An Exploratory Study of Mobile Collaborative Learning in Developing Regions

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ABSTRACT

Researchers have studied how game-based approaches to education might have impact in resource-constrained regions. However, the use of mobile technology, which allows freedom of movement and thus potentially enables more natural game-play behaviour, has not been extensively explored in the context of collaborative learning. In this paper, we explore two mobile-based approaches for using collaborative game-play to supplement ESL (English as a Secondary Language) education in developing regions: (1) *Mobile Single Display Groupware*: a pico-projector connected to a cell phone, with a handheld controller for each child to interact, and (2) *Mobile Multiple Display Groupware*: a cell phone for each child. Our exploration considers the types of interaction that occur in both of these conditions, and the impact on learning outcomes. Our observations also provide insights for the future design of games in this context.

Author Keywords

Game-based Learning, Developing World, Mobility, CSCL.

ACM Classification Keywords

H5.3. [**Information Interfaces and Presentation**]: Group and Organization Interfaces – Computer-supported cooperative work.

INTRODUCTION

While technology has been widely adopted to supplement, as well as impart, education around the world, deploying technological education aids in the developing world is fraught with social and infrastructural challenges not typically present in the developed world [31]. For example, over 90% of the public schools in U.S. have internet access [24], but that is certainly not the case in developing regions like India.

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On the other hand, cell phone penetration has been steadily increasing in developing nations [27,28], creating an opportunity to leverage cell phone based solutions for augmenting education. The mobility fostered by cell phones allows learning to occur anytime, anywhere [3,12,17,30]. One such initiative, MILLEE [3] has been investigating the use of cell phone-based games for out-of-school language learning in developing regions.

Within educational contexts, it is often collaborative explorations with rich social interactions that best foster learning in children [7,20]. Work by Pawar et al [4], for example, supports collaboration on a single PC using multiple mice. While the cell phone has been explored as an education aid, it has typically been considered as an individual-use device, and its potential in collaborative learning has not been explored in developing regions.

In this research, we investigate two different mobile-based approaches for collaborative ESL (English as a Secondary Language) education in developing regions. We use an educational game-based approach, which has been previously shown to be effective by various researchers [1,3,4,6,10,30]. As games are socially engaging, relaxing, and fun, we believe that games designed for collaborative mobile-based learning tasks will make learning more accessible and encourage spontaneous adoption by the children. Further, the mobility and low cost of cell phones make them a good way to introduce educational technology in the developing world.

Our first technology prototype implements *mobile single display groupware* using a pico-projector connected to a cell phone, with a separate handheld controller used by each child for interaction. The second prototype implements *mobile multiple display groupware* by providing each child with a cell phone. In the following sections, we discuss the rationale for these two approaches, the design of ESL education games for them, followed by evaluation of the approaches with children in a developing region. The contributions of our work include: articulation of this new design space, the game designs, and the insights learnt from the evaluations.

RELATED WORK

Roschelle and Teasley [32] defines collaboration as "*the mutual engagement of participants in a coordinated effort to solve the problem together.*" [4] suggests that co-located collaborative learning has higher learning outcomes, in terms of retention, compared to individual learning. Apart from peer-learning and children's liking for doing things together, collaboration has other advantages [7,20] such as giving children more motivation to learn, strengthening their communication skills, helping them resolve conflicts, building positive attitude towards their friends, removing stereotypes, and reducing the cognitive difference between the learners by providing parallel access to the same objects at the same time. However, in some cases, collaboration can also result in new conflicts and frustrations, resulting in more time consumption per task. From a technology perspective, various approaches have been proposed to enable co-located collaborative learning, such as multiple mice [4,5,18] and the SMART Table™ interactive learning center [29].

Researchers [1,6,10] have also studied the design of games to help in education with learning benefits. Educational computer games, better known as "Serious Games", are widespread with examples like Math Blaster, SimCity (a city-building simulation game), Re-Mission (a game that teaches about cancer), and Civilization (a strategy game teaching history). Digital games have immersive properties, demand active participation and challenge an individual to develop new skills, which can increase the enjoyment of a learning experience [6,10].

For effective learning, most of these educational games require one PC per person, which makes it difficult to deploy in the developing world where students typically do not have easy individual access to PCs. To support collaborative learning and efficient usage of existing computing resources, Pawar et al. [4] explored the use of multiple mice on a single PC to enable active engagement by every child in a shared PC scenario. It was found that children were more motivated to play, and they were more successful when every child has their own device to interact with the PC. The Hole-in-the-Wall [8] project explored another approach, installing outdoor computer kiosks in parts of India and Cambodia to support unsupervised group learning. Non-Governmental Organizations like the Azim Premji Foundation and Pratham are developing and freely distributing pedagogically focused multimedia content to impart text-book education in rural India. Digital StudyHall [26] digitally records live lectures and then distributes it on DVDs to rural schools, aiming to provide education along with teacher training. While many of these initiatives have demonstrated value in various ways, most do not directly address collaborative learning per se.

Another factor that can affect the outcome of supplementing educational technology using game-play is mobility – enabling anytime, anywhere learning. As a mobile device, e.g., netbook, cell phone, handheld projector, is typically battery-powered, it doesn't require electricity while operating (though electricity is needed for charging the batteries), thus enabling technology usage in a wider range of settings. Researchers [9,12,30] have investigated the role of mobile technologies in the collaborative learning process. Cole and Stanton [12] developed three different mobile-based learning applications for out-of-school co-located settings, and showed that such game settings allows for more useful sharing of information, can increase children's attention, and are more engaging than traditional game settings. Chipman et al. [9] explore collaborative digital knowledge artifact creation in outdoor environments. Geney [30] is a collaborative application teaching genetic concepts using handheld computers. However these are focused on developed nations, with emphasis on sharing ideas and discussion, rather than on measurable learning outcomes.

Mobile phone-based research initiatives [3,17] have been carried out in the developing world. MILLEE [3] uses cell phone games to impart ESL education, mainly in India and China. MobilED [17] provides audio-wikipedia on cell phones in Africa. These projects provide evidence in support of the value of mobile technology for education, but none of these projects combine both collaboration and mobility in exploring game-play based learning.

CURRENT WORK

Research on co-located collaboration (e.g., [19]) shows that sharing the same physical space is socially engaging and enables non-verbal communications like gestures. In general, there are two ways to support shared interaction with a PC or mobile device, either using a shared public display called Single Display Groupware (SDG) [11], or connecting multiple input devices, called Multiple Display Groupware (MDG). It has been shown [16] that MDG is better suited for task duties completed by individuals, whereas SDG performs better for accessing shared resources, and supporting the teamwork aspects of collaborative work. Scott et al. [18] compared both display conditions for learning activities, using multiple mice. Children rated the SDG condition as more enjoyable and easier to play, because they were able to communicate more effectively and better understand their partner in the SDG condition, compared to MDG.

In spite of the benefits of SDG identified by previous work [4,5,11,16,18], SDG for mobile collaborative learning is yet to be explored, though many researchers [9,12,30] have explored the use of mobile devices in a multiple display collaborative setting. In our present work, we investigate the following two mobile-based co-located collaborative systems, in the context of ESL-education:

(1) *Mobile Single Display Groupware (SDG)*: uses a *projector phone* (a cell phone attached to a pico-projector), with a *handheld controller* (a wireless Bluetooth device similar to a joystick) for each child to interact with the projected game (Figure 1). While integrated projector

Figure 1. Our SDG setup. Each child has their own input device but share a display.

phones are available commercially, none are easily end-user programmable. Hence our prototype simply combines a programmable phone with a pico-projector. The use of projector phones has been previously explored for picture browsing and map application [34], but we are the first to use projector phones for collaborative learning scenarios.

(2) *Mobile Multiple Display Groupware (MDG)*: uses a cell phone for each child (Figure 2). The cell phones are communicating over Bluetooth.

Both our mobile-systems are cheap, plug-and-play, and have very few controls, thus reducing the device-related learning curve. Our hypothesis is that both the display conditions will result in positive learning outcomes. We were also interested in preliminary answers to the following questions: How to design a co-located collaborative learning game that suits both the systems? How does the student play behaviour differ in the two display conditions? What kind of communication occurs, both as individual and as teams, and does that have any impact on learning?

To test our hypothesis, we developed an ESL-vocabulary acquisition game for both the SDG and MDG conditions, and conducted a field study in two rural Indian schools.

Figure 2. Our MDG setup enables interesting leveraging of mobility: hiding under the table in groups and playing.

According to [21], vocabulary is one of the key issues for both teachers and learners of foreign language. In developing nations like India, knowing a foreign language, especially English is considered as a pre-requisite for socio-economic development [22], and as such tools that foster ESL education can play an important role.

GAME DESIGN

Boggle is a word-building game, in which random letters appear in a 4x4 board, and players attempt to find words in sequences of adjacent letters. Any number of players can individually participate. The player forming the most words in 3 minutes is the winner. Boggle offers frequent exposure to words, which may result in learning new words. Boggle [33], introduced in 1972 is time-tested, independent of age limits, and fast and time constrained. One drawback with Boggle is that it is not a traditional Indian game, hence not culturally meaningful [2].

Boggle has the potential to be an educational tool, but lacks elements of control that enable it to facilitate learning of specific words. We thus developed our own version of the game (CollaborativeBoggle) that controls the letters appearing on the board, enforces collaboration, defines teachers' active role in pedagogy (by allowing them to choose the words forming a board), checks whether the submitted word is right, wrong or previously submitted, and teaches new words using image-word association.

In CollaborativeBoggle (Figure 3), two teams consisting of two players each, compete against each other, such that to enter a single word, the team players need to collaborate and select each letter in turn (i.e., one player at a time). Thus two teams are competing against each other, with players of the same team collaborating in a turn-taking manner. Inclusion of competition has added benefits, as students with high achievement motivation have the desire to compete and welcome challenges [14], while collaboration is good for students with low achievement motivation who dislike evaluation and avoid achievement situations. Hence adding competition in conjunction with collaboration can cater to both groups of students in a learning environment.

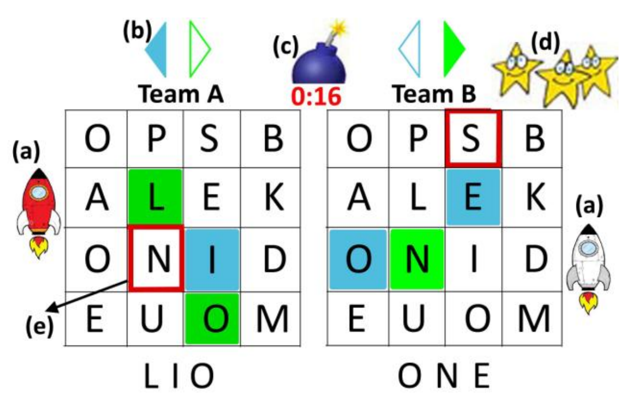

Figure 3. CollaborativeBoggle

While designing the game, we endeavoured to ensure that the game is not biased to a particular system (e.g., an image-word association game would have performed better in the MDG condition, because of the cell phone's QWERTY keyboard layout). We followed the educational game-design heuristics laid down by Malone [1], which are:

Challenge: A game, by nature, should be challenging, and must provide obvious but hard-to-accomplish goals. To make the game more challenging, we added three difficulty levels: Easy (3x3 Boggle board, duration: 2.5 minutes), Medium (4x4 Boggle board, duration: 5 minutes) and Hard (5x5 Boggle board, duration: 7.5 minutes). Within each difficulty level, there were 3 to 9 different Boggle boards (referred to as *lessons*) to choose from. In the SDG condition, the difficulty level and lesson number needs to be chosen using the phone connected to the projector; while in the MDG condition, one of the cell phones randomly showed the selection screen at the start of a new game. To increase time pressure on the participants, a timer was added (Figure 3c). To minimize negative impact of the performance feedback, no negative mark is given for entering wrong words. When the game ends, the score board is followed by a screen asking the winning team to enter the team name, after which a list of *top scorers* is shown.

Malone [1] suggests that to make a goal more obvious, visual effects should be used, but Kam [3] argues that visual animation distracts a child, leading to only fun and no learning. Hence minimal visual effects like a rocket for scores (Figure 3a), and blinking stars (Figure 3d) for every 3 correct responses, acting as a sub-goal and performance feedback, were added. A green tick mark, a red cross mark, or an exclamation mark, with different sound effects was used to depict whether the submitted word is right, wrong, or previously submitted, respectively. To remove confusion over whose turn it is, an arrow was added showing whether it's the left or the right players turn (Figure 3b).

Fantasy: Elements of fantasy makes a game more interesting. Along with a digital timer (Figure 3c), a time bomb ticks towards an explosion during the last 20 seconds and explodes when time becomes zero. Also, a rocket moving upwards, with crackers bursting sound and twinkling stars might be of interest for the children. For simplicity, no characters or story elements were added.

Curiosity: While challenge and fantasy helps children to stick to the game, and play it again and again, curiosity motivates them to learn. At the end of every game, seven (or less) possible new words as suggestions are shown, one at a time (Figure 4, showing APPLE as a suggestion), along with the positioning of the word on the Boggle board and an associated image. The words to be suggested were selected using a *Suggestion Engine*, which takes into account all the answers being input by both the teams, and chooses the suggestions that are closest to one or more of the entered answers. This provides opportunity to the

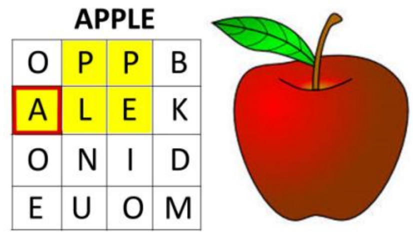

Figure 4. Suggestion screen of CollaborativeBoggle

children to identify their spelling mistakes, or learn new words by relating it to the words they already know. Children were expected to remember the suggested word, so that they can use those words to win the next game. This involves a cued recall task which is cognitively more demanding than a recognition task, and requires higher levels of processing, leading to more retention [15].

Game-play Rules

The game consists of 4 parts, in the following sequence – a) choose the difficulty level and lesson number, b) make words on the Boggle board, c) scoreboard, entering the winning team name, watching the *top scorers* list, and d) suggestion words. The only restriction enforcing the Boggle rule is on the movement of the *selection block*. The selection block is a red-coloured block hovering over a letter that can be selected (Figure 3e). The players are allowed to move the selection block only to those letters that can be selected at a given time. Copying is allowed intentionally by the design of the game, as each team can see what the other team is doing, hoping that this might result in the copying team learning the (copied) word. For example, a copying instance would be Team B copying and submitting the word LION, just after Team A submitted LION (Figure 3).

In the SDG condition, a small handheld controller (Zeemote [23], called a *joystick* in this paper) is used as an input device, which has two basic controls: a *thumb pad* to move the selection-block and a *button* to select the letter under the selection-block. Following the same analogy, the cell phone's *directional keys* and the *Select* key were used in the MDG condition. If a letter that is already selected is being selected again, then the word formed thus far is submitted, reducing the number of controls required for game-play.

FIELD STUDY

Two studies were conducted in different settings: (1) an out-of-school informal setting, and (2) in a formal school setting. A within-subjects design was used, such that each participant played using both the display conditions. Children were allowed to interact freely during the game-play, with no teacher supervision. One of the authors was the only facilitator throughout the study. The facilitator took notes of interesting observations throughout the study.

The two conditions differ in terms of the display and input device. The screen resolution of the cell phone is 640x360, and it has a QWERTY keyboard layout. As the same cell phone is used for both the SDG and the MDG conditions, they thus have same processing power and resolution. Although the projector and phone combination in the SDG condition could be used in a mobile fashion, for the study it was placed on a fixed surface. The projected screen (approx 63 cm x 36 cm) was of much bigger size compared to the cell phone screen (7 cm x 4 cm). The distance between the pico-projector and the projected screen was approx 133 cm.

Study 1

A 4-week long study was conducted at Children's Lovecastles Trust (CLT), an after-school facility situated in the outskirts of Bangalore, India, where students from nearby resource-constrained schools come every evening to learn basic computer skills. As CLT is an after-school facility, the students were from different grades, different schools, and with different English proficiency level. To check this, a paper-based English proficiency test of 40 minutes was conducted during the first week, consisting of 40-image word association questions. Each question was worth a single point, with half points for partially correct answers (e.g., if APPLE is spelled APPEL, the student gets partial credits). The only criterion to participate in the proficiency test is that the child should have basic knowledge of the English alphabet, and have been given formal English training for at least a year in a school. Students who had taken the proficiency test were the only ones considered for the formal study. The words were chosen from [13,25]. 33 students (7 females, 26 males) participated in the test and the mean score was 20.3 (SD=7.7, lowest=6.5, highest=33.5).

During the same first week, the rules of the Boggle game were explained using a version of the Boggle game played on an ordinary blackboard, without the use of any technology. Later that week, the children were divided in groups of two, and were asked to compete against each other on several 3x3, 4x4, and 5x5 blackboard Boggle games. The second week was used for pilot testing, and both SDG and MDG game-play approaches were introduced. A few usability issues were observed which were fixed on a day-to-day basis.

As CLT is an after-school facility, the children's attendance was very irregular. Attendance records revealed that only 13 out of the 33 who took the proficiency test attended more than 70% of the sessions in the initial two weeks (till Friday of Week 2). Out of those 13, 8 students were randomly selected to be part of the formal study over weeks 3 and 4. The 8 participants (1 female, 7 males) belonged to 4 different schools and 5 different grades – 3 from grade 7, 2 from grade 9, and one from grade 5, grade 6 and grade 8 each. The participants age ranged from 11 to 15 years (m=12.75, SD=1.28). All, except one, were introduced to English as a subject from grade 5, resulting in poor English proficiency. Only two of them were able to understand English, and none of them could speak English. A translator was hired to help the facilitator communicate with the participants in their native language, Kannada.

Semi-structured interviews were conducted to learn about the participant's earlier exposure to technology. It was found that all the participants have multiple cell phones at home, and 6 of them regularly play cell phone games, though none of them have past experience with educational games. On the last day of the second week, a 30-minutes paper-based pre-test consisting of 30 image-word association questions, was conducted. The words were the same for all the 8 participants. Even though the participants varied in age, the proficiency test showed they have similar level of English proficiency (m=24.5, SD=4.63), and 30 words that would be unfamiliar to most of them were chosen. The participants were expected to learn these words the following week, using the game, though this was not conveyed to them.

18 Boggle boards (6 for each difficulty level) were constructed using the 30 words, with a single word appearing in multiple boards. During the 3rd week, the 8 participants were divided in teams of two as per their choice. Two random teams were asked to play against each other using the SDG condition, and the remaining two using the MDG condition. Following the within-subject design, for the 4th week, the teams swapped SDG/MDG conditions. The participants played daily from Monday-Thursday, followed by a post-test for the current week and pre-test for the coming week on Friday. The duration of the game-play was flexible depending upon the participant's interest, with an upper limit of 1 hour. During the last 2 weeks, in total, 113 games (SDG=63, MDG=50) were played. The observed mean play-time was 54.18 minutes (SD=4.48). For all the sessions (14 hours 27 minutes), only the participants were video-recorded, not the games screen.

Study 2

The second study was 5-weeks long and conducted at Christel House India (CHI), a school serving children from poor communities. At CHI, 34 students (16 females, 18 males) of grade 3 participated in the first 4 weeks of the study. During the 5th week, due to remedial classes, only 16 (10 females, 6 males) of them, who were high-performing students not requiring remedial classes, continued. All the students were able to understand and speak English. All the paper-based tests at CHI were conducted under a teacher's supervision in the classroom.

Similar to the approach taken at CLT, the first week comprised of an English proficiency test, black-board Boggle and group-wise competitive black-board Boggle. The English proficiency test consisted of 40 words taken from the list of words students have learnt in grade 2. The mean score was 9.5 (lowest=4, highest=22, SD=4.16). A spelling test was also conducted with the same words, and the mean score was 21.1 (lowest=4, highest=34, SD=8.25). This shows that though the children know how to spell the words, they weren't able to recognize the words. During the second week, students were given the actual devices to play the game. On the Friday of the second week, a 20-minutes paper-based pre-test comprising of the 20 words to be taught the next week was conducted.

In weeks 3 and 4 a set of 15 Boggle boards (3 Easy, 6 Medium and 6 Hard each) were created from a subset of 20 words. The set of words were selected from [13,25], after discussion with the English instructor. The mean game-play time was 43.48 minutes (SD=4.37), with a total of 296 games (SDG=148, MDG=198) and 34 hours 4 minutes of game-play. 16 hours 28 minutes of video recording was done.

Study 2: Weeks 3 and 4

As we could not provide a cell phone for every student, half of the students were asked to play on Mondays and Wednesdays, and the remaining half on Tuesdays and Thursdays, followed by a post-test for the current week and pre-test for the coming week, on Fridays. The students were paired in teams of two, as per their classroom sitting arrangement, which was such that a desk was shared between a high and a low performing student. Following the game principle that competition occurs best between teams of equal strength, two such teams (of two) with approximately same average marks in the English proficiency test and pre-test were asked to compete against each other. The two competing teams form a group. With 34 students, 8 such groups (A to G) were formed, and the remaining two students freelancing, i.e., they joined any team in which a member was absent. On a particular day, two groups (Table 1) play using SDG and two using MDG. Groups A, E, C and G were video recorded throughout the study. We only recorded a subset of the groups because only a single experimenter was present during the study.

Study 2: Week 5

For the last week, as there were only 16 students, four groups (A', B', C' and D') were formed, with no freelancers. All children played daily, swapping the conditions after two days (Table 2). Pre and post-tests were conducted in the same manner. Groups A' and C' were video-recorded.

DATA ANALYSIS

Data from different sources – pre-post tests, log files, video recordings, field notes and semi-structured interviews – were collected. Quantitative learning data mainly consisted of 6 pairs of pre- and post-tests. Two were given in CLT (N=8), 2 in CHI, Weeks 3 and 4 (N=34) and 2 in CHI, Week 5 (N=16), totaling 116 pairs of pre-post test data for comparison. A paired t-test was performed separately for both the studies, to measure the learning outcome.

	Days	SDG	MDG
Week 3	Monday, Wednesday	A, B	C, D
	Tuesday, Thursday	E, F	G, H
	Friday	Test+Interview	
Week 4	Monday, Wednesday	C, D	A, B
	Tuesday, Thursday	G, H	E, F
	Friday	Test+Interview	

Table 1. Study Design of Weeks 3 and 4 of Field Study 2

Log files from the cell phone were used to measure game-play time, game count, difficulty level count and scores. We conducted a Display(2) x Team(2) x Day(2) repeated measures ANOVA on the *Total Score* scored by a team on each day. In total, there were 28 such teams (making 14 groups): 4 in CLT, 16 in CHI, Weeks 3 and 4, and 8 in CHI, Week 5. The data from the first two days in CLT were dropped to assess just 2 days of game play in line with data from CHI.

Qualitative data consisted of 31 hours of video recordings of children playing the game. In watching the videos, we identified three discrete types of communication – A student while playing mainly communicated with his/her team partner (*intra-team communication*), the competing team (*inter-team communication*), or the facilitator (*third-party communication*). Based on the more frequent communications in the videos, a video coding scheme was created.

Intra-team communications were often related to the mechanics of the game. We also observed learning-based discussions and non-game, non-learning interactions. Non-verbal intra-team communications like fighting physically, celebrating, and taking control of other player's device, were also noted as part of the coding scheme. *Inter-team communication* mainly was comprised of arguments between the two teams on issues like copying, selecting level, making fun, and challenging the other team. The players were found communicating with the *third-party* for technical assistance, sharing happiness, asking learning-based questions and complaints about other players. In total, 31 coding categories, divided between the three kinds of communication, were defined.

To reduce the possibility of bias, two independent coders (one for each study) coded the videos, noting each time a communication incident occurred. To train the coders, multiple examples for each category were provided to them. An hour of tutorial was conducted on how to perform the coding, with examples. Coders also played the game a few times to get acquainted with it, helping them to better understand the context of the players' communication. A paired t-test to compare participants' performance across the two display conditions, with teams (of two) as the level of analysis was conducted on the data obtained from video

	Days	SDG	MDG
Week 5	Monday, Tuesday	A', B'	C', D'
	Tuesday	Test	
	Wednesday, Thursday	C', D'	A', B'
	Thursday	Test	

Table 2. Study Design of Week 5 of Field Study 2

coding. CLT data was comprised of 4 teams, while CHI had 12 video-recorded teams. As the two studies differed in duration, participant age, play setting, and had different video coders, separate t-tests were required. Due to only 4 teams at CLT, no t-test was performed with the CLT data.

On the last day of every week at each site, semi-structured interviews were conducted to know player's view about the game. Also, the participants were asked about their preference over the playing technique and the reasons.

RESULTS

A paired t-test of the pre-test scores (m=3.06, SD=1.9) and post-test scores (m=8.1, SD=3.89) at Christel House India (CHI) suggests significant learning with t(99)=1.98, p<0.00001. A t-test with the CLT data showed similar result with t(15)=2.13, p<0.0001, pre-test scores (m=5.46, SD=4.9) and post-test scores (m=14.34, SD=9.76). No statistically significant learning difference was found between the two display conditions in either of the studies. Figure 5 shows the mean pre-test and post-test scores, with standard error of means as error bars, which clearly reveals significant learning throughout the study.

At CLT, for week 3, the pre-test mean score is 5.31 (SD=5.22) and the post-test mean score is 14.43 (SD=10.02), indicating that on average children learned around 10 new words, out of the 30 suggested words, after approximately 4 hours of game-play. At CHI, the last two days of week 5 show strong learning effects with mean pre-test score of 4.65 (SD=2.63), and mean post-test score of 11.46 (SD=4). Hence, a child learned around 6-7 new words, from 20 suggested words, with mean play time of 81.3 minutes (SD=5.3). This can be attributed to the high-performing students who participated in Week 5, continuous game-play without a day-break in between, and/or the children getting more familiar with the game-play. We believe that while playing the game, children would also have learned words that were not part of the suggestions, but there is no way to measure such serendipitous learning. With our design, however, we do not know if the learning improvements are due to properties

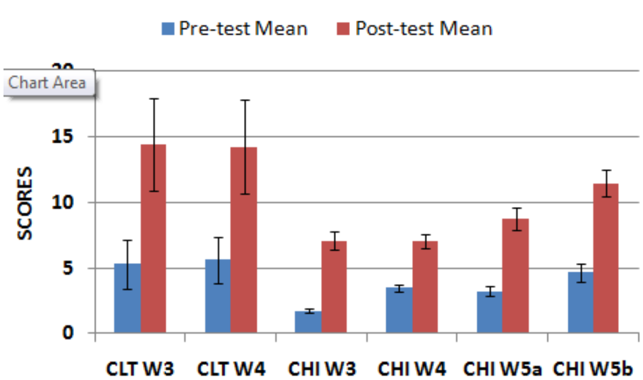

Figure 5. Pre and post-test mean scores (Note: The scores of CLT children are higher because the score is out of 30 points, instead of 20 at CHI, and also CLT children played for longer)

of the game/setting vs. being the result of repeated exposure to the words. The remaining results bolster our argument that our game and collaboration played a role in these learning outcomes.

Observations and Discussion

We were interested in what caused the observed learning improvements, and how students' interactions with the system differed. Because comments were similar from the two sites, we aggregated them and report on them as if they were a single data set, except in situations where an observation occurred in one study and not the other. (Players of the same team are to referred as P1 and P2).

Learning-based Communication

We found children discussing the word, which might be the reason for positive learning outcomes. Students were observed reciting the suggested words as "*Aiyo! Aiyo! We missed SQUEEZE again*", "*I wrote CRANE, I wrote CARAVAN* (in the pre-test)". Team discussions related to submitting words included: "*Let's form B, U, L, B. BULB*"; P1: "*Let's do CAB*"; P2: "*no CAN first*"; P1: "*Enter NOSE*". P2: "*But there is no E. Its N, O, S, E*". Still P1 started with N, and asked P2 to submit O. Finally they submitted NOS and when it was wrong, P2 said "*I told NOSE is N, O, S, E. It ends with E!*" These kinds of interactions likely resulted in serendipitous peer-learning.

Incidental learning was also noted. For example, one team discussed submitting FIN, but one of the players mistakenly selected G, instead of N. They submitted FIG just to start afresh, and were very happy to see FIG as a correct answer. This led them to ask the facilitator "*Sir, what is FIG, sir?*" illustrating how the game-play motivates learning. However, on the negative side, it also encouraged the teams to make random guesses. In some cases, children were aware that they were not just playing, but learning too, as a player telling his team partner "*even if we have to lose, let's just play, at least we can learn English na*."

In the SDG condition, children were more actively asking learning-based questions to the facilitator, like "*What is an AARDVARK, sir?*", "*Is it pynafore or peenafore* (asking about the pronunciation of PINAFORE), *sir*?", "*Sir tell the spelling of YAWN* (along with mocking yawn)", "*I know how a PALETTE looks, but I didn't know the name sir*". A paired t-test on the video coding data shows that the total number of learning based third-party communication per two game-play sessions at CHI, was more in SDG (m=4.16, SD=3.04) than MDG (m=0.66, SD=1.5) with t(11)=2.2, p<0.001, indicating that a classroom situation is more suited for the SDG scenario.

Display(2) x Team(2) x Day(2) repeated measures ANOVA showed that there was a significant effect of Display on learning based communication, F(1,13)=9.1, p<0.01, with SDG significantly outperforming MDG.

SDG vs. MDG

In both SDG and MDG, the dominant child was observed taking control of his/her partner's device (Figure 6), as previously found by Pawar et al. [4]. A paired t-test on the video coding data obtained from Christel House India (CHI) shows that taking control was more common in the SDG condition with $t(11)=2.2$, $p<0.004$. It might be because the cell phone requires both the hands to operate so it is tough to take control of a partner's cell phone in the MDG case, whereas a child can operate two joysticks simultaneously in the SDG case, one in each hand.

Team partners were found scolding, abusing, and even physically fighting with each other (Figure 7), during the game-play. Mostly the dominant players were scolding their partners as "*Whatever you say it's always wrong*", "*you don't know anything. You stupid fellow!*" Inter-team conflict was mostly due to copying instances. A paired t-test analysis on the video coding data shows that the total number of such communications per two game-play sessions, at CHI, was more in SDG with $t(11)=2.2$, $p<0.02$. This might be because a shared screen allows pointing out a player's mistake easily.

Certain other limitations of each system were observed. In SDG the losing team was noted to disturb the game-play by either moving, or blocking the projector. 2 joysticks were broken during the game-play; one was dropped by a child while dancing after winning the game, and other by "*Sir he was cheating* (copying) *so I throw his* (joystick)". In the SDG condition, the children were also found to work in close proximity to one another (Figure 8).

In SDG, children were found directing the joystick to the screen, taking the analogy from the household TV remote controller, and were pointing fingers to the projected screen while discussing, asking their team partners to "*come to S, this S*". In MDG, the dominant child was either found inclining towards his/her team partner (Figure 9) to point and tell, or asking the partner to look into his/her screen, while instructing them what to do.

Though children's preference for any particular display condition was not significant (at CLT, 5 votes for MDG and 3 for SDG, while at CHI, 17 votes for each), we noted some reasons for the stated preference. Students preferred the SDG condition because it has a "*big bright screen*", "*it's easier to play as joystick needs to be moved, not pressed. There is something in centre, and we can move left, right, up or down*". On the contrary, few children also reported that "*it's tough to move to a particular spot, as joystick is very fast, not so accurate*", while children preferring MDG were of the opinion that "*it's perfect aiming in cell phone", "can move letters easily*", "*screen is good, it's more viewable and clear*", but children did complain about the "*smaller screen* size". Children enjoyed playing with the joystick as it "*look like a gun*", "*similar to a* (TV) *remote control*". Children preferring MDG liked the cell phone features as "*touch screen is super*", "*looks like a laptop".*

Figure 6. Dominant child taking control of partner's device

Figure 7. Physical fighting in MDG

Figure 8. Physical proximity in SDG

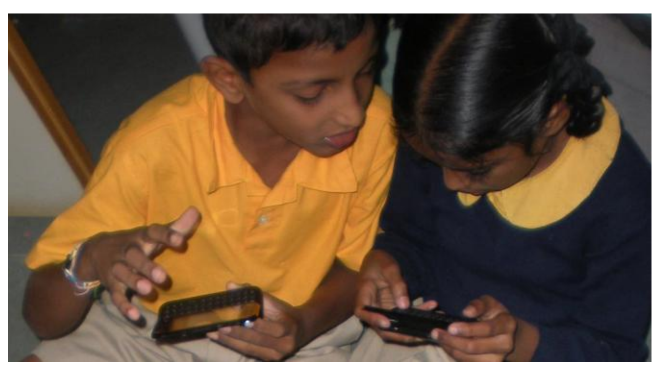

Figure 9. Physically leaning to see partner's screen

Game-based behaviour

Students were frequently noted clapping, singing, dancing, and yelling ("*Ye! Ye!*", "*boo-boo*", "*We are the Winners. We are the Winners.*"), not only after winning a game, but sometimes also after getting a submitted word correct. This shows that the children were enjoying the game and having fun. As the children at CHI were younger, the facilitator noted a higher level of excitement than at CLT.

Copying from the competing team was intentionally allowed. But during the field study, children were found preparing cheat sheets. An interesting incident happened where one of the players (P1) started writing all the suggested words on a piece of paper. During the next few games, P1 tried to enter the words from the cheat sheet, but found little success as the boards were different. Watching P1 concentrating more on cheating and less on finding words, P1's team partner got angry and left the game, saying "*I don't wanna play as he* (P1) *is not playing by proper means.*" However in another similar incident, the two players divided the work among themselves. One of the players found words from the cheat sheet, while the other submitted it using both the joysticks.

Interesting game-related strategies were developed by the teams, like *divide-and-rule* wherein the higher performing player is being asked to remember longer words, as "*I will remember RUG, and you will remember OSTRICH*". The other game-winning strategy, in the player's words: "*Don't go for small words. Let's make big words and make more points. It will save time too, as we need to press OK only once then.*" The students were not explicitly told about the marking scheme, but the scoreboard shows all the correctly submitted words along with the points awarded for each, and longer words carried more points. We believe that these strategies motivated them to learn more.

Children gave several reasons for liking the game: a) Goal of the game: "*I like finding words, and after finding a new word, I feel so happy*", "*I like to spell, spelling is good*", b) Aesthetic of the game: "*Drawings were very good*", "*After making words, the showing of stars and rocket going up is really good*", c) Competition factor: "*I love to compete*", "*Winning is good*", and d) Playing with friends: "*… nothing specific about the game, I just like playing with my friends.*", "*I like to beat him* (my team partner) *when he don't listen to me*". Reasons stated for not liking the game were: "*When I lost, it's bad*", "*Only the time over is bad*".

Usability and Game-design Issues

The following usability issues were noticed during the pilot study, and changes were made accordingly:

Common on-screen controls like *Pause/Resume*, *Time+*, and *NextWord*, were removed after the pilot study, because of their misuse, primarily in the MDG condition. *Pause/Resume* button allows the game to be paused, but as all the phones are connected, pausing (resuming) on one phone causes all the phones to pause (resume). The losing team started using this option to obstruct the game-play. *Time+* resulted in longer games, but a decrease in the suggestion screen time per game, which could have a negative effect on learning. In SDG, time was rarely incremented as changing time requires a player to use the cell phone (connected to the projector), and also other players can intervene, which is not the case in MDG. This indicates that designers should *minimize introduction of common controls* in these situations, more so in SDG.

In [2], some cultural games with a strong narrative component were studied, and they concluded that identifying with a culturally relevant narrative was important to game success. We studied a game with no strong narrative, but showed clear positive effects. This surprised us, and we speculate that *cultural relevance may matter less when narrative is less prevalent*, and players need not identify themselves with any character(s) of the game-story. To make a stronger claim, more research is required.

During the study, some game components were found to have a positive impact on the game-play:

Incidents indicate that to top the *top scorers* list was a constant motivating factor to perform well, as "*we need to score 56 to get to 2nd position, and 61 to be at the top.*", "*Sir see, see na. We are 1st, 2nd, and 3rd* (in the top scorers list). *We are awesome!*"

The *Suggestion Engine* was well taken by the students as we came across statements like, "*Aiyo! I misspelt SQUIRREL!*", "*Oops*! *Missed PUZZLED again, though entered PUZZLE.*" Thus the suggestion engine was making them curious to know the words they missed or misspelt in the Boggle board, and helping them to identify new words by relating to the words they already know.

Game components which could have been improved:

Entering winning team-name led to many conflicts like "*see sir, he is always putting his name first*". The winning team-name entry component could have been designed such that the system take input of each team name only once at the beginning of the game, and then after shows the winning team name throughout.

Submission of the suggested words during the game-play could have been followed by showing the image of the word, for *positive reinforcement*.

CONCLUSION

Our results suggest that mobile collaborative technologies have benefits in educational environments. The video data indicated interesting trends suggesting differences between the two display conditions, but these results must be interpreted with caution. The small sample size, high variability between the choice of difficulty level and play-time, limited these analyses. SDG encouraged more learning based-communication with the third party, but also led to more off-learning behaviour, including the dominant child taking control of his/her team member's joystick.

With increasing cell phone penetration, and prototypes of projector-phones already in the market, we believe that within the next few years, system like those explored here can be integrated both in and out of the classroom.

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