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EXPLORING SYNCHRONOUS, REMOTE COLLABORATIVE INTERACTION BETWEEN LEARNERS USING MULTI-TOUCH TABLES AND VIDEO CONFERENCING IN UK PRIMARY SCHOOLS.

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Abstract

This study explores remote, non-collocated collaboration via multi-touch table (SynergyNet) and video conferencing software (Skype). Twenty-four participants (aged 10-11 years) in two locations -- primary school classrooms located 300 miles apart in the UK -- engaged in simultaneous collaborative activity to solve a History mystery task. Audio-video data recorded in the first minute of the activity was analysed to explore the emergence of collaborative working practices both within groups in the same location (resizing for shared reading) and between the groups communicating via video conferencing software and through the 'flick' multi-touch gesture (sharing clues between groups). Results indicated that most groups focused first on the establishment of intra-group collaboration before reaching out to their remotely located partners. However, when the second data set was analysed, audio data from

delayed interviews conducted after the original study, participants reported that the discussion between groups supported by the 'flick' gesture were the most important and memorable features of the activity. The study relates these findings to existing literature on collaborative learning using multi-touch tables and considers how teachers are best able to help support the emergence of collaborative practices.

Keywords

Multi-touch, Collaboration, Collocation, Primary, CSCL,

Practitioner Notes

What is already known about this topic

- Research suggests that collaborative interaction supports learning.
- Multiple users can jointly control and interact with each other on the same screen
- using touch, instead of traditional mouse

What this paper adds

- A new dimension, it is possible for two groups to work together to solve the same problem
- remotely, quickly establishing both inter- and intra-group collaborative working
- practices.
- SynergyNet technology was extensively researched in a lab environment; this study
- takes the evolving technology and explores participant behaviour in a more authentic
- school context.
- The immediacy of the flick gesture built a memorable and motivating link which inspired
- meaningful collaborative interactions between remote groups.
- Implications for practice and/or policy
- Multi-touch surfaces can support synchronous collaborative interaction between
- groups in different locations which prove to be memorable and engaging for the
- participants.
- Further study is needed to explore further collaborative working practices between
- and within groups.
- Teachers are potentially able to lead sessions guiding both closely located and remotely
- located groups using video conferencing software.

Introduction

This paper explores a new phase in the development of *SynergyNet*, a framework for integrating multi-touch software in classrooms for collaborative learning. This technology, developed and previously only tested under lab conditions, has been piloted in schools for the first time. This study builds on previous research projects based upon using divergent, collaborative tasks with a History curriculum focus. The principal difference between the technology deployed here and that used in previous *SynergyNet* studies is the facility for

remotely located groups to work concurrently on a single problem, sharing information digitally via a 'flick' gesture, as well as communicating in real-time with each other via video conferencing software. The scope of this paper is to explore and analyse the role this new gesture-based sharing has in the collaborative discussions of the groups, how able are teachers to facilitate these inter-group interactions and finally, to explore the reflections of participants on the activities after they have taken place to explore any enduring impressions made by the activity.

In recent years, there has been an increasing interest in the educational potential of multi-touch tables, where multiple users jointly control and interact with each other on the same screen using touch, instead of traditional mouse control. In this context, 'the table surface acts both as the screen and provides shared control.' (Mercier, Higgins and Joyce-Gibbons, 2016, p.2) and 'when working in a group around a multi-touch surface, there is no longer the need to negotiate who has access to the content through a single interaction point.' (Mercier, Vourloumi and Higgins, 2017, p.164). The use of large multi-touch surfaces (tables) was explored in the *SynergyNet* project (funded jointly[1] by the ESRC and EPSRC, two of the UK's national research councils) and, after developing innovative teacher orchestration software, established that they did indeed support effective interaction between pupils (Higgins *et al*., 2012). When compared to the outcomes of paper-based group activities conducted prior to using the multi-touch tables, equivalent activities undertaken on multi-touch tables resulted in greater uptake of ideas (Mercier *et al.*, 2016) and more engagement in sophisticated reasoning, with more time being spent on problem-focused, rather than procedural talk (Higgins *et al.*, 2012). Furthermore, data from these studies highlighted the importance of the division of roles and different patterns of leadership (Mercier, Higgins and Da Costa, 2014), the development of adaptive expertise among group members (Mercier and Higgins, 2013) and the potential of the tables for structuring representations of reasoning processes (Mercier and Higgins, 2014). In addition, data from teacher observations highlighted differences in how teachers made decisions when moving between group and whole-class dialogue (Joyce-Gibbons, 2017)

Other studies have examined the efficacy of multi-touch tables at various ages in educational settings, from pre-kindergarten (Ward *et al*., 2016) through to higher education (e.g. Shaer *et al*., 2012; Martinez-Maldonado, Yacef and Kay, 2015), as well as informal settings outside of education, such as museums (Ciocca and Schettini, 2011; Zaharias *et al*., 2013) and tourist information centres (Marshall *et al.*, 2011). Other studies have explored their efficacy in other collaborative activities, such as gaming (Antle *et al.,* 2011) and working with children and youths with special needs (Bossavit and Pina, 2013). Evidence suggests that multi-touch tables can be applied effectively both in different areas of the school curriculum, such as mathematics (Ladel, Silke and Kortenkamp, 2013), and beyond, such as English as Second Language Learning (Lin *et al,* 2016). All of these studies exploit the unique potential of multi-touch, horizontal tabletops, such as collaboration, group work and problem solving (Mercier and Higgins, 2014), using techniques such as clicking, zooming/resizing (Gao and Sun, 2015), drag and drop (Hwang *et al.*, 2013), and rotating (Ku and Chen, 2013). When these devices are networked these techniques become available to all users to share ideas developed using them. As well as *how* the devices themselves have been used, the *SynergyNet* project also explored the impact of use of various classroom layouts. These studies suggested that the classroom layout had little impact, but that 'the use of technology in the classroom may be

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influenced by the location of the technology, both in terms of the learning outcomes and the interaction behaviours of students.' (Mercier, Higgins and Joyce-Gibbons, 2016; p.504). A centred room layout, where all tables were facing inwards towards each other rather than a traditional layout where all faced the front, encouraged a more collaborative discourse among group members. The current study seeks to build upon these findings by incorporating the metaphor of face-to-face group collaboration, echoing the 'centred' room layout in the original study, between the groups through positioning of the video conferencing screen (see Figure 2).

However, although previous SynergyNet studies replicated a classroom environment, they were conducted in controlled laboratory conditions. Users were networked in the same co-located setting, where they could see and communicate with each other face-to-face, working with other users they already knew, in the same room. As such, there was a need to explore the potential for collaborative interaction and learning by using the *SynergyNet* software on multi-touch tabletops in *real* educational settings, with networked users in *separate* geographic locations (i.e. non-co-located) – although the software allowed the tables to still operate virtually as though one was co-located with the other. In addition, there was a need to assess if collaboration was possible using real-time video communication (in this case Skype), with others whom they had not met before. The study reported in this article is the first attempt to explore this potential, working with pupils (aged 9-10 years) from two primary schools located 300 miles apart within the UK. We have reported elsewhere on the technical challenges involved in adapting the software and ensuring an adequate network connection (McNaughton *et al.*, 2017). This study explores the pedagogical interactions between learners participating in remote, synchronous collaborative activities using networked multi-touch tables in two different geographic locations.

An innovation from the previous *SynergyNet* project was the development of the 'Network Flick' gesture which allowed learners working at each table to 'flick' content from a table in one location to the other in the other location (see Figure 1). This ability to quickly share (predefined) content in either direction was a key addition to the verbal interactions facilitated by the video feeds.

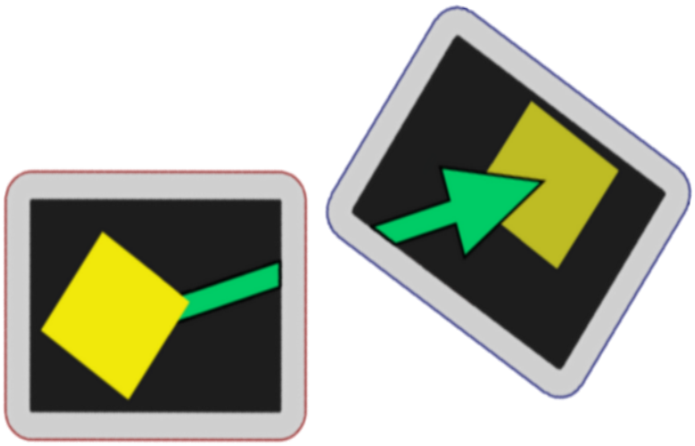

Figure 1 - The use of the network flick gesture to transfer content between two interfaces

Research Questions

This exploratory study sought to build on the work of the earlier *SynergyNet* studies by piloting synchronous non-co-located collaboration in the school rather than the single co-located lab setting to explore what behaviours emerged when groups worked in different locations. This exploration was guided by the following research questions:

RQ1: What *intra*-group collaborative practices did the groups establish during their initial strategies?

RQ2: What *inter*-group collaborative practices did the groups establish during their initial strategies?

RQ3: How did the recollections of the participants relate to the collaborative problem solving or subject-knowledge based experiences in the task?

Methods

The two participating primary schools were approximately 300 miles apart in the UK: one in the North East of England and the other in South Wales. Both schools were located in villages with a common industrial heritage based on an historic thriving coal industry, but in recent time the mines have closed with an associated socio-economic decline in each area. Both were positive about the potential of technology to improve learning outcomes and keen to be involved in projects which would broaden the experience of their pupils.

To facilitate the remote collaboration a multi-touch table was located in a quiet teaching room in each of the two primary schools. Each was connected to the internet using a wireless dongle – as the school network security blocked ad hoc network connections (see McNaughton *et al*., 2017) – and to the other table using the *SynergyNet* software. In addition, each location had a tablet device facing the table which connected to the other location using the video conferencing software Skype to allow the children to see and talk to each other.

Following Falcão & Price (2011), pupils were divided into groups of three around a shared interface, with one group working together at each location. Each group was video-recorded by two fixed cameras positioned to capture interactions, both verbal and non-verbal, between learners, teachers and the tables. The technical set up and data capture are summarised in Figure 2.

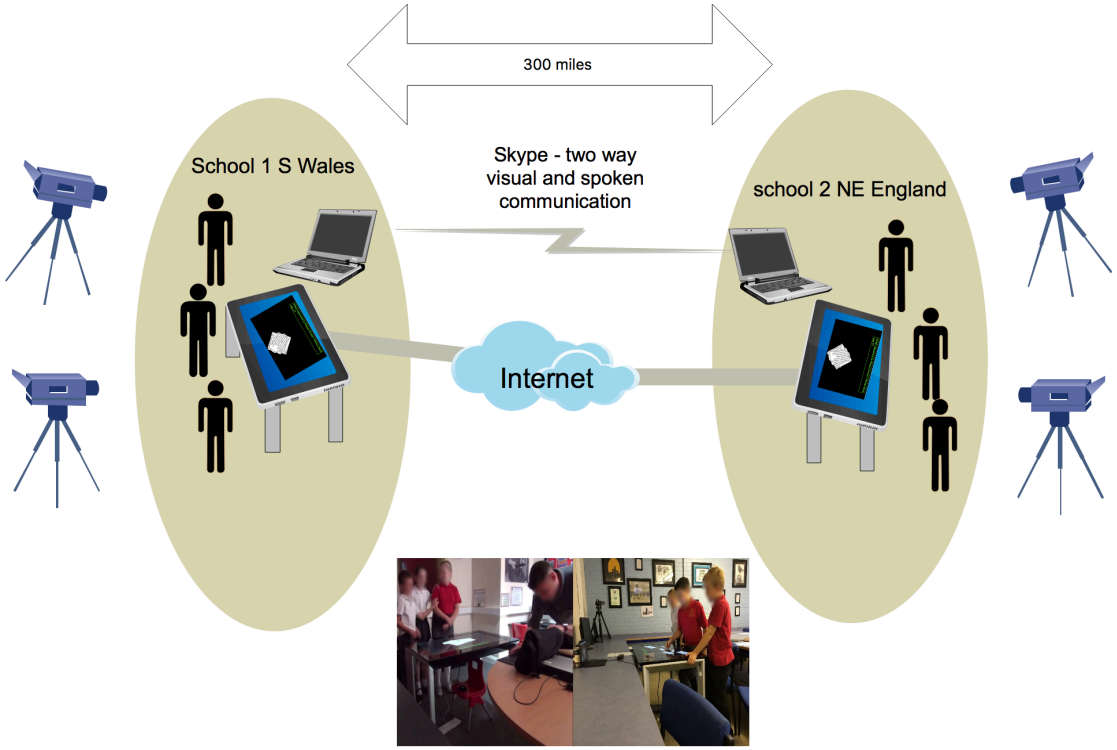

Figure 2: Summary of technical set-up and data capture between school 1 and school 2

In each location, a researcher (a qualified primary teacher) worked with each group of three pupils to set up the technology and explain the task. In total 24 children, aged 9-10 years, in two primary schools (n=12 in each) took part in the study, organised into four groups of three in each school. One group from each school collaborated together in real time. Prior to each data collection session, the children from each location introduced themselves to each other over skype and explored common interests to establish a rapport, which they quickly did due to their familiarity with skype interactions from other school activities and their fascination with each other's regional accents! Each data collection session lasted for approximately 20 minutes. The activity was then repeated with paired groups from each location. Prior to taking part, informed ethical consent was gained from school, parents and pupils, in line with institutional protocol. Each group was mixed-gender and membership was determined by their class teacher. Participants were introduced to the other group via the video-conferencing software prior to the beginning of the exercise. They were told each other's names and encouraged to talk and ask questions of the members of the other group.

The task

Both schools were chosen based on the common heritage of their communities in the mining industry. Each paired group were trying to solve a Mystery task, validated in the original *SynergyNet* project, to investigate an historic mining accident that involved a 10-year old boy who had suffered injuries. Based on the available evidence they were asked to jointly arrive at an explanation of what had actually happened to cause his injuries. The Mystery task represented an attempt to engage the learners in a collaborative activity and give them the opportunity to share their understanding.

The groups of pupils were 'facing' each other via the video conferencing software (allowing them to both see and hear each other). The task commenced with a pile of clues, which the pupils dragged apart to read and discuss – see Figure 3.

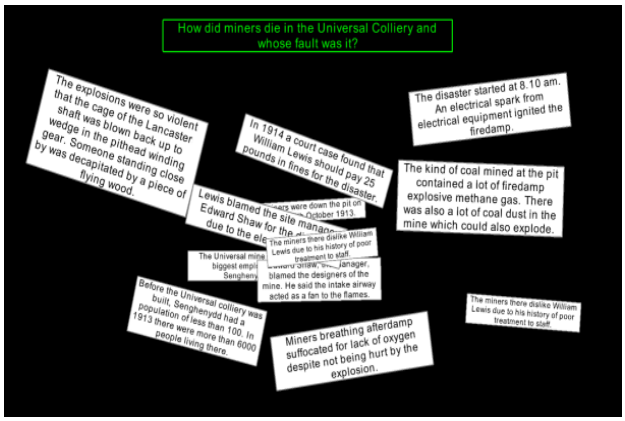

Figure 3 – The *SynergyNe*t Mysteries app with task content

The *SynergyNet* framework allowed any clue to be manipulated by users through common multi-touch gestures to move, resize and share between locations through the flick gesture. Collaboration was encouraged through the task design as groups in each school only had half of the clues (n=12) each on their screens. As one pupil described them, "like boxes, and they had, like, ideas in them". (W2)

The researcher facilitators in each location jointly introduced the activity, setting the geographic context and introduced the main protagonists involved in the mystery task to the pupils. Pupils were given a very short familiarisation time with the multi-touch tables, as they had all used iOS or Android tablet computers and were familiar with basic touch controls. They were then encouraged to start the activity and engage in reading the clues. Collaboration was built into the task from the outset as to view all the clues, the pupils had to share with the other group via the network flick gesture - which would send the selected clue to the other school. The facilitators encouraged the groups to articulate their reasoning via the video conferencing software and to come to an overall decision as to who was to blame for the accident.

Data and analysis

The activities resulted in two main data sets: video from both settings of all practical sessions; as well as audio and contemporaneous notes from pupil interviews in both settings. Each are analysed separately below after a brief overview of the analysis involved in each.

To explore emerging collaborative practices using the tables, video data from the first minute of each task was analysed to replicate the analysis (Higgins, *et al.*, 2012) used in previous *SynergyNet* studies. This allowed analysis of both intra-group (resizing) and inter-group (flick gesture) activity. Frequencies of intra-group resizing and inter-group flick gestures by participants were counted. Resizing could either be an action which enlarged or reduced the size of a clue. A resizing gesture or flick gesture was considered shared if two or more participants discussed it, simultaneously touched it or simultaneously read it for a period of at least one second during the first minute. If no discussion, shared touch or shared reading event took place then it was considered a non-shared gesture. The frequencies of each

gesture (*Resizing–not shared*, *Resizing–shared*, *Flick–not shared*, *Flick-shared*) are presented in Table 1. Rotation of clues to orientate them prior to reading was not counted as an indicator of agreed salience or joint attention. Similarly, resizing or flicking caused by technical issues was not counted as indicating agreed salience or joint attention. To aid in the analysis, the first minute of each session was also transcribed, noting additional features such as gaze and silent reading. All the videos were rated independently by two researchers based on agreed definitions above. This resulted in 81.3% agreement (26/32). Any disagreements were resolved by simultaneous video analysis, leading to the final agreed figures presented here.

Researchers also noted any behaviours by individuals working on the tasks which either were either similar to those noted in the previous *SynergyNet* studies or those which were in some way different. The focus was on whether these gestures were shared in some way as part of a collaborative activity or whether they were used by one individual. Shared resizing gestures could indicate the emergence of intra-group joint attention during discussion or an agreement on the salience of a piece of information (Higgins, *et.al,* 2012).

After the activity was completed, each group of pupils (in their activity groups) took part in a semi-structured interview in each location with a research team member not previously introduced to the participants. The role of these interviews was to triangulate data on participants' recollections to enhance the validity of data interpretation. It also sought to give an initial indication of post-test durability of the experience in the memories of the participants, seeking to explore whether novel forms of communication (Skype or flick) became associated for the participants with either the collaborative practices or the subject content.

The study took place at the end of the participant's summer term in their school Year 5. The original plan was to interview them about their recollections during the autumn term of their Year 6. However, logistical and professional commitments among the research team, the long school summer holidays and planned school activities, meant this was delayed until the winter term. Nevertheless, all pupils were able to easily recall the activities and were keen to discuss. The delay makes the recall of the participants all the more noteworthy. Each interview was audio recorded, as less obtrusive for the pupils, with contemporaneous field notes taken during the interviews, noting social cues (Opdenakker, 2006), and particularly use of gesture – such as the 'flick'.

Video data from activities

Group 1 (G1): School 1 (S1) and School 2 (S2) speech and gesture

Table 1 shows clear differences between the schools in each group in their emergent collaborative practices. For example, the differences between G1S1 (group 1, school 1) and G1S2 (group 1, school 2) reflect different approaches from the start. G1S1 were very individualistic, with much sorting and reading done individually rather than together. Each struggled to get the other's attention when they wished to share a clue or an idea.

		Resize	Flick

		Not Shared	Shared	Total	Not Shared	Shared	Total
Group 1	School 1 (G1S1)	2	1	3	2	1	3
	School 2 (G1S2)	0	2	2	0	0	0
	Total	2	3	5	2	1	3
Group 2	School 1 (G2S1)	0	1	1	0	0	0
	School 2 (G2S2)	2	1	3	0	0	0
	Total	2	2	4	0	0	0
Group 3	School 1 (G3S1)	3	2	5	1	0	1
	School 2 (G3S2)	1	1	2	0	1	1
	Total	4	3	7	1	1	2
Group 4	School 1 (G4S1)	2	1	3	1	0	1
	School 2 (G4S2)	0	0	0	0	0	0
	Total	2	1	3	1	0	1

Table 1: Frequency of resizing and flick gestures by groups in the first minute of the task.

In contrast, as shown in Table 2, the participants in G1S2 spent much time in silent reading. The direction of gaze implied that much of the time two or three participants simultaneously focused their attention on individual clues, reading silently or in turns. They undertook resizing after a brief discussion or with the tacit approval of other group members indicated by hand gestures and nods.

Time	**G1S1 Speech**	**G1S1 Gestures**	**G1S2 Speech**	**G1S2 Gestures**
9.38	S1B: I think we should send this one over.	S1B: Points to clue in front of him.		

9.40	S1C: Wait, give us look.	S1C: Reads to himself		
9.48	S1A: Yes	S1A: Begins to touch the clue.		
9.51	S1C: Do it	S1A: Puts their finger on the clue.		
9.53	S1A: Should we send it	S1B: Begins to manipulate another clue and reads silently	S2A: Robert has six younger brothers and sisters, his oldest sister …	S2A & S2B reading together until clue arrives.
9.54	T1: Yes send whatever you like.	S1C: Sends clue S1B: Tries to send a clue (no discussion)		
10.01	T1: But if they're reading	S1B: brings clue back after it does not slide and gets stuck on edge of screen.	S2A: Stopped it	S2A & S2B both tried to stop clue by touching it.
10.04	S1A: You've got it.	S1C: leans across and pulls over clue from in front of S1C	S2C: We just received it.	S2C Was talking to her own group not camera.
10.06	S1B: I think we should send this one.	S1B: Slides clue to edge of screen and it disappears. They cheer.	T2: What's that one say?	S2B: Resizes clue – rotates and enlarges.
10.09			S2B: Wages	
10.10			S2A: Wages	S2A & S2B laugh and read silently.
10.14			S2B: Depended on the price of coal…	
10.16			S2A&S2B: If the price was low the miners had to dig more coal to keep the same wage and work longer hours.	G1S1 send another clue but it bounces off the back wall and G1S2 were unable to stop it rebounding back.

10.19	S1A: Workers at the mine had to supply their own candles.	S1A: Resizes (enlarges) clue in front of her and reads it out.		
10.10	S1C: Ah this one.	S1C: Resizes (enlarges) clue moves to centre of table.		
10.16	S1C: Here comes one.	S1B: touches clue which stops the flick. He then tries to flick it.		
10.19	S1C: [S1B] Leave go.	S1C: Continues to try to flick it.		
10.21	S1B: Why isn't it going?	S1C: Continues to try to flick it. S1A jumps up and down with excitement as clue arrives from S2.		
10.26			S2B: Oh no!	
10.27			T2: If there's words you don't understand, just ask.	
10.29	S1A: That's the one I just sent.	S1A: Points at the clue which has just arrived.		
10.31			S2A: The weather has been unusually hot this summer.	
10.34	S1B: The mine inspectors had reported that there was not enough fresh air in the mine but John Robson thought that they were being too fussy and had not done anything about it. Bye!	S1B: Reads clue with finger on it all the time. When he has finished reading he flicks the clue to the other school.	S2B: What about this one. Robert normally works from 6am to 6pm but recently he has had to work longer because wages have gone down.	

Table 2: Group 1 dialogue and gestures observed in first minute of activity

In G1S1, pupils S1A and S1C both use resizing gestures to enlarge clues and engage in initial moves to discuss them with other group members. When they decide to flick it is after some attempt at discussion with their school group members as well as an attempt to communicate with the other school via the video conferencing software. Pupil S1B focuses on private reading without resizing and then flicking without consultation.

In G1S2, all three participants focus on joint reading of the clues they have, reading aloud and working systematically through them as a unit. S2A and S2B are the more vocal in the group, but S2C remains peripherally involved throughout.

Group 2: School 1 and School 2 speech and gesture

Table 3 shows that for both schools in Group 2 there was less resizing, and no flicking observed in the first minute of the activity. This did not indicate that there was no development of collaboration using the tables; rather, these took very different forms and were influenced by teacher intervention in the case of G2S1 (group 2, school 1).

Time	G2S1 Speech	G2S1 Gesture	G2S2 Speech	G2S2 Gesture
3.48			T2: There's loads of clues here guys so have a think what's the most important clues	
3.50			T2: So you can resize them… read them and decide then which are the best ones to share.	T2: Demonstrates resizing and rotation as speaking.
3.58	S1D: So you read the first one.			
4.00	S1F: The coal mine is the only employment in the village			
4.02			S2D: Robert Dixon is ten years old…	S2D reads, S2E looks away, S2F looks at clue S2D is reading.
4.05	S1D: That is not important.			
4.06	S1F: Not important.			
4.07	S1E: So shall we just leave it over there?		S2D interrupted by non-participant children entering the room	
4.08	S1D: So shall we just leave it here?	S1D: Pulling clue towards them.		

4.11	S1E: Dude!	S1E shakes fist in mild frustration.	S2D: … He works down the mine as a trapper.	
4.13	S1F: Right, [S1E]			
4.14	S1E: Wages varied on the price of coal, if the price was low then miners had to dig more coal and work longer hours to keep the same wages.			S2D gestures to another clue, S2E looks and S2F nods. They may whisper but it is unintelligible
4.25	S1D: That's not important.		T2: You can talk guys, ok.	
4.26	S1E: But it kind of is because then they had to work more to keep the prices.	S1E explains to S1F. S1D moves clue with one finger.		
4.30	S1D: Oh, yeah, flick it then.	S1D makes flicking gesture with fingers in the air.		S2D resizes and reorientates clue so they and other group members can read it.
4.32	S1E: Don't they?	S1E to S1F S1E brings clue towards them (as if preparing to flick)		
4.33	S1D: Yeah.			
4.34	S1F: Yeah.			
4.35	S1D: There's one coming to you.	S1D shouts at the video conferencing screen.		
4.36	T1: Well wait, just keep that for now and look at the other clues before you send them ok?	S1E draws another clue to the centre (perhaps to start reading).		
4.38	S1D: Oh, ok.			
4.39			S2D: Those two look good.	

4.41	T1: If you think it's important then put it somewhere maybe.	S1F: Takes clue about wages and moves to far corner in front of them.	S2F: Yeah.	
4.44	S1E: So that pile's…		T2: If you think any are important and worth sharing…	
4.45	S1D: So that's the important ones	S1D: Points at clue but does not touch. S1F moves clue to corner.		S2D and S2F both select and rotate clues S2E focuses on clue already enlarged by S2D directly in front of him.
4.47	S1E: Whoa, whoa, you made it	S1F touches clue and it enlarges involuntarily.		S2D, S2E and S2F engage in individual reading.

Table 3: Group 2 dialogue and gestures observed in first minute of activity

G2S1 began to engage in reading and discussion of the merits of the clues immediately. S1D took the initiative and appeared to assume an organisational leadership role from the outset. S1E shows signs in this extract of developing as the group's intellectual leader, a role they could be said to be fulfilling later in the session. Although the group did not resize clues, preferring to move them to the centre of the screen to allow for shared reading without enlargement, they were eager to begin flicking clues to G2S2. The teacher intervened to stop them doing so, possibly to enable them to focus more closely on reading the clues they had before sharing.

G2S2 (group 2, school 2) were quiet, but focused on the clues. After a period of distraction through interruption the group settled into a routine of individual reading with occasional discussion. S2D was active, rather than dominant, as they were the only one to engage with the resizing possibilities of the table. T2 (Teacher in school 2) was anxious to encourage talk between the children, but they remained reticent to do so in this first minute of the task.

Audio data from pupil interviews

The audio recordings were transcribed and analysed using an iterative open process of initial and then focused codes. These codes emerged easily as the pupils in both locations as both groups had very similar memories of the activities. While they varied in their recollections of the actual content of the activities (the events of the disaster), they were remarkably similar in their memories of using the table. The most significant codes the emerged from the data, both in terms of frequency and richness of description, were:

1.) use of gesture (predominantly flick and resize);

2.) (collaborative) problem-solving procedure they adopted;

3.) problems with the software;

4.) fun/exciting (including meeting new people)

1.) Use of gesture

During the interviews, pupils either described in words, or used their hands to imitate, predominantly two gestures: flip and resize/rotate. The dominant theme with all groups in both locations was the use of the 'flick' gesture.

There was some technical fascination with the novelty of flicking, such as

> *'Well, I'm really amazed how they were flicking it over to their side even though they were very far away.'*
>
> **Group W2**
>
> *"That it was just really clever, that you could flick it, like- I know it's not half way across the world, but like- …"*
>
> **Group W1**

All of the groups were clear, however, that the 'flick' was an essential and purposeful part of the collaboration, and not just 'fun'. A typical explanation is shown in the extract below when discussing the flick gesture:

> *Facilitator: Why did you want to send it to them?*
>
> *Child A: They might have needed it.*
>
> *Child B: To know more about.*
>
> *Child C: It could be interesting information that they didn't know and then they could send us one back that we didn't know.*
> **Group E1**

Nearly all explanations in the interviews were accompanied by the use of a physical memory and mirroring of the actual gestures used on the tabletops, such as:

> *Child: If you wanted to send something to somebody, if you wanted to send it to them and you didn't want to press send, you would push, like uh.*
>
> *Facilitator: You just flicked your fingers up?* [Referring to gesture child had made on table – field note]
>
> *Child: Yes, because normally you would have to press send, but then that would load for ages. With that, all you had to do was flick it and then it would go over to them. Then that didn't really take much time.*
> **Group E1**

This was also true of references to resizing and rotating:

> *Female: Yes. You have got to, like, to make it bigger you just like open your fingers out, and then to make it smaller. And to move it, you just hold down and you can turn it whichever way you want.*

Male: And rotate. [Pupil was pinching and un-pinching, and twisting with two fingers – field note]

Group W3

2.) (Collaborative) problem-solving procedure they adopted;

All groups in both schools were clear that using the tabletops allowed them to solve the problem collaboratively by a mixture of discussion and sharing of clues through the flick gesture. The pupils were clear, however, that the ability to share content and then discuss at either an intra- and inter-school level, was important to their ability to work collaboratively as exemplified in this exchange:

Female: We worked together.

Male: And we had to listen.

Female: Yes, we had to listen to each other, so you could know what the information they got, and what information we got. And we just basically worked together to see what information needs to go to [name of] school.

Facilitator: And how did you decide which to flick to the other school then?

Female: Because they would, we would, read out a piece of the clue, then they would say, then they would read a bit out, and if, if it like matches, we would ask them to send it over. And then if we didn't need it, they would keep it,

Group W3

It is worth noting that although collaborative problem-solving was the research focus of the paper, for the pupils this was less important, or less memorable, to them than the other themes.

3.) Problems with the software:

It was, perhaps, inevitable that trialling a completely new technology, using secure school networks between different across two nations (who manage security settings – including firewalls – for schools in different ways) or using the internet wirelessly would present some technical and logistical challenges. Most groups of pupils mentioned problems (some more than others reflecting their experience), but none in a pejorative manner. If anything, they added to the fun element of the activities, particularly at the start. Besides actual malfunctions due to connections issues, the main problem encountered was a control issue with flicking clues, making it hard to 'stop' the clue as it arrived. As one child explained, 'if you flicked it too hard it bounced back [from one school to another].' (Group E3) All the pupils who mentioned this were not distracted from their task, but rather they enjoyed it as in the extract below:

Child 1: Yes. We (Laughter) tried to catch it, but it was really hard.

Child 2: Yes because if you flicked it too hard it would bounce back to us.

Child 3: We were all trying to catch one

Group E2

This problem was, however, easily overcome by the pupils as they calibrated their flick speed, due to their previous experience of similar technologies.

4.) Fun/exciting (including meeting new people)

There was also a strong theme of regarding the 'fun' element of the activity, including as a learning experience, as shown in the following extract:

> *Facilitator: You're flicking your finger, aren't you? (Laughter) Yes?*
>
> *Child: …instead of shouting all the time. For example, if someone on a different table didn't know what to write, you can just send them an idea.*
>
> *Facilitator: For the recording, you're flicking your finger again at me! (Laughter)*
>
> **Group E2**

> *Child: … and it was really cool how they got the information that we had on our screen.*
>
> **Group W3**

Also, part of the fun was in meeting pupils from outside of their school as summed up below:

> *Child A: Communicating with people who are actually really far away and from a place where I've never been. …*
>
> *Child B: My favourite thing about it is that we actually met new people, that we actually met new people from a different school. It made it a little bit like feeling like you're in a house full of strangers. (Laughter) I'm not sure why.*
>
> **Group E2**

> *Female: It was good how they were all confident in speaking to us, and it seemed as if we knew each other for like ages, but we actually knew them for like five minutes.*
>
> **Group W3**

Discussion

The results presented here compliment some key findings from the original *SynergyNet* study. In particular observed group behaviours surrounding emergent collaborative practices, negotiation of salience, intellectual and organisational leadership. This suggests that non-collocated collaboration is potentially a fruitful learning strategy to deploy using touch screen devices and offers a meaningful collaborative experience with multiple channels of communication and dialogue at different levels. As such non-collocated collaborative activity using *SynergyNet* is worthy of continued study both technically and pedagogically.

RQ1: What intra-group collaborative practices did the groups establish during the first minute of each task?

A range of both individual and collaborative practices were observed in the first minute of the activity. Some individual resizing gestures were focused on exploring the technical potential of the multi-touch gestures and while these behaviours were not always task completion focused, individual practices were closely connected with subsequent collaborative ones (See Table 1: G1S1). Resizing was used by some groups to indicate salience, as clues were enlarged for shared reading and reduced in size if not regarded as important (See Table 2: G2S1). Such behaviour relates directly to that reported in Higgins, *et al.* (2012). Participant interviews indicated that everyone had enjoyed participating, both as individuals and as part of an intra- and inter-group activity.

Some emergent leadership practices showed initial signs of developing (Mercier & Higgins, 2016). Some group members showed early signs of emergent organisational leadership (e.g. S2D or S1D) or intellectual leadership (e.g. S1C). It is important to note that intra-group behaviour when using these tables, though linked to other groups remotely, showed some features of previously reported behaviours.

RQ2: What inter-group collaborative practices did the groups establish during the first minute of each task?

There was almost no attempt by group members to talk to each other during the first minute of the task, participant S1B being a notable exception. This is perhaps not surprising given that the groups had already been introduced to each other during the pre-task introduction preceding the data presented here. It also perhaps reflects the focus of the participants at this point in the task on their own clues, their attempts to read and then evaluate these before sharing them. The facilitators themselves played an important role in this lack of interaction. Facilitator 1 stopped G2S1 flicking a clue they had decided was important to their partners, G2S2 (See Table 3). Facilitator 1 was also tried to encourage, but also temper the enthusiastic flicking of S1B and others in G1S1, anxious that the other group should have the time to read before being sent additional clues (See Table 2). The focus of Facilitator 2 was on encouraging dialogue between group members, sometimes of any kind. In the case of G2S2, Facilitator 2 began by seeking to encouraging dialogue, but seeing the joint attention of the group emerging, they started to try and shift group attention to sharing important clues (See Table 3).

There was no appreciable lag between the two groups, the positioning of the screens and speakers used for Skype meant that children were aware of the other group's dialogue. However, many showed signs of ignoring this and focusing on their own discussions until such time as one or more group members wished to deliberately talk to the other group. This was frequently supported by the teacher, who recruited the other group's attention. Group 2 developed the convention of a group wave. When all three members of one school group were waving it signalled that they required the other school group's attention. Sometimes it was the teacher who noticed that this was happening and brought it to the participant's attention, on other occasions it was a participant themselves. Facilitator intention and focus when scaffolding the interactions was not specifically directed in the design of the task. However, it appears that the different priorities of teachers here may echo those discussed

by Joyce-Gibbons (2017), which inform the teachers' decisions to intervene in group discussion.

The focus of participants in the early stages on familiarising themselves with their own group's clues is very understandable. It is remarkable that inter-group interaction was seen at this early stage. Future studies will explore whether there is a shift in focus from intra- to inter-group interactions as the groups develop in their exploration of the task. This study choses to focus solely on the first minute of the task for two reasons. Firstly, the study draws upon the findings of an earlier *SynergyNet* study which explored emerging collaborative practice in the initial stage of single-group versions of this activity (Higgins, et al. 2012). The second reason is that teacher instruction during the tasks diverged between the groups depending on the technical and conceptual needs of each group. For meaningful comparisons between groups to be made throughout the task, a more structured design should be implemented, where sharing and dialogue between groups are interspersed by periods of intra-group discussion and teacher support focuses on managing the transitions between these different levels of interaction.

RQ3: How did the recollections of the participants relate to the collaborative problem solving or subject-knowledge based experiences in the task?

It was clear from the responses that the gestures supported by the tables, resizing and flick, were regarded as very important by the participants. In particular, they found the flick, a facility by which to share with the other group to be very important and memorable. They regarded their interactions with the other group as primarily confirmatory. They shared information which they already believed was important, seeing their role as to curate the important clues they had been given.

The gestures within *SynergyNet* which support collaboration were readily recollected by the participants. However participants rarely, if ever, mentioned the content, relating to a historical mystery or the collaborative problem-solving process itself. Given that the mystery content was not related to the History curriculum in general terms but was a standalone investigation, not incorporated in to their regular History scheme of work, it is perhaps unsurprising that this was not as memorable as novel gestures and communication (Department for Education, 2014).

Conclusions

This study set out to explore some of the emergent working practices that groups located in different schools developed when working simultaneously on the same History problem. We believe there is a clear relationship between a range of collaborative practices established by groups working on similar problems in single groups in one location and reported in previous studies of the *SynergyNet* project, and those which were established by groups in this study in two locations. Specifically, these relate to group organisation of clues, the emergence of intellectual and organisational leadership roles and the roles of the facilitators in influencing the collaborative interactions both within and between groups.

The enthusiasm of the pupils evident from the interview responses indicates that *SynergyNet* and the Network 'flick' gesture both have a great, and possibly unique, potential as

pedagogical tools supporting collaborative investigation. The addition of a school linked remotely by video conferencing software and by 'flick' gesture adds a range of possible interactions that can enrich the teaching and learning experience for all participants, regardless of the distance between them. Furthermore, with recent significant changes to the structure and assessment in the English and Welsh national curriculums - especially in the context of ICT and cross-curricular digital competencies (Brown, Sentence, Crick and Humphreys, 2014; Arthur, Crick and Hayward, 2013) - we envisage future application of our approach across two diverging educational jurisdictions, with the potential for impact on both pedagogy and practice.

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The SynergyNet framework is available for free download from: https://github.com/synergynet.

Statements on open data, ethics and conflict of interest

a. The researchers do not have permission to share the data.

b. The research was approved by the Ethics Committee of the Durham University School of Education.

c. The authors have no conflicts of interest to declare.

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