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While research indicates that technology can be useful for supporting learning and collaboration, there is still relatively little uptake or widespread implementation of these technologies in classrooms. In this paper, we explore one aspect of the development of a multi-touch classroom, looking at two different designs of the classroom environment to explore how classroom layout may influence group interaction and learning. Three classes of students working in groups of four were taught in the traditional forward-facing room condition, while three classes worked in a centered room condition. Our results indicate that while the outcomes on tasks were similar across conditions, groups engaged in more talk (but not more off-task talk) in a centered room layout, than in a traditional forward-facing room. These results suggest that the use of technology in the classroom may be influenced by the location of the technology, both in terms of the learning outcomes and the interaction behaviors of students. The findings highlight the importance of considering the learning environment when designing technology to support learning, and ensuring that integration of technology into formal learning environments is done with attention to how the technology may disrupt, or contribute to, the classroom interaction practices.

Keywords: CSCL; collaborative learning; multi-touch technology; classroom design; primary education; mathematics

Introduction

The field of technology-enhanced learning and computer-supported collaborative learning (CSCL) provides many examples of research that indicates that technology can be useful in supporting learning and collaboration (Lou, Abrami, & d' Apollonia, 2001; Tamim, Bernard, Borokhovski, Abrami, & Schmid, 2011). However, uptake of technology in classrooms is still fairly limited and the potential of technology to radically change the learning environment has not been realized (Cuban, 2001; Higgins, Mercier, Burd, & Hatch, 2011). One possible explanation for this is the need, not just to design the technology to support the learning experiences of each child, but also to redesign the classroom environment in which the technology is used. In this paper, we describe the design of a multi-touch classroom, and explore how two configurations of the room influenced the amount and type of talk that

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students engaged in, and their outcomes on the task, to begin to shed light on the importance of classroom design on the implementation of technology in formal learning environments.

A range of technologies can support group collaboration and interaction in classrooms, particularly large shared displays (Caballero, van Riesen, Alvarez, Nussbaum, & De Jong, 2014), complementary input devices (Verma, Roman, Magrelli, Jermann, & Dillenbourg, 2013) or a combination of large displays and multiple mice (Szewkis et al., 2011) with technology available to support both large groups and even whole classes (Moraveji, Inkpen, Cutrell, & Balakrishnan, 2009). The key issue for collaboration is that learners can see and interact with or control the digital information represented. In this paper, we look at one possibility where the table surface acts both as the screen and provides shared control.

The design of classrooms, and how the physical organization and layout influences students' learning opportunities and interactions with each other and the teacher, has received sporadic attention in the educational research literature (Wheldall & Bradd, 2013; Woolner, Hall, Wall, Higgins, & McCaughey, 2007b). Recently, a study of classroom design found associations between six classroom features and student outcomes on standardized tests, including color, light and flexibility of the learning space (Barrett, Zhang, Moffat, & Kobbacy, 2013). However, while this study attempts to explain the outcome on tests, it says little about the mechanisms through which the design of a classroom may influence behavior, and the learning opportunities available to the students, particularly with digital technologies (Tondeur, Van Den Driessche, De Bruyne, & McKenney, 2011).

Research that explores how the layout of tables in classroom influences behavior, however, has found a range of contradictory evidence (Wheldall & Bradd, 2013). Overall, there is some evidence to indicate that seating students in rows leads to more on-task behavior than groups (Hastings & Schwieso, 1995; Wannarka & Ruhl, 2008), though some research indicates more on-task behavior in circular arrangements, followed by groups, with rows showing the least amount of on-task behavior (Rosenfield & Lambert, 1985). Marx, Fuhrer, and Hartig (1999) also found that primary age pupils asked more questions with a semi-circular arrangement of desks compared with sitting in rows. These contradictions point toward the complexity of designing classrooms, and the likely interaction between classroom layout, teachers' pedagogic strategies and task demands (Wannarka & Ruhl, 2008). This is reflected in work looking at how teachers arrange their classrooms (Pointon & Kershner, 2000), which indicates that the classroom arrangement is related to the pedagogic beliefs of the teachers, and the emphasis they place on the cognitive or socio-emotional style of their classrooms.

With increasing recognition that the design of classrooms needs to take into account the range of stakeholders involved in the classroom (Slotta, 2010; Woolner, McCarter, Wall, & Higgins, 2012) and that designing technology-integrated classrooms requires keeping an intentional focus on the pedagogic goals of including technology into the classroom (Smith, Chen, Johnson, O'Brien, & Huang-DeVoss, 2012), we approached the study of the use of multi-touch technology with attention both to the research on collaborative learning and CSCL and to the design of learning spaces to support interaction. While research on collaborative learning indicates that collaboration is an effective pedagogic strategy (Barron & Darling-Hammond, 2008; O'Donnell, 2006), it is a strategy that remains rarely used in classroom settings (Baines, Rubie-Davies, & Blatchford, 2009; Higgins et al., 2005). One reason for this limited uptake of an effective strategy may be that there is little research on collaborative learning in classroom settings, or how a teacher should support and intervene in groups who are working on collaborative tasks (Webb et al., 2009). In addition, while numerous studies have shown that CSCL activities can lead to positive learning outcomes, few explore the use of this technology beyond the lab setting, looking at how it changes when implemented in classrooms (Roschelle, Rafanan, Estrella, Nussbaum, & Claro, 2010). To begin to address these issues, the project described in this paper aimed not just to understand how multi-touch tables can be used by isolated groups of students, but also to look at the technology within the classroom setting. In this paper, specifically, we examine how the placement of the technology within the classroom may influence the group interactions and learning outcomes. We hypothesized that changes to the configuration of the classroom would influence the way group members interacted with each other and their success on the math problems they were working on.

The development of multi-touch interactive surfaces provides new opportunities for computer-supported collaboration in classrooms (Dillenbourg & Evans, 2011; Higgins et al., 2011). Large horizontal multi-touch screens allow multiple participants to interact directly with the content, rather than using a mouse or keyboard, which reduces reliance on a single input device. In collaborative groups, this should reduce the need to negotiate the control of the input device, allowing more equitable participation and greater ability to focus on the task rather than coordinating roles.

While research on this particular technology for educational uses is still in its infancy, preliminary evidence from studies with children indicate that multi-touch tables can support joint attention and more interactive discussion when compared with paper-based versions of the same activity (Higgins, Mercier, Burd, & Joyce-Gibbons, 2012). Research also indicates that, when compared with single-touch conditions, the use of a multi-touch table is associated with more task-focused and less process-focused conversation (Harris et al., 2009). Additionally, work with adult teams indicates that using a multi-touch table led to a better performance and more equitable collaboration than a comparison paper-based condition (Buisine, Besacier, Aoussat, & Vernier, 2012). Taken together, these findings indicate that multi-touch technology may increase the attention to the problem and equity of participation in collaborative groups, suggesting that they have significant potential for supporting collaborative learning activities.

This study was one of a series conducted in a lab classroom specifically developed to investigate the use of multi-touch tables for collaborative learning in a classroom setting (Figure 1). The classroom contains four sit-to-use student tables, which are networked to connect to each other, to the teacher's orchestration desk and to the interactive whiteboard.

The multi-touch tables are rear-projection tables that were built to allow the user to put their legs under the table, and as such, the projector within the table is located on one side of the table, which leads to a triangle of solid space on one side of the table, making this side too awkward to sit at. The tables can, therefore, be used from three sides, with an obvious front of the table that is not suitable for use. This is similar to the way that tables are commonly organized in primary or elementary classrooms with groups of pupils sitting around the tables but with one side of the table kept free so that no one has their back to the teacher (Woolner et al., 2007b). This arrangement is also thought to facilitate transitions between whole-class and group work sections of a lesson (Galton, Hargreaves, Comber, Wall, & Pell, 1999; Wheldall & Bradd, 2013) as it is believed to be easier for the teacher to gain the attention of groups as they are working. The hardware was developed with the support of Evoluce (Hallbergmoos, Germany) and the manufacture of the tables used to house the technology by Ness Furniture Limited (Croxdale, Durham, UK), who are experienced school furniture designers and manufacturers and provided advice on the table height and dimensions to ensure that they were suitable for upper primary school pupils (8–12-year-olds) to use.

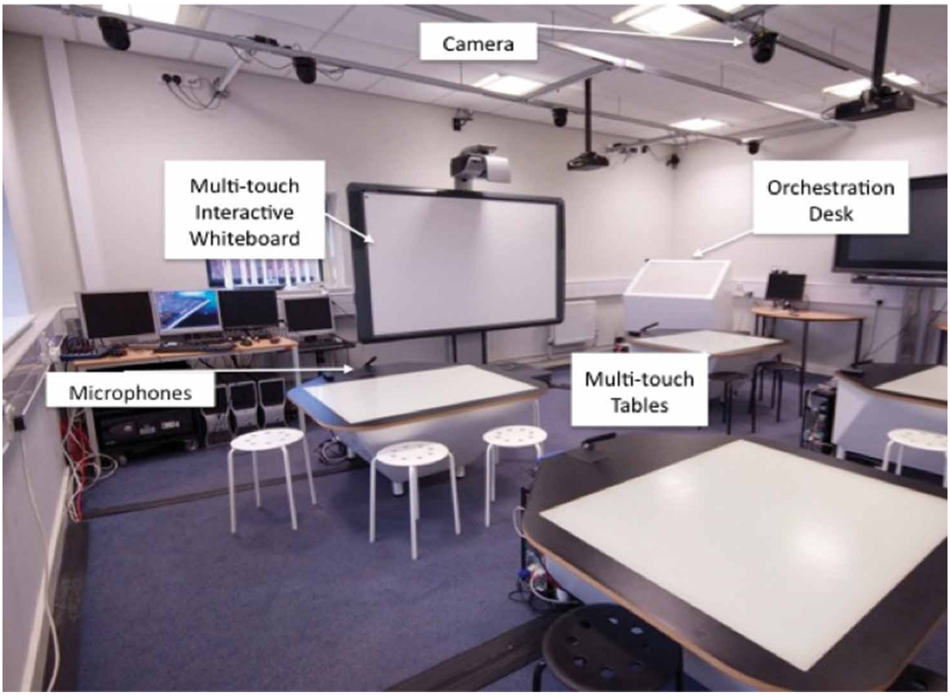

Figure 1. The multi-touch classroom.

Figure 2. Centered classroom configuration.

Figure 3. Traditional classroom configuration.

During the first half of the study, the classroom was organized so that the front of the tables were facing the center of the room forming a circle of the tables (see Figure 2: The centered configuration). For the second half of the study, the front of the tables faced the interactive whiteboard, creating a more traditional classroom environment (see Figure 3: The traditional configuration). One of the aims of the overarching project was to explore pedagogical and technological designs which ease the transition between teacher-centric and student-centric interactions. Three classes were, therefore, taught in each configuration to allow us to examine if the position of the tables influences how the students interacted during the collaborative activities and whether there were differences in the outcomes of the tasks. As discussed above, previous research on classroom seating arrangements indicated that such changes may indeed influence interaction and task success (Hastings & Schwieso, 1995; Wheldall & Bradd, 2013). A study funded by the Design Council (Woolner, Hall, Wall, & Dennison, 2007a) had noted some of the potential advantages and challenges of a circular arrangement in their exploration of a 360° classroom.

Research questions

The aim of this study was to examine whether the physical configuration of the tables in a multi-touch classroom influenced the interactions and outcomes of groups of students engaged in collaborative learning activities. This aim was formalized in terms of examining whether the students' time on task, their progress and success in completing the tasks, and the duration and frequency of the teachers' and students' talk was different in different physical configurations. The intention was, therefore, to focus on any changes in students' behaviors and overall participation in the tasks, as well as any influence on the groups' outcomes which resulted from their collaboration.

Methods

Design

A between-groups (classes) design was used for this study, with half of the classes taught in each of the two room configuration conditions (three in the centered and three in the traditional configuration).

Participants

Participants were 96 students in their final year of primary school in England (mean age 10.58 years; SD = 0.39 years). They were recruited from six local primary schools during the 2010–2011 academic year.

There were 48 male and 48 female students in the sample. Participants were brought to the lab in groups of 16 – eight males and eight females. In each condition, two schools worked in same-gender groups, while one school worked in mixed gender groups (two male and two female students per group).

Students from one class in each of six schools were invited to participate in the study. All the schools who participated are ranked as average, or just below average, on national tests of academic achievement in England. For each of the schools, two or three of the research team went to their classrooms and led the pupils through a number of mysteries and showed photographs and video of the multi-touch classroom. Parental consent forms were distributed, and teachers selected the students to attend from those who returned consent forms. Teachers were asked to select randomly eight male and eight female children to attend. Return rates of consent forms were very high in all schools.

The task

The tasks used for this study were based on a "mystery" framework activity. One goal of framework activities is that they provide a similar structure to tasks, so that students and teachers can become familiar with them, and then different content can be added, allowing for the exploration of the use of the multi-touch classroom, while holding the underlying task design relatively constant. The mysteries framework activities were based on a pedagogical strategy created for the development and assessment of complex thinking in schools (Leat & Higgins, 2002). During mystery tasks, groups of students are given a question and clues that they need to sort through to solve the question. Mysteries are designed to be open-ended, with the clues pointing to multiple possible answers, but the framework can also be used for problems which have a single right answer.

Three mathematics problems are the focus of this study, all of which had a single correct answer. The first task, Sneaky Sydney, required the application of mathematical knowledge to eliminate all but the correct answer, finding the answer to which hotel room a stolen statue was hidden in (e.g. "The room number does not contain the digit three"; "The room number is a multiple of five"). In the second activity, Waltzer, the groups needed to order the clues, working through a series of calculations in the correct order to determine how much it would cost a fairground owner to provide prizes to every 10th person who went on the Waltzer in one day. The final task, Dinner Disasters, was a logic problem, where five fictional children needed to be matched with their food of choice after the school lunch trays had been mixed up. The format and content of the tasks was discussed with each of the teachers who confirmed that these were appropriate activities for their students and typical of the kinds of tasks undertaken in the English National Curriculum.

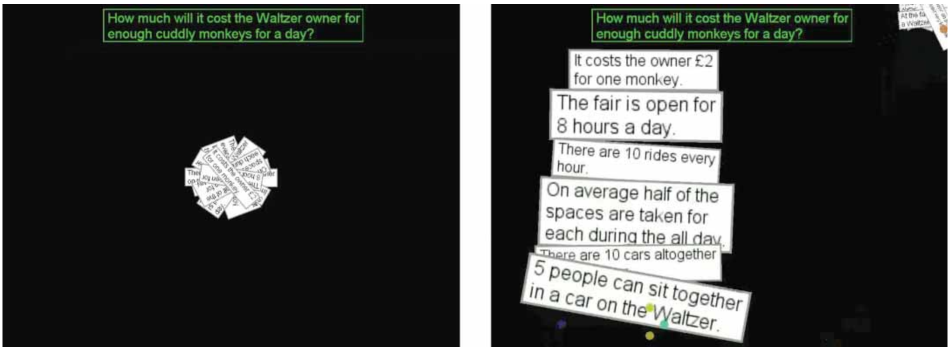

Figure 4. Screen shot of beginning and end of a mystery.

The task design supports collaboration and interaction between students (Leat & Higgins, 2002) and the level of challenge of the task is set so that one child cannot easily solve the problems, ensuring collaboration and interaction (Higgins et al., 2012). Similar paper-based versions of the activities are commonly used by elementary school teachers in the UK; for a full description of the task structure, see Higgins, 2001 (Chapter 5).

Clues were presented on digital "pieces of paper," which were placed in a pile in the center of the screen, while the question appeared at the top of the screen (Figure 4). The digital paper could be moved like normal paper to change the orientation or the location on the screen; the size could also be changed, allowing the groups to enlarge the clues to support joint attention, and to decrease the size of the clues they did not deem to be important. A discussion of the differences between paper-based and digital versions of these collaborative tasks can be found in an earlier study (Higgins et al., 2012).

Procedure

Groups of 16 students were brought to the lab classroom on the day of the study. Students were asked to sit in either mixed it or same-gender groups depending on the condition. Students were then led through a series of activities to help them become familiar with using the multi-touch tables. They then completed a divergent history mystery, which had a similar organizational and presentational structure to the mathematics activities described in this paper, although it did not have a single correct answer. After completing the history task, the students were given a brief break, before returning to the multi-touch classroom to work on the math activities.

Two members of the research team taught in the multi-touch classroom. Each taught three of the six groups (two in one room configuration condition, and one in the other). Both had extensive primary school teaching experience and were familiar with the mysteries tasks and the technology and orchestration tools in the multi-touch classroom.

For each of the three tasks, the teacher introduced the question while standing at the teacher's orchestration desk at the front of the room. They then sent the question and clues to each of the student tables, using tools built into the orchestration desk, and instructed the students to start working on the task. The teachers moved about the room during the activity, monitoring the groups' progress and intervening to help when necessary.

The multi-touch classroom was designed to allow the teacher to take screen shots of the student tables, and project them to the shared interactive whiteboard. The teachers could choose to use this feature both during and at the end of the activity, projecting one of the screens from the students' tables to facilitate whole-class conversation about the task. This was used by teachers during the tasks, to check that all groups were solving the problem correctly, and at the end of the task, for groups to explain how they had come to a particular solution. Teachers selected when to stop the activity, usually when some, but not all, of the groups, have found the solution.

Data

The multi-touch classroom was designed for data collection of group interaction, with 10 video cameras embedded in the lab ceiling. Two of each of the eight traditional cameras collect data from each table, and two fishbowl cameras were placed in the corners of the room, to gather data from the whole classroom. Audio from the tables was collected using a directional microphone, embedded in each table, and the teacher wore a radio microphone. Screen capture software was used to collect the content of the student and teacher tables.

Each video was imported into an analysis tool developed by the project team. Video, audio and screen data were synchronized and the data were transcribed. The analysis tool was created to allow for both timeline and playscript views of the transcript. Analysis was conducted using the timeline view of the transcripts with the video.

Coding of data

Time on task

The length of time that each task took as well as the amount of time spent in small group and whole-class discussion were calculated from the videos for each of the six schools.

Progress on task

Progress on solving the task was coded using a four-level coding scheme, to identify groups who made no progress, little progress, some progress and successfully solved the problem (see Table 1 for definitions). Two authors coded two groups' attempts at each of the three tasks, with a reliability of 83% across the six transcripts.

Duration and frequency of teacher and student talk

When the timeline transcript is exported, data on the number and length of utterances for each participant can be extracted. These data were used to examine differences in the frequency of

Table 1. Definitions of progress on the task.

Title	Description
No progress	No attempt to engage with the task or extremely limited engagement confined to sporadic reading of clues by one or more group members
Some progress	Two or more group members read clues. Little structure when sharing clues, e.g. turn-taking. Calculations based on erroneous reasoning (such as taking numbers in clues out of context and using them in calculations). Only single step relevant calculations. Group makes little progress toward solving the problem beyond reading the clues and single step reasoning
Good progress	Coherent attempts by two or more group members to read and use clues. Multi-step calculations and reasoning to try and solve the problem but final solutions are not reached
Successful	Two or more group members solve problem

utterances and duration of talk that occurred during the task for both students and teachers. Number of turns and duration of student talk were calculated at the student level.

Off-task conversation

Off-task conversation was defined as any utterance that was not related to the content of the task or the collaborative process. All transcripts were coded for off-topic conversation using the time-line view of the transcript. Number of turns, and duration of off-topic talk, was calculated at the group level due to the relatively low amount of off-topic talk in some groups.

On-task conversation

The number of on-task turns was calculated by subtracting the total number of off-topic turns per group from the total number of turns per group. The duration of on-task talk was calculated by subtracting the total duration of off-topic conversation per group from the total duration of talk per group. On-task talk, in this context, indicates some level of collaborative interaction as this had to relate to utterances about the content of the task or the collaborative process.

Results

Time on task

The length of time that each task took was calculated by using the video recording to identify the length of time between when the teacher started talking about each of the three math tasks and when the teacher indicated that the discussion of the task was finished. The time students spent working as small groups, and the time spent in whole-class discussion was also calculated from the video.

The mean length of each task was 7.67 min (SD = 2.18). In the centered classroom, the mean length of task was 8.38 min (SD = 2.71), while the mean length of task in the traditional room was 6.95 min (SD = 1.28). A multivariate analysis of variance (MANOVA) was conducted to examine whether there were differences in the total length of the class, the amount of time spent in small groups or whole-class discussions, depending on the teacher or the room configuration. Results indicated that the main effects of configuration and teacher were not statistically significant, and the interaction effect was not significant. See Table 2 for details.

Across the three tasks and six schools, six tasks were interrupted by the teacher for a mini plenary, while the other 12 tasks were completed without a mini plenary. As can be

Table 2. MANOVA of effect of teacher and room configuration on time on task.

		Df	F	p	η^2
Total time	Room configuration	1, 14	1.63	.222	.105
	Teacher	1, 14	0.004	.949	.000
	Room*teacher	1, 14	0.021	.887	.002
Group time	Room configuration	1, 14	0.305	.589	.021
	Teacher	1, 14	0.063	.806	.004
	Room*teacher	1, 14	0.029	.868	.002
Whole-class time	Room configuration	1, 14	3.312	.09	.191
	Teacher	1, 14	0.203	.659	.014
	Room*teacher	1, 14	0.005	.945	.000

Table 3. Number of classes who had mini plenaries in each task.

	Centered	Traditional
Sneaky Sydney	1	0
Waltzer	0	2
Dinner Disasters	2	1

seen from Table 3, there is no apparent relationship between room configuration and task, in when the mini plenaries occurred.

Progress through task

The progress groups made through the tasks were coded into four categories, ranging from no progress to success. Of the 72 attempts at tasks (3 tasks for each of the 24 groups), only 6 showed no progress, while 28 were categorized as successful. Twenty showed little progress and 18 showed good progress. Table 4 shows the categorization of progress by task and room configuration.

Chi-square analysis indicates that there is no statistical difference in the distribution of success categories for Sneaky Sydney, χ^2 $(N = 24) = 4.74$, $p = .19$, or for Dinner Disasters χ^2 $(N = 24) = 5.37$, $p = .15$. However, the distribution approached statistical significance for the Waltzer task, χ^2 $(N = 24) = 7.77$, $p = .051$, with more groups showing good progress or completing the task in the traditional configuration than in the centered configuration. Chi-square analysis also indicated no differences in success based on gender groupings (all male, all female or mixed gender) for any of the three tasks.

Teacher talk

As two members of the research team taught three classes each, analysis was conducted to examine whether there were difference in the duration of talk and number of turns across teachers. A MANOVA was conducted with duration of teacher talk and number of teacher turns as the dependent variable, and teacher as the independent variable. Results indicated that the main effect of teacher was significant for number of turns, $F(1, 16) = 3.56$, $p < .05$, $\eta^2 = .001$, while the main effect of teacher on duration of talk was not significant, $F(1, 16) = .79$, $p = .39$, $\eta^2 = .05$. This indicates that while both teachers spent a similar amount of the class time talking, their speech patterns are different, with one teacher

Table 4. Distribution of success categories by task and room configuration.

	No progress	Little progress	Good progress	Successful
		Centered		
All tasks	5	15	4	12
Sneaky Sydney	1	3	1	7
Waltzer	3	6	1	2
Dinner Disasters	1	6	2	3
		Traditional		
All tasks	1	5	14	16
Sneaky Sydney	0	1	5	6
Waltzer	0	3	6	3
Dinner Disasters	1	1	3	7

Table 5. Number of teacher turns and time speaking in seconds.

	Number of turns		Duration in seconds	
	Mean	SD	Mean	SD
		Centered		
All tasks	132.67	22.19	797.55	174.98
Sneaky Sydney	34.67	8.50	195.76	69.74
Waltzer	58.67	17.67	336.65	117.92
Dinner Disasters	39.33	5.86	265.14	53.77
		Traditional		
All tasks	93.33	43.84	764.62	153.18
Sneaky Sydney	25	12.77	189.73	80.41
Waltzer	33.33	12.22	314.84	35.63
Dinner Disasters	35	21.66	260.05	81.29

making shorter, more frequent utterances, and the other speaking in longer utterances. Thus, while the speech patterns of the teachers were different, the fact that they spoke for similar amounts of time allowed for the classroom data from both teachers to be compared. This is consistent with other studies of teacher talk in primary classrooms (Galton et al., 1999) and with interaction studies of classroom technology use in primary or elementary schools, such as the use of interactive whiteboards (Smith, Hardman, & Higgins, 2006).

To determine whether there were differences in the amount the teacher talked during the class depending on configuration, the data from the transcript on number of turns and duration of talk were examined. A MANOVA was conducted with number of turns and duration of talk in seconds as the dependent variable; room configuration and task were independent variables.

Results indicated that the main effect of room configuration was not significant for number of turns, $F(1, 12) = 3.87$, $p = .07$, $\eta^2 = .24$. The main effect of task was also not significant, $F(2, 12) = 1.97$, $p = .18$, $\eta^2 = .25$. The room configuration by task interaction was not significant, $F(2, 12) = 0.89$, $p = .44$, $\eta^2 = .13$.

Results also indicated that the main effect of room configuration was not significant for the duration of talk, $F(1, 12) = .09$, $p = .77$, $\eta^2 = .007$. However, the main effect of task was significant, $F(2, 12) = 4.43$, $p < .05$, $\eta^2 = .424$, with more seconds of talk during Waltzer, followed by Dinner Disasters and then Sneaky Sydney. The room configuration by task interaction was not significant, $F(2, 12) = 0.02$, $p = .978$, $\eta^2 = .004$. See Table 5 for details of the means.

Total student talk

To determine whether there were differences in the amount of student talk during the tasks depending of the room configuration, the transcript data on number of turns and duration of talk in seconds for each participant were examined. A MANOVA was conducted with number of turns, and talk in seconds was the dependent variable; room configuration and task were independent variables.

Results indicated that the main effect of room configuration was significant for number of turns, $F(1, 282) = 9.67$, $p < .05$, $\eta^2 = .03$, with more turns in the centered than the traditional room configuration. The main effect of task was also significant, $F(2, 282) = 9.5$, $p < .001$, $\eta^2 = .06$. The room configuration by task interaction was not significant, $F(2, 282) = 1.61$, $p = .202$, $\eta^2 = .01$.

Table 6. Number of student turns and duration of talk in seconds.

	Number of turns		Duration in seconds	
	Mean	SD	Mean	SD
		Centered		
All tasks	24.67	14.41	63.93	41.70
Sneaky Sydney	19.15	10.73	48.07	31.36
Waltzer	29.50	13.46	75.42	43.15
Dinner Disasters	25.38	16.73	68.30	45.11
		Traditional		
All tasks	20.37	9.27	53.96	32.27
Sneaky Sydney	18.13	8.16	46.63	20.63
Waltzer	22.48	8.47	54.65	30.98
Dinner Disasters	20.50	10.66	60.60	41.02

Results also indicated that the main effect of room configuration was significant for the duration of talk in seconds, $F(1, 282) = 5.4$, $p < .05$, $\eta^2 = .02$, with more talk in the centered than the traditional room configuration. The main effect of task was also significant, $F(2, 282) = 7.32$, $p = .001$, $\eta^2 = .05$. The room configuration by task interaction was not significant, $F(2, 282) = 1.76$, $p = .173$, $\eta^2 = .01$. Descriptive statistics are presented in Table 6.

Student off-topic talk

To determine whether there were differences in the amount of off-topic talk during the tasks, depending of the room configuration, the student interactions were coded for evidence of off-topic talk, using the timeline analysis software and the export of the frequency and duration of off-topic utterances. Due to the smaller amounts of off-topic talk, the total number and duration of utterances are calculated at the group level (N = 24 groups). A MANOVA was conducted with number of off-topic turns and duration of off-topic talk in seconds as the dependent variable; room configuration and task were independent variables.

Results indicated that the main effect of room configuration was not significant for number of off-topic turns, $F(1, 66) = 3.29$, $p = .07$, $\eta^2 = .05$. The main effect of task was significant for number of off-topic turns, $F(2, 66) = 5.19$, $p < .01$, $\eta^2 = .14$. The room configuration by task interaction was not significant for number of off-topic turns, $F(2, 66) = 1.2$, $p = .31$, $\eta^2 = .04$.

Results also indicated that the main effect of room configuration was not significant for the duration of off-topic talk in seconds, $F(1, 66) = 2.95$, $p = .09$, $\eta^2 = .04$. The main effect of task was significant, $F(2, 66) = 4.61$, $p < .05$, $\eta^2 = .12$. The room configuration by task interaction was not significant, $F(2, 66) = 0.99$, $p = .38$, $\eta^2 = .03$. Descriptive statistics are presented in Table 7.

On-topic talk

The number of on-topic turns and duration of on-topic talk were examined to determine if there were differences in the amount of on-task conversation during the tasks across the room configuration conditions. This analysis was conducted at the group level. A MANOVA was conducted with number of on-topic turns and duration of on-topic talk in

Table 7. Number of off-topic turns and duration of off-topic talk in seconds.

	Number of turns		Duration in seconds	
	Mean	SD	Mean	SD
		Centered		
All tasks	14.94	18.04	34.83	40.78
Sneaky Sydney	5.33	6.61	13.58	16.26
Waltzer	23.67	24.7	50.74	56.53
Dinner Disasters	15.83	14.03	40.83	32.11
		Traditional		
All tasks	8.97	10.66	21.41	27.65
Sneaky Sydney	4	4.75	9.09	10.88
Waltzer	10.58	11.39	21.76	26.22
Dinner Disasters	12.33	12.94	33.36	36.13

Table 8. Number of on-topic turns and duration of on-topic talk in seconds.

	Number of turns		Duration in seconds	
	Mean	SD	Mean	SD
		Centered		
All tasks	83.75	36.18	220.87	94.46
Sneaky Sydney	71.25	25.55	178.69	70.29
Waltzer	94.33	24.07	250.95	79.91
Dinner Disasters	85.67	51.34	232.99	118.21
		Traditional		
All tasks	72.5	25.19	194.44	54.39
Sneaky Sydney	68.5	18.3	177.42	17.03
Waltzer	79.33	24.73	196.84	62.67
Dinner Disasters	69.67	31.56	209.05	68.11

seconds as the dependent variable; room configuration and task were independent variables. Descriptive statistics are presented in Table 8.

Results indicated that the main effect of room configuration was not significant for number of on-topic turns, $F(1, 66) = 2.35$, $p = .13$, $\eta^2 = .03$. The main effect of task was not significant for number of on-topic turns, $F(2, 66) = 1.79$, $p = .18$, $\eta^2 = .05$. The room configuration by task interaction was not significant for number of off-topic turns, $F(2, 66) = 0.34$, $p = .71$, $\eta^2 = .01$.

Results also indicated that the main effect of room configuration was not significant for the duration of off-topic talk in seconds, $F(1, 66) = 2.21$, $p = .14$, $\eta^2 = .03$. The main effect of task was not significant, $F(2, 66) = 2.78$, $p = .07$, $\eta^2 = .08$. The room configuration by task interaction was also not significant, $F(2, 66) = 0.74$, $p = .48$, $\eta^2 = .02$.

Comparison with other studies of collaborative talk in groups in classrooms (Baines et al., 2009) and whole-class studies of interaction involving technology (Smith et al., 2006) suggests that these patterns of interaction are consistent with other studies of collaborative interaction in primary classrooms.

Gender and talk

In two of the classes (one in each condition), students worked in mixed-gender groups, while in the other four classes (two in each condition), students worked in same-gender

Table 9. Number and duration of all, on-topic and off-topic turns by gender of group.

	Number of turns	Total duration in seconds	On-topic turns	On-topic duration	Off-topic turns	Off-topic duration
All male	95.75 (37.48)	242.16 (81.08)	77.83 (38.94)	200.27 (86.84)	17.92 (20.56)	41.90 (48.33)
All female	77.79 (33.26)	234.05 (90.2)	71.54 (31.13)	217.98 (85.58)	6.25 (7.67)	16.07 (22.32)
Mixed	96.71 (23.9)	231.11 (61.69)	85.00 (21.84)	204.71 (59.86)	11.71 (11.98)	26.40 (25.46)

groups. To determine if the gender grouping was related to on- and off-topic talk during the task, a MANOVA was conducted with gender of group (all male, all female or mixed) and room configuration as independent variables, and amount and duration of talk, on-topic talk and off-topic talk as dependent variables. Results indicated the main effect of gender of group was not significant for amount of talk, $F(2, 66) = 2.84$, $p = .07$, $\eta^2 = .08$, for duration of talk, $F(2, 66) = .13$, $p = .87$, $\eta^2 = .004$, for amount of on-task talk, $F(2, 66) = 1.13$, $p = .33$, $\eta^2 = .03$ or duration of on-task talk, $F(2, 66) = 2.07$, $p = .72$, $\eta^2 = .01$. The main effect of gender grouping was significant for amount of off-task talk, $F(2, 66) = 3.11$, $p < .05$, $\eta^2 = .11$ and duration of off-task talk, $F(2, 66) = 2.81$, $p < .05$, $\eta^2 = .09$, with all male groups engaging in more off-task talk than mixed-gender groups, who engaged in more off-topic talk than all female groups (Table 9). The main effects of room configuration are reported above, and the room by gender grouping interactions was not significant for any of the measures.

Review of results

The study used a range of measures of success and student and teacher talk, to examine the effect of room configuration on interaction and learning in a multi-touch classroom. A summary of the results is given in Table 10.

Table 10. Summary of relationships of room configuration with other variables.

Relationships of room configuration	Significance
With time on task	ns
With teacher and time on task	ns
With progress through Task 1 – Sneaky Sydney	ns
With progress through Task 2 – Waltzer	ns
With progress through Task 3 – Dinner Disaster	ns
With teacher talk – number of turns	ns
With teacher talk – duration of talk	ns
With student talk – number of turns	<.05
With student talk – duration of talk	<.05
With student talk – off-topic number of turns	ns
With student talk – off-topic duration	ns
With student talk – on-topic number of turns	ns
With student talk – on-topic duration	ns
Gender grouping and talk	ns

Discussion

The aim of this study was to examine whether the physical configuration of a multi-touch classroom influenced the interactions and outcomes of groups of students. A comparison of a traditional, forward-facing classroom and a centered seating configuration indicated that the room layout influenced how the students interacted with each other, had some influence on their success on the task, while having little impact on the teachers' behaviors.

Understanding the impact of classroom configuration on interactions and outcomes requires that we attend both to the aspects of the study that changed across conditions, and also those that did not change. Results indicated that the duration of the tasks, the duration and frequency of teacher talk and the amount of off-task conversation were similar across the two room configurations, while total amount of talk was higher in the centered configuration and task success was higher in the traditional configuration. Taken together, these results provide a complex picture of the interaction between group behavior, outcomes, teacher pedagogic flexibility and room configuration.

While the differences in number of groups achieving success in each room configuration was not statistically significant, the frequency data in Table 4 indicate that more students in the traditional classroom were making good progress or were successful than students in the centered classroom. However, the fact that there was no differences in the amount of off-topic conversation between room configurations suggests that, while the centered groups were not making progress as quickly, they were engaging in similar amounts of on-task talk, so were possibly working more collaboratively, with all members of the groups engaged in discussion of the tasks, thus taking longer to show progress, at least according to our metrics. This does suggest that the groups took different approaches to the task depending on the room configuration. Groups in the traditional classroom worked a little faster to complete the tasks, while groups in the centered classroom were engaging in more conversation about the task, and thus making slower progress. This leads to the possibility that students interpreted the goals of the activities differently in the different classroom layouts, seeing the more traditional classroom as one where the goal was to get the answer correct and to provide this to the teacher, while the centered classroom lent itself to higher levels of collaboration and talk about the activity. The forward-facing arrangement more closely matched the classroom layouts that the children were familiar with from their own schools, so they may have "read" into this that the aim was task completion. The circular arrangement may have appeared more informal to the students and so influenced the way they interacted with each other and with the teacher. This interpretation is consistent with the studies of arrangement of classes in groups and rows (Hastings & Schwieso, 1995; Wheldall & Bradd, 2013) which indicate that less interaction is sometimes associated with faster task completion at the class level. This study is important because it demonstrates that the increased interaction was not off-task talk. We do not know from this study, however, whether the slower task completion might lead to a better retention or a better understanding for all of the members of a group, or whether the increase in talk is simply less efficient.

The findings also indicate that, although the number of groups who were successfully completing the task in the centered room was lower than in the traditional classroom, the teachers kept the time-on-task relatively constant across conditions, and each spoke for similar lengths of time. While both teachers reported finding it harder to teach in the centered room, which can be understood in light of the increase in student conversation in that condition, it does not appear that either made significant changes to their own teaching behaviors. This reflects the research that argues for the importance of considering the alignment of teacher preparation and pedagogies, classroom design and technologies (Pointon & Kershner, 2000; Slotta, 2010). While the teachers in our study were members of the research team, and committed to the ideas of collaborative learning, their training was in traditional classroom settings, and it is likely we did not sufficiently prepare them to adapt their teaching behavior to the centered room configuration.

Our findings also indicated that there were no differences in outcomes across the different gender groupings, and that there was no significant interaction between gender grouping and room configuration. Results did show that all-male groups engaged in more off-topic talk than mixed-gender groups, who engaged in more off-topic talk than female groups, indicating that the composition of groups influences the interaction behaviors regardless of room configuration, although the high standard deviations evidence in Table 9 should lead to caution in generalizing this finding see also (Smith, Hardman, & Higgins, 2007). Overall, research indicates that the variation in group formation and performance (Isotani, Inaba, Ikeda, & Mizoguchi, 2009; Webb, 2009) also indicates that caution is needed in interpreting these findings.

Another important implication from these findings for those building CSCL activities is that simply changing the location of the technology within the classroom and the orientation of the desks that students sit at may have an effect on how the students interact with each other and interpret the task demands. Studying new technologies, without attending to the context within which they are being used, is unlikely to provide sufficient understanding of how the context will influence students in a range of classroom environments, leading to a poorer implementation if the technologies are scaled up beyond the experimental setting. The findings confirm, to some extent at least, the research of Marx et al. (1999), who found that a semi-circular arrangement was associated with more questions in fourth-grade classrooms (9–10-year-olds). To promote talk and collaboration, seating arrangements do make a difference but this is mediated by variation in tasks and teachers' behaviors (Wannarka & Ruhl, 2008). Some caution is needed in interpreting any changes in patterns of interaction in experimental studies of new technologies in classrooms compared with existing classroom settings as any change may be as much related to changes in the physical arrangement of the setting as the use of a specific technology. Similar caution is also needed in other experimental studies of classroom environments where the seating arrangements are altered but where this is not one of the variables controlled for in the study.

Future work in the multi-touch classroom will expand to consider how classroom teachers manage their own students in the different room configurations. There is also a need to examine a wider range of tasks, and consider how non-collaborative activities might be affected by the different configurations of the classroom technologies. The tasks in this study were designed to support collaboration in groups (intra-group interaction). They were not designed to support collaboration or interaction between groups (inter-group collaboration or interaction) except where this was mediated by the teacher. Inter-group interaction is likely to have been facilitated by the circular arrangement. Further exploration of classroom interaction which moves between whole class, within *and* between group interactions could also usefully be undertaken, both with and without new technologies.

Dillenbourg and Jermann (2010) talk about the importance of the "physicality" of the classroom in relation to learning technologies. It may be that we can no longer ignore such apparently small changes in our understanding of classroom interaction. This has particular relevance for the use of multi-user technologies and mobile devices, such as tablets, where planning for effective interaction through the organization of the space and the seating arrangements for learners may be as important as the digital affordances of a new technology.

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