your finger.
```

In the above example, P2 had to ask the same questions twice before he was answered by P1. On the other hand, P3 and P4 were focusing on the item on their pantograph and the manipulations that they could do on those objects. This appears to contradict the findings of Nacenta et al. [15] in which the pantograph technique seemed to support conflict resolution and coordination. However there is a difference in how the study conditions were setup. The participants in Nacenta et al.'s study were adults (average age of 24 compared to 12 in our case) and the nature of the task (a cooperative game with no planned learning outcomes) may have lent itself less to individually orientated action.

Task Utterances

For task utterances, pairwise comparisons showed that there were significantly more utterances per minute in the non-digital table condition ($M = 26.1$, $SD = 2.93$) compared with the direct touch ($M = 14.4$, $SD = 4.29$), $p < 0.0001$, and pantograph ($M = 9.2$, $SD = 4.45$), $p < 0.0001$. There were also significantly more utterances per minute of this type in the direct touch condition than when using the pantograph, ($p = 0.027$). The following example illustrates topic-based conversation (from G5):

```
P2: Your height...
P1: Height, (it is) inherited.
P2: No it's not!
P3: Sometimes, no it's inherited!
P2: It's environmental.
P1: No, your height is inherited.
P2: How is it?
P4: No it's not, some of it's not.
P1: Yeah it is, because when your dad's tall,
you're going to be tall.
```

Interaction Method

For interaction method, there were significantly more utterances per minute in the pantograph condition ($M = 10.9$, $SD = 6.5$), compared with the non-digital table ($M = 2.2$, $SD = 1.55$), $p = 0.009$. None of the other comparisons were significant.

In the pantograph technique, interaction method-based directives were issued in two conditions:

1) lack of confidence in using the technique (based on the feedback given by the participants) and,
2) when someone else has access to the object via their pantograph.

Interaction method-based communication was seen more on the pantograph technique compared to the other two techniques. Lack of confidence in using the technique caused participants to issue instructions to other members to manipulate the objects. A typical example of this occurred when one participant was not confident about how to draw line and she instructed her team members to do it for her. In another example, one of the team members (P4) had access to an object through her pantograph. P1 and P3 wanted to make the object smaller and instructed P4 to do so (in G5):

```
P1: Right, no make it smaller P4!
P3: P4, make it smaller!
```

The directives issued in both the direct touch and the non-digital tables were commonly related to interacting with objects. A typical example can be seen in G4:

```
P3: What's that? Pass me that!
P4: Just link this up to this one!
P1: Just put it here!
```

Participants found it difficult to reach distant objects and provided instructions or made commands to the other team members to perform some form of interaction method (move, pass, rotate, draw and line) to the objects.

Playfulness

There were significantly more utterances coded for playfulness in the pantograph condition ($M = 5.4$, $SD = 5.18$), compared with the non-digital table ($M = 0.04$, $SD = 0.06$), $p = 0.044$. No other comparisons were significant.

In our observations, we found that when some participants exhibited playfulness, they irritated other participants by interrupting the task and were asked to stop what they were doing by other members (example G2):

```
P1: P3, rub out all this drawing!
P2: P3, you've put all this stuff on my thing!
P3: I don't know what I was doing, I was just
showing how I feel.
P2: I think P4 is just doing random stuff now.
P1: Yeah, I know. P4 and P3 aren't concentrating.
P4: P3, you've drawn everywhere!
P3: Have I?
P4: Yes, look at it!
```

In the example above, P3 was being playful and used the pantograph technique to draw some images as a form of expressing his feelings. His team members were annoyed with his drawing as he was messing their workspace up and was not working together to complete the task. He was instructed to look at his drawings and subsequently erased them.

Playfulness is not observable in the non-digital table but occurred frequently when using the pantograph technique. From our observations, this could be due to the nature of the technique itself. First, the pantograph technique allowed users to reach distant objects without having to rely on any of the other participants. Second, the user was able to take other participants' objects using his or her pantograph tool even if the other user was currently controlling that object through their own pantograph tool. Third, as the technique was new to them, users occasionally showed off their skills to others as a form of playfulness. They appeared to see this technique as something fun and as a form of expressing their creativity (as seen in G7 below):

```
P1: Watch! You can get it and just shoot it over
there!
P1: Like toot, toot [makes some shooting noises
while using the pantograph]!
P1: And go far away [i.e. the object can move far
away using the technique]!
P1: That's amazing, that's quality!
P2: Get them here, look!
P1: Yeah, thank you very much!
P1: That was fun!
P2: Come on P3, you've got a lot!
P3: Yeah, because everyone dumped it on me!
P4: That's just a game.
P3: I don't really like it! I can't play anymore!
P3: Look, I hate it I can't move anything!
P3: All of you are touching it!
P1: Oh, don't give it all to her, that's not very
nice.
P3: Guys, stop chucking it at me!
P1: All right.
P3: Why is everyone passing it to me then?
P2: Well, you should stop your little whine!
P3: P1, I feel you ought to take mine away now.
P1: All right.
P3: So I'll just chuck it all over to you then!
P1: Blocks it, blocks it!
P3: (Why does) everyone want to dump it to me?
P1: Chuck it all!
P1: It's amazing, I love this!
```

Since the rest of the members in G7 above were more competent than P3 in using the technique, they used this advantage to show off their skills by creating a shooting game. In this game, they passed or shot some of the objects to P3's pantograph area making it difficult for P3 to use her tool. At various points of the task, P3 appears frustrated by the playfulness of her team members and issued a number of directives to protest about this. Towards the end of the sequence, when P3 became more familiar with the technique, she shot some of the objects toward P1's pantograph area to create another blocking game.

In a different example, the participants in G2 appeared to divide themselves into two sub-groups. One pair was more playful while the other was more task-orientated. There were times during the task where the task-orientated group presented utterances that expressed annoyance at the lack of commitment of the playful group towards the task. This caused further division within the group. This can be seen in an example from G2:

```
P3: I'm going to draw a tiger.
P1: What are you doing P3?
P2: Just ignore him!
P3: Look, I'm colouring!
P3: I like having fun.
P1: P3, rub out all this drawing!
P2: P3, you've put all this stuff on my thing!
P3: I don't know what I was doing, I was just showing how I feel.
P2: I think P4 is just doing random stuff now.
P1: Yeah, I know. P4 and P3 aren't concentrating.
P4: P3, you've drawn everywhere!
P3: Have I?
P4: Yes, look at it!
P3: Yeah, no one else knows how to draw, only the professional, see, I'm the professional!
P2: Are you doing to do this properly?
P4: Just shut up P3!
P2: You know what, I'd like you to shut up (P3)!
P3: Yes P2.
P4: I feel like P3 is just getting in the way now.
P2: So are you P4!
P1: Leave P3 and P4 alone! They're just having fun.
P3: Yeah.
P1: Why do you have to get so stressed about everything?
P2: P1, you're going to get into trouble so I don't know what you're on about.
P4: P1, join, join, join the drawing gang!
P3: Yes, you are wasting all your fun!
```

In the example above, P3 started the task by exploring the facilities offered by the pantograph technique. In doing so, he discovered how to move objects and draw. He drew some task-unrelated images on the surface that appeared to cause conflict and tension with the other members as he was interfering with their work. A number of directives were uttered towards P3 to stop him from doing this. P3's playfulness was joined by P4 and this was acknowledged by P1 and P2. Towards the end, P4 invited P2 to join the 'drawing gang' (i.e. P3 and P4) to have some fun together.

While the pantograph technique appeared to afford more playfulness within the groups (by the measure of upm), this was not seen to any great extent in the other interaction techniques. Through the pantograph technique, members were seen creating various games with each other as well as freely expressing themselves using the drawing tool. However, as can been seen in the qualitative data above, their playfulness frequently led to conflict and tension with the other participants who appeared to be more focused on the activities and topic on hand.

Reflection

There were a significantly higher number of reflective utterances per minute when using the non-digital table ($M = 11.0$, $SD = 3.52$), compared to when using the pantograph table ($M = 1.7$, $SD = 1.22$), $p = 0.001$. No significant differences were found between the direct touch ($M = 6.5$, $SD = 4.74$), and pantograph ($p = 0.093$) and between direct touch and non-digital table ($p > 0.05$).

Participants reflected on (i.e. discussed, expanded and explained) the topic in both the non-digital and direct touch conditions more than in the pantograph condition. The task-related conversation was also richer in content and there was more sharing of knowledge (from G1).

```
P3: Hydro is basically water.
P1: Yeah, waves and all that then.
P3: So that connects to wave.
P4: It's not just water!
P1: Which can be replaced!
P2: Yes!
P3: Because water is always flowing.
P4: You can't make water go!
P3: We can make water!
P1: We keep water because water from the mountain goes to the sea (and when) it gets to sea, it gets evaporated and it rains.
P1: So we're always going to have water, isn't it?
P4: Yeah, but we're not making it!
P1: So?
P3: We always have water on earth.
P1: Isn't it? It gets replaceable all the time.
P3: It gets replaceable by evaporation.
P3: Earth is like 75% of water.
```

In the example above, the team members discussed the sources of water, expanded the topic by talking about the process of evaporation and provided some factual information. Group communication was also seen in the conversation as team members used group identification and interdependence coded utterances. Group members were seen to encourage each other to contribute and participate in the conversation.

Participants working around the non-digital table also uttered more task-related utterances than the other two techniques. They reflected on the topic not only by expanding the discussion but also by relating it to similar topics. In the pantograph technique, lower numbers of task-related and reflective form of utterances were seen as the nature of the conversation was mostly based on playfulness, at the expense of other forms of utterance.

DISCUSSION AND IMPLICATIONS FOR DESIGN

Our analysis of the types of utterances that take place under different conditions of tabletop interaction points to a number of key differences in the nature of talk in the different conditions. Most notable here are the differences in talk between the pantograph and the non-digital table, and to a lesser extent some demonstrable differences between the direct touch tabletop and the pantograph technique. In particular, the use of the pantograph technique led to lower numbers of interdependence-coded utterances, less discussion of task-related aspects of the topic, and less general reflection on the topic outside the immediate task-dependent aspects of topic discussion relative to the non-digital tabletop condition.

In the pantograph condition, there was evidence of more off-task conversation relating to the interaction method and episodes of play. The pantograph technique also led to less discussion of task related aspects of the topic relative to the direct touch condition. By contrast, the direct touch condition was only found to be significantly different from the non-digital table in terms of its lower frequency of topic-based

aspects of topic discussion, with none of the other comparisons revealing significant differences. However, the direct touch technique was almost as good as the non-digital table for generating a reflective form of conversation. Participants reflected on the topic not only by expanding the discussion but also by relating it to similar knowledge and providing examples.

The differences highlighted in the study relate to the central concerns of the paper raised by Teasley [22] whereby it is not just about *participation* in peer collaborations, but the *nature* of talk comprising this participation that is key to successful learning. What we have seen in the study is how the choice of interaction technique, while offering some of the benefits outlined by previous research (e.g. Nacenta et al. [15]), may actually be detrimental to particular and important dimensions of collaborative talk that relate to learning. These concerns are documented below.

The first key concern here relates to aspects of group communication. While no significant differences were found in the level of group identification, the lower levels of interdependence found in the pantograph condition relative to the other two conditions suggests that teamwork is hindered by this interaction technique. With this technique, the ability to reach to all parts of the table means that there is less dependence on the support of other group members to get the task done. Indeed, in our qualitative analysis, we saw how members of the group became overly focused on their individual pantographs, often ignoring the talk and discussion of others as a consequence.

With the direct touch and the non-digital tables, where reach to all parts of the table is compromised, there is a more explicit need to rely on others to successfully complete the activities. This appears to encourage a high level of teamwork that is reflected in their levels of interdependence coded utterances. With regards to the pantograph and direct touch techniques used in our current study, the patterns of reach and territorial arrangement of group work was very different. The pantograph, with its increased reach capabilities, resulted in more homogenous use of the entire tabletop space, while direct touch created more highly localised interactions by users.

A second area of concern is the extent to which conversation is focussed on task and discussion of the topic areas as bounded by the activities. With both the pantograph and the direct touch interactive tables, the conversation consisted of a lower frequency of talk about the topic concepts, as defined by the activities, compared to when pupils were using a non-digital table. The pantograph, in particular, fared less favourably than both the other tabletop conditions. There are a number of explanations that can be put forward here, especially in light of data relating to other utterance types. Of note here is that the pantograph is more difficult to use and master compared to the direct touch technique and compared to the non-digital table.

This is reflected in the increased amount of talk relating to aspects of the interaction methods that we see in the pantograph condition. It is not clear from the data whether such difficulties are an inherent part of interacting with the pantograph technique or whether it is simply a more difficult technique to master. It is worth noting that in a study comparing interaction techniques for a Fitts' type target acquisition task it has been shown that pantograph is slower than direct touch techniques [14]. It may be that with further practice and exposure, pupils could improve their confidence and skills with this technique to the point where it disappears into the background allowing a better focus on task-relevant aspects of the learning topic.

Of significance here too is the increased frequency of play-related utterances in the pantograph condition. What we saw in the study was how the pantograph technique seemed to encourage more off-task playful behaviour and talk. This kind of playing, or 'messing about' reflected in these utterance levels appeared distracting and frustrating for other members in the group, drawing attention away from topic-related discussion in a way that is potentially detrimental to learning outcomes. It is possible that this technique may be more suitable for tasks that encourage play-like behaviour such as collaborative games.

A related concern here is the amount of extended topic-based conversation between the different conditions of the tabletop interaction. This form of reflective communication discussed ideas that were beyond the concepts defined in the presented topic, such as knowledge that was learnt from other classes or from reading books. This broader reflective discussion can be considered a desirable aspect of learning whereby children are able to independently extend their discussion and learning beyond the basic task foundations [4]. As mentioned earlier, direct touch and non-digital tables promoted on-topic and reflective form of conversation. Such features are desirable for collaborative peer learning tasks.

What is problematic with the pantograph interaction technique is how this higher-level independent peer learning can be compromised when compared to non-digital and direct touch tabletop usage. Again, the greater requirement for focusing on the interaction technique and higher levels of distracting playfulness are likely contributing to these concerns.

Interactive tables offer many potential benefits and features that can be valuable in a learning environment. Interaction and visualisation techniques such as those described in the literature can be employed in creative ways to support collaboration and learning. Our results show that one needs to be careful how these techniques are used as they can significantly influence communication styles. This does not mean that digital tables in general are not useful in a learning environment but that due consideration needs to be given to communication styles when designing for collaborative use.

CONCLUSION

This paper provides empirical evidence to the designers of interactive tables of how particular tabletop interaction techniques (direct touch, pantograph and non-digital table) resulted in different types of communication patterns during collaborative learning. Our main finding is that direct touch is as good as the non-digital table with respect to interdependence and reflective form of topic-based conversation. Such features are desirable for collaborative peer learning tasks. Meanwhile, the pantograph technique encourages playfulness and directives but is not very good at promoting interdependence, topic-orientated and reflective form of conversation in support of small group communication for classroom-based activities. Prior to this work, designers of interactive table had access to few findings, methodologies and stimulating points of reference that can be used to motivate particular forms of communication around interactive tables. This paper contributes by presenting firstly a systematic analysis of communication patterns between different interaction techniques, secondly, a coding scheme based on existing literature to investigate the talk styles and thirdly a guide for designers when using different interaction techniques to produce collaborative learning tasks for children.

ACKNOWLEDGEMENTS

We would like to thank KPT (Ref:810502055410) and UPM (Ref:T01839) in Malaysia for partially sponsoring this research. Thank you also to Mark Marshall, Dan Welsh, Tim Brown, Ruth Taylor, J Glasson, City Academy, BEC and all of our participants for their helpful support.

REFERENCES

1. Aronoff, M. and Rees-Miller, J. The handbook of linguistic. Blackwell Handbooks in Linguistics. Oxford:Blackwell, 2001.
2. Birnholtz, J.P., Grossman, T., Mak, C., and Balakrishnan, R. An exploratory study of input configuration and group process in a negotiation task using a large display. In Proc. of CHI 2007. ACM Press, pp: 91-100.
3. Cao, X., Lindley, S.E., Helmes, J., and Sellen, A. Telling the whole story: anticipation, inspiration and reputation in a field deployment of TellTable. In Proc. of CSCW 2010. ACM, pp: 251-260.
4. Cohen, E.G. Restructuring the Classroom: Conditions for productive small groups. In Review of Educational Research, 1994. 64(1): pp. 1-35.
5. Eisenberg, A.R. and Garvey, C. Children's use of verbal strategies in resolving conflicts. In Discourse Processes, 1981. 4: pp. 149-170.
6. Engleberg, I. and Wynn, D. Working in Groups. Communication Principles and Strategies. Houghton Mifflin Company, 2000.
7. Fless, J.L. Statistical methods for rates and proportions. New York: John Wiley & Sons, Inc, 1981.
8. Ha, V., Inkpen, K.M., Whalen, T., and Mandryk, R.L. Direct Intentions: The Effects of Input Devices on Collaboration around a Tabletop Display. In Proc. of the HIHS 2006. IEEE Computer Society, pp: 177-184.
9. Han, J.Y. Low-cost multi-touch sensing through frustrated total internal reflection. In Proc. of UIST 2005. ACM, pp: 115-118.
10. Harris, A., Rick, J., Bonnett, V., Yuill, N., Fleck, R., Marshall, P., and Rogers, Y. Around the table: are multiple-touch surfaces better than single-touch for children's collaborative interactions? In Proc. of CSCL 2009, pp: 335-344.
11. Hornecker, E., Marshall, P., Dalton, N.S., and Rogers, Y. Collaboration and interference: Awareness with Mice or Touch Input. In Proc. of CSCW 2008. ACM Press, pp: 167-176.
12. Kruger, A.C. and Tomasello, M. Transactive discussions with peers and adults. In Developmental Psychology, 1986. 22: pp. 681-685.
13. Kruger, R., Carpendale, S., Scott, S.D., and Greenberg, S. Roles of Orientation in Tabletop Collaboration: Comprehension, Coordination and Communication. In Proc. of CSCW 2004. ACM Press, pp: 501-537.
14. Nacenta, M.A., Aliakseyeu, D., Subramanian, S., and Gutwin, C. A comparison of techniques for multi-display reaching. In Proc. of CHI 2005. ACM, pp: 371-380.
15. Nacenta, M.A., Pinelle, D., Stuckel, D., and Gutwin, C. The effects of interaction technique on coordination in tabletop groupware. In Proc. of GI 2007. ACM Press, pp: 191-198.
16. Perlmutter, M., Behrend, S.D., Kuo, F., and Muller, A. Transactive discussions with peers and dults. In Developmental Psychology, 1986. 25: pp. 744-754.
17. Rogers, Y., Lim, Y.-K., Hazlewood, W., and Marshall, P. Equal Opportunities: Do Shareable Interfaces Promote More Group Participation Than Single User Displays? In Human-Computer Interaction, 2009. 24(2): pp. 79-116.
18. Rogoff, B. Apprentinces in thinking: Cognitive development in a Social Context. New York: Simon & Schuster, 1990.
19. Scott, S., Sheelagh, M., Carpendale, T., and Inkpen, K. Territoriality in collaborative tabletop workspaces. In Proc. of CSCW 2004. ACM Press, pp: 294-303.
20. Searle, J.R. Speech Acts. Cambridge University Press, 1969.
21. Segal, L. Effects of Checklist Interface on Non-Verbal Crew communications 1994. NASA Research Center
22. Teasley, S. The Role of Talk in Children's Peer Collaborations. In Developmental Psychology, 1995. 31(2).
23. Webb, N. Group composition, group interaction and achievement in cooperative small groups. In Journal of Educational Psychology, 1982. 74(4): pp. 475-484.
24. Webb, N. and Palincsar, A. Group processes in the classroom. In D.C. Berliner & R.C Calfee (Eds), Handbook of educational psychology. New York: Simon & Schuster, 1996.