

An Exploratory Study of Unsupervised Mobile Learning in Rural India

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ABSTRACT

Cellphones have the potential to improve education for the millions of underprivileged users in the developing world. However, mobile learning in developing countries remains under-studied. In this paper, we argue that cellphones are a perfect vehicle for making educational opportunities accessible to rural children in places and times that are more convenient than formal schooling. We carried out participant observations to identify the opportunities in their everyday lives for mobile learning. We next conducted a 26-week study to investigate the extent to which rural children will voluntarily make use of cellphones to access educational content. Our results show a reasonable level of academic learning and motivation. We also report on the social context around these results. Our goal is to examine the feasibility of mobile learning in out-of-school settings in rural, underdeveloped areas, and to help more researchers learn how to undertake similarly difficult studies around mobile computing in the developing world.

Author Keywords

Cellphone, Developing countries, India, Mobile learning, Informal learning, Out-of-school learning

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms

Design, Experimentation

INTRODUCTION

According to the World Bank, “there are still precious few widespread examples of the use of [mobile] phones for education purposes inside or outside of classrooms in

developing countries that have been well documented, and fewer still that have been evaluated with any sort of rigor” [21]. The cellphone has been argued to be an appropriate device for educational delivery in the so-called developing world [3, 10]. It is a low-power device that can be used in places without reliable electricity. Even though it is largely purchased for voice communications – which semi-literate users rely on for their social and economic needs – it is also able to run educational software that support visuals and voiceovers. Most of all, the cellphone is the fastest growing technology platform in the developing world. There are 2.2 billion mobile phones in developing regions like Africa and India, as compared to only 11 million desktops [6].

While cellphones can be deployed in schools in developing countries, the greatest opportunity is to facilitate informal learning in out-of-school environments so as to complement formal schooling. In underdeveloped regions, particularly rural areas, many schools are not only poorly equipped or lack highly-trained teachers. Worse, school attrition can be prevalent in underdeveloped regions. For instance, in rural India, about 43% of school-age children cannot attend school regularly because they have to work for the family in agricultural fields or households [1]. Mobile learning thus empowers poor children to balance their educational and income earning goals, by enabling them to learn anytime, anywhere, in places and times more convenient than school.

This paper’s contribution is to report on how rural children use cellphones in their everyday lives when they were given access to cellphones throughout 26 weeks. The cellphones were pre-loaded with our applications that target English as a Second Language (ESL) – an important “gateway” to economic advancement in India – but our findings should generalize to other subject matter. To our knowledge, this is the first study on how rural children in the developing world used cellphones in their everyday lives, when researchers were not present to artificially influence participants to use the phones for learning. As the first such study, it is inevitably exploratory. We wanted to understand the opportunities for children to engage in mobile learning in everyday rural settings. More importantly, what are the social contexts that exist in these settings? What are the challenges to mobile learning in such naturalistic settings?

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RELATED WORK

Koole [14] argues there is a tremendous scope for mobile learning and establishes a framework to assist practitioners in designing activities appropriate for mobile learning. Klopfer [13] adds that mobile learning games are not only engaging, but can also account for the user's context and environment to improve on the learning process. Mobile learning has been applied to the domains of nursing education [12], online communities [4, 5] and distance education [8, 16]. Similarly, Jarkievich et al. [9] and Scanlon et al. [17] explore the usage of mobile phones in outside classroom settings, whereas Bell et al. [2] study the social interactions around cellphone-based games in everyday settings. However, all of the above studies are based in developed world settings. A major contribution of this paper is instead to explore the scope of mobile learning in poorer developing regions of the world.

We are not the first researchers who have evaluated mobile learning in the developing world. It has been examined in the context of specific developing regions like Africa [3, 6, 8], China [20] and India [10]. Whereas Ford et al. [6], Gregson et al. [8] and Kam et al. study mobile learning for education in developing regions, their studies took place in controlled classroom settings. Moreover, Brown [3] draws a comparison between the existing e-learning techniques and opportunities for mobile learning; whereas Wang et al. [20] describe the opportunities of mobile learning in K-12 and higher education in China to improve teaching, learning and course delivery. With the exception of studies by Scanlon et al. [17], Jarkievich et al. [9] and Bell et al. [2] in the industrialized world, no one has made an attempt to study mobile learning in unsupervised settings. This paper hence extends the body of knowledge about mobile learning to unsupervised settings in the developing world.

STUDY TIMELINE AND METHODS

The entire study was conducted in two phases: (i) summer 2008, and (ii) spring and summer 2009. The time spent in the field totaled 28 weeks. The field research took place in two neighboring villages in a mango-growing district in the northern state of Uttar Pradesh in India. By rural standards, one village was relatively prosperous while the other was typical. We chose to work with both communities because we have had a successful history of running mobile learning trials with them, one of which was a pilot deployment that took place as an after-school program three times per week over an entire semester [10]. In those studies, researchers were present throughout all sessions. This study was a significant departure in that we wanted to understand rural children's mobile learning behaviors in non-school, everyday settings. It is infeasible for researchers to be present in these settings – some of which are private social spaces – over months. Worse, the presence of researchers could artificially affect participant behavior. We believe that we have had enough successes with both rural communities to collect meaningful data without needing our researchers to supervise their use of cellphones.

Phase 1: Participant Observation (2 weeks in June–July 08) with 45 children from 20 households to understand the social dynamics around cellphone use and adoption among children in rural India. The first week focused on getting a glimpse of the participants' everyday lives. We carried out participant observations, after which we analyzed our field data to construct accounts for “a day in the life of a child.” We then offer plausible scenarios for everyday, cellphone-enabled learning that emerged from these accounts. In all, we identified 9 distinct scenarios. In the second week, we examined the feasibility of these scenarios by having participants use our mobile learning applications during various times in the day. Instead of imposing predefined tasks, we encouraged the children to come up with their own ways of using the applications. Our observations and interviews gave us preliminary insights to these scenarios.

A researcher who is a native of India led this 2-week field study. Her grandparents taught her the social norms around village life when she grew up in a village. Her education on rural culture continued over a seven-year stint as a social worker in villages throughout North and South India. She speaks 5 official languages in India, including Hindi, which was the participants' native language. She was introduced to the villagers by a respected community leader who had excellent ties with the community and was supportive of our study. His support helped us to establish our credibility among the villagers. On the other hand, he belonged to the priestly (i.e. elite) caste, which could lead to lower-caste villagers associating us with the upper castes. To mitigate this barrier, she cultivated ties with the lower castes by not spending her time exclusively at the community leader's home. To gain further acceptance, she wore the traditional garb that the participating families wore, spoke their dialect, and accepted the refreshments they offered.

Phase 2: Deployment in Naturalistic Setting (26 weeks in January–July 09) with 18 children from 15 households to understand their mobile learning behaviors in everyday rural settings. This phase built on the initial lessons that we learned about various rural scenarios for everyday, mobile learning from phase 1.

It was unfeasible to re-enroll all participants from phase 1 into phase 2 since the latter, being significantly longer-term than the former, implied that their parents needed to take responsibility for the phones we loaned. In the beginning of phase 2, we interviewed participants on their demographics such as their ages and grades they were enrolled in. We loaned each participant a Motorola Razr V3m cellphone that was preloaded with our mobile learning applications. Participants were asked to keep the cellphones for the entire duration of phase 2 and could put the phones to any uses so long as they had parental permission. This flexibility was important in allowing us to examine, under naturalistic conditions, the degree to which participants will engage in mobile learning voluntarily. (Most participating households owned cellphones, but it was necessary to loan cellphones to participants given the engineering complexity in ensuring

that our prototypes were compatible across a diverse range of cellphone models.)

In the first 10 weeks, we visited the villages twice per week to train the participants to play the applications and show them how to troubleshoot technical problems. We also used these occasions to hold short, semi-structured interviews with participants on their use of the cellphones. We ceased these visits after the 10th week, when it seemed participants could use the cellphones on their own, so as to transition the study from a controlled setting to an unsupervised setting.

In order to collect more data about participant use of the mobile applications, we designed these applications to log user actions. We had also designed these applications such that they took the form of game-like activities, to motivate participants to play them in the absence of teachers. Due to the challenges that we will describe later, however, we were only able to retrieve the logs from 13 of the 18 cellphones at the end of phase 2. In the last two weeks of phase 2, we conducted exit interviews in order to obtain qualitative data that helped us contextualize our logs.

PHASE 1: PARTICIPANT OBSERVATION

This phase took place over 2 weeks. The first week was spent understanding the daily lives of the participants and identifying scenarios for mobile learning in unsupervised settings. The second week examined the feasibility of these scenarios by asking our participants to use mobile learning applications under conditions that reflect these scenarios.

Participants

Participants for this phase were recruited through snowball sampling, i.e. we began with the families we knew best, and their children led us to their friends and so on. In total, they comprised 45 children from 20 households, broken down as: 6 upper-caste girls, 3 upper-caste boys, 23 lower-caste girls and 13 lower-caste boys. This breakdown mirrored the local demographics. These children were between 7 and 18 years old (mean=12 years). The participants were from 3 different schools in the community – 2 private and 1 public. These schools mostly varied in their affordability, i.e. only the upper strata of village households could afford private schooling and the poorest went to public school, if at all. Attending school for the poorer children also implied less time to earn a living from working in the fields. More importantly, English teachers in all schools were unable to converse with us in English, thus supporting the need to supplement English classes in school for participants.

Among the 20 households from the above community who participated in the study, we learned that all of them owned a cellphone each, with at least two households owning more than one cellphone each. The phone was usually used by the eldest male in the family. In poorer households, children were allowed to receive calls, but not play cellphone games due to the fear that they may drop the phones. In wealthier homes, children were allowed to play games on the phones, and one boy possessed a phone of his own.

Scenarios for Cellphone-Enabled Learning

We observed that our participants' everyday lives revolved around four functional contexts beside school: agricultural work, household chores, home and play. In particular, key differences in these everyday contexts seemed to be highly delineated along two major social factors, i.e. gender, and caste. Owing to agricultural work, we observed qualitative differences in the activities of the boys between school and non-school days during different times of the day. But there were no significant differences between school and non-school days for the girls since their lives revolved around domestic work.

Given the non-homogeneity among participants in our field data, we shall attempt to simplify this complexity for the reader by emphasizing the similarities across participants along the major dimensions of gender, caste and time of day (Table 1). Specifically, we constructed accounts of a school and non-school day in the lives of the following four hypothetical characters. Two siblings come from an upper-caste home: Amit (15 year-old boy, 10th grade) and Gauri Trivedi (13 year-old girl, 8th grade). The second pair of siblings Hari (10 year-old boy, 4th grade) and Resham Gautam (12 year-old girl, 6th grade) belong to a lower-caste household. These archetypes have been constructed so as to deliberately represent the entire spectrum across age, caste and gender to the maximum extent possible.

Time of Day	School Day		Non-School Day	
	Upper Caste	Lower Caste	Upper Caste	Lower Caste
Early Morning	2 Boys 6 Girls	11 Boys 23 Girls	n/a	n/a
Morning	2 Boys 5 Girls	11 Boys 20 Girls	3 Boys	10 Boys
Afternoon	3 Boys 6 Girls	13 Boys 23 Girls	3 Boys	10 Boys
Evening	2 Boys 6 Girls	12 Boys 21 Girls	n/a	n/a
Night	3 Boys 5 Girls	13 Boys 22 Girls	3 Boys	13 Boys

Table 1. Each cell gives the number of participants who corresponded to each archetype, broken down by the time of day, type of day, caste and gender.

Early Morning (5:30 am to 7:00 am)

Both Gauri and Resham wake up earlier than their brothers because the girls are responsible for all the household chores in the morning like cooking and house cleaning. In contrast, the boys wake up and go straight to school if it is a school day. If it is not a school day, both Amit and Hari head to the fields.

Morning (7:00 am to 2:00 pm)

On a school day, all four children walk to and from school in groups consisting of their neighbors or relatives. (We shadowed participants walking to school on ten separate occasions. We observed that the children walked for at least

an hour a day on average.) The children are busy in classes for the entire duration while they are in school, except for a 15- or 20-minute break in the middle of their school day.

On non-school days, the girls Resham and Gauri stay at home to help with household chores, and possibly also any agricultural work. For Resham and Gauri, work is not a continuous activity – instead it occurs sporadically and they often have “idle time” between “bursts” of activity. Hari works as a hired laborer who plucks mangoes or tends to fields belonging to Amit’s family, while Amit supervises child laborers including Hari.

Afternoon (2:00pm to 5:30pm)

Upon return from school, Reshma and Gauri help with household chores e.g. washing the dishes, carrying water, gathering grass for cattle etc. Later, when the adults take an afternoon siesta, Gauri plays indoors or in the backyard with her neighbor’s daughters. She stays indoors because it is socially unacceptable for girls in general and upper-caste girls in particular to roam about in the streets. In contrast to Gauri, lower-caste girls such as Reshma are expected to go out to the fields to graze their goats during the afternoons. On the other hand, boys such as Amit and Hari are allowed to go outside to play outdoors with other boys in the village.

In the afternoon on a non-school day, while Reshma and Gauri follow the above routine, Hari helps to transport the mangoes which he plucked in the morning to Amit’s home. Amit takes the mangoes to the market to sell.

Evening (5:00 pm to 7:30pm)

On a school day, in the evening, both Resham and Gauri help to prepare dinner at home. They are interrupted every few minutes by a family member who asks them to do some housework chores. Both the girls do their homework in the free time between chores. On the other hand, Amit and Hari either do their homework or watch TV until dinnertime at night.

On a non-school day, Amit keeps watch in the fields with his upper-caste friends. While keeping watch, they would also listen to the radio or play board games like snake and ladder. On the other hand, Hari stays at home to finish his homework or goes to his neighbor’s house to watch TV. In contrast Reshma and Gauri have housework to do all day.

Night (7:30pm to 9:00 pm)

On a school day, Hari and Amit watch TV at a neighbor’s or his home respectively before having dinner. After dinner, they stay up for an hour before going to bed. Resham and Gauri wash the dishes after their families had dinner. Like the boys, Resham and Gauri also find an hour of free time before they go to bed.

During non-school days, Amit keeps watch in the fields at night. Accompanied by other upper-caste boys in the fields, Amit sleeps in tents that are erected in the fields (Figure 1). On the other hand, Hari stays at a neighbor’s home to watch TV.



Figure 1. An upper-caste boy plays an e-learning game on a cellphone, sheltered from the sun by a tent in the fields (left). In fact, upper-caste boys spend so much time in the fields that the inside of the tent’s roof became a convenient location for stashing things that they use while in the fields (right).

From “a day in the life accounts” such as the ones above, we analyzed them to identify opportunities for mobile learning. These opportunities are presented in the form of 9 scenarios (i.e. scenarios A to I) for mobile learning:

- A. *A child uses a mobile learning game when walking to school or work.* Since the child has to concentrate on walking on the road, audio-based learning applications that do not distract the child from paying attention to where he or she is heading are more viable.
- B. *A girl plays an e-learning game on a cellphone when she has downtime between housework.* We found that there is intermittent downtime between chores, such as cleaning the home, cooking, washing dishes, gathering firewood and getting fodder for cattle.
- C. *An upper-caste child (usually a boy) plays a cellphone-based e-learning game when in the fields.* We do not expect boys from the lower castes to use their cellphones in the fields, since they would have to be at work as hired laborers. In contrast, upper-caste boys have time to play e-learning games in the fields, since they are present only to supervise their hired laborers.
- D. *A girl is sharing a cellphone with other girls and is playing an e-learning game with them, just as the adults are taking their afternoon rest at home.*
- E. *A lower-caste child (usually a girl) plays an e-learning game on a cellphone while grazing the goats outdoors.* This scenario only applies to lower-caste households, who are the only people to keep goats. In such families, it is the girls who take the goats out to graze.
- F. *A boy is sharing a cellphone with other boys and is playing an educational game together with them, in the afternoon.* Since boys are permitted to go outdoors more freely than the girls, boys have access to a greater social circle of playmates. In any case, children never play with other children from different castes.
- G. *A boy plays an e-learning game on a cellphone during his free time in the evening before dinner.* On the other hand, after girls have completed their homework in the evening before dinner-time, they would be occupied in the kitchen helping their mothers prepare dinner.

- H. *Siblings play an e-learning game together as a group, on a cellphone that they are sharing, in their free time between dinner and bedtime. In both upper- and lower-caste families, boys have more time than girls to play. But after the girls have completed the housework, they have time to play with their brothers, albeit usually as passive observers.*
- I. *Upper-caste boys share a cellphone in order to play an e-learning game, while they keep watch in the mango groves either in the day or the night.*

Questions Raised

We needed to investigate the extent to which the above scenarios were culturally appropriate within the rural Indian context. As such, in the second week of phase 1, we asked participants to use a suite of e-learning software prototypes over various times of day. Initial results showed that with the exception of scenario A, the other scenarios seem to be feasible. Here's why: An upper-caste boy said he would not take the cellphone to school lest it was stolen. Similarly, 2 girls from lower-caste households told us that their parents prohibited them from taking their cellphones out of their homes for fear of theft. Hence, although we had imagined children learning via cellphones when walking to school or work in scenario A, this scenario did not appear feasible when school was the destination. On the other hand, we saw 2 upper-caste boys carrying their cellphones with them when they were in their fields. Likewise, participants took our phones to their neighbors' and their own homes to show the mobile learning games to their friends.



Figure 2. The boy is attempting to take the cellphone away from his sisters (left). Since girls in India are conditioned to accede to the male members in their families, they handed the cellphone to him. They were not only denied their chance to play the educational game on the cellphone, but also had to “wait on” their brother by holding the phone for him (right).

In phase 1, we observed that the children's mobile learning behaviors varied with their caste, gender and the time of the day during which the participants tried out the mobile learning games (Figure 2). However, this phase left us with some open questions that needed to be answered in order to understand the efficacy of mobile learning in the absence of supervision from facilitators or instructors:

- *What are some patterns of cellphone usage that are observed over a non-trivial length of time in the absence of supervision from researchers?*

- *What are the challenges – both social and technical – that affect cellphone usage and mobile learning?*
- *How well does the cellphone mediate social interactions among rural children?*
- *To what extent does mobile learning actually happen voluntarily in everyday settings?*

We set out to address the above questions in phase 2.

PHASE 2: DEPLOYMENT IN NATURALISTIC SETTING

This phase took place over 26 weeks, in which the actual unsupervised portion comprised 14 weeks.

Participants

Despite an initial reluctance from parents in the two village communities to enroll their children in the study due to the need to be accountable for the phones, we faced a deluge of interest from more parents after a few parents agreed to have their children participate in the study. In total, parents expressed interest to have 25 children participate. We had to turn 7 children away because they did not exhibit, on a screening test, the level of prerequisite English knowledge that would enable them to cope with the curriculum in our mobile learning games. The 18 children came from 15 households and were broken down as follow: 2 upper-caste girls, 6 upper-caste boys, 7 lower-caste girls and 3 lower-caste boys. They were 10 to 14 years old (mean = 12 years). There was no attrition throughout the study.

14 out of 18 participants came from families who owned at least one cellphone. In general, cellphones were primarily used by the eldest male member in the family. 7 children belonged to families who owned phones with color screens, as opposed to monochrome displays. At least 5 of the above families had cellphones that were programmable i.e. we could install custom Java-based applications on them. Most cellphones owned by participating families had commercial games such as Snake pre-installed. From our demographics interviews, we learned that participants previously played these games on their fathers' or elder brothers' cellphones.

Prototypes

Participants were loaned cellphones with preloaded games. Due to the non-existence of mobile learning games that target rural children, we designed and implemented a set of games for phase 2. The game designs are based on traditional village games which have been found to be intuitive, engaging and motivating for rural children [11]. In total, we had four different game designs that targeted different ESL competencies spanning across both oral and written modalities. The games that targeted vocabulary covered a total of 180 word families.

Figure 3 shows one of these games. It was adapted from a traditional game called Marakothi, in which the player is required to pick up a stick and climb up a trees before an opponent catches him. We adapted Marakothi into a digital learning game that targets English listening comprehension.

In this adaptation, a set of words are introduced by playing their audio pronunciations and showing graphics of their meanings on the screen. A randomly selected word from the set of introduced words is read aloud and the player has to pick up the stick that corresponds to its meaning.

Findings

Although the study took place in a rural setting, there were electrical outlets in all but 2 of the participants' homes to recharge their phone batteries. The real challenge was that the power supply was irregular or unstable. For example, electricity could be randomly available on the grid for 2 hours in the afternoon and for another 2 hours at night. One of the participating families owned a power generator at home that was used to charge its phones. This family was among the wealthiest in the community. We learned that in at least 3 other participating households, the adults had electrical sources at their workplaces (e.g. generators) that were more reliable than their electricity supply at home. Their children would therefore recharge our cellphones at their parents' workplaces. Lastly, at least 4 households in the study had power outlets at home that supplied electricity with highly fluctuating voltages. This fluctuation damaged our battery chargers and required us to replace the chargers twice to these 4 families in the first 10 weeks of phase 2. It turned out that these 4 families were among the poorest in the community and could not afford their own cellphones. They were hence unaware that their electrical outlets could not support cellphone chargers until enrolling in our study.

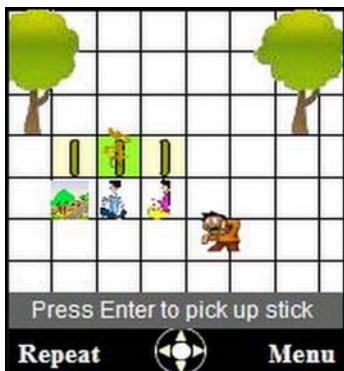


Figure 3. A screen from “Marakothi” that shows the player picking up a stick, while the enemy figure tries to catch him.

We saw several social rituals around electricity. Participants who lacked an electricity outlet or generator at home relied on their neighbors who did to recharge our cellphones. The latter households were generally more than willing to allow neighbors to recharge our cellphones using their generators, but the former seemed hesitant to take advantage of the latter's generosity on every occasion, potentially due to the implied obligations. (Neighbors who allowed their power sources to be used were not necessarily participants in our study). In addition, we observed that participants would not leave their cellphones plugged into the wall outlets while away from home because it was considered unsafe to leave equipment lying around without their constant vigilance. In

other words, they would charge their cellphones at home only when physically at home. Worse, we observed that the power situation was exacerbated since participants enjoyed watching and/or listening to music clips on the phones (which they bought at point-of-sales outlets in town and shared among themselves via Bluetooth). These multimedia applications consumed more power than regular cellphone applications and drained their batteries more quickly. Participants also exchanged wallpapers and ringtones with one another on our cellphones. Lastly, at least 4 participants paid about 10 rupees (US\$0.20) per month for prepaid calling cards, which they used to make voice calls to other participants.

Duration of Cellphone Usage

Despite the above electricity challenges, participants were still able in most cases to keep their cellphones sufficiently charged to access our e-learning games, as our logs showed. On average, participants accessed the games for a total of 46 hours ($\sigma = 44$ hours) throughout the entire study, i.e. 2 hour 23 minutes in each week. Figure 4 shows the breakdown by each participant. (However, we were not able to retrieve the logs for 5 participants after week 10 due to the battery “swelling” problem, which we describe below. These participants are marked by asterisks in Figure 4. We believe that the missing logs do not significantly affect our statistics on cellphone usage for the affected participants because 4 of them had siblings who monopolized their use of our cellphones, as we elaborate below.)

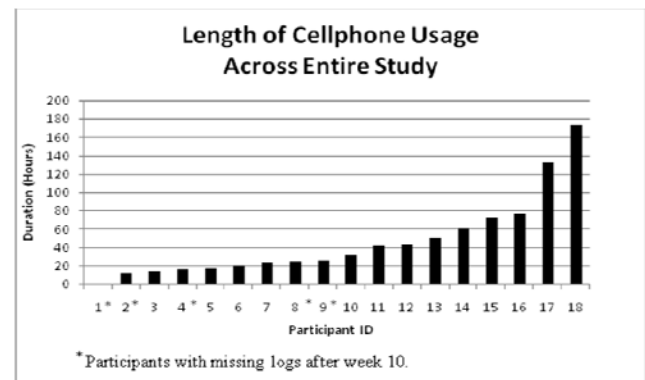


Figure 4. Length of time that each of the 18 participants had used our mobile learning applications throughout phase 2.

In our exit interviews, participants reported that on average, they spent 75% of their time with our mobile application in their homes (scenarios B, D, F, G and H), as compared to 15% at a neighbor's or relative's home (scenarios D, F and H), and the remaining 15% outdoors in the fields (scenarios C, E and I). Participants engaged in mobile learning more often in their own homes than elsewhere for two reasons: (i) concern about the cellphone's security, and (ii) the summer heat, such that the home was cooler than outdoors.

Social Relationships

More importantly, Figure 4 is consistent with some of our findings from the exit interviews on social relationships:

- *Power users:* from our exit interviews, we learned that 2 participants had emerged as “expert” users who helped other participants overcome technical problems that they encountered with the phones (e.g. resetting the phones if it crashed or adjusting the volume). We learned that both users had learned to perform these tasks from watching us fix similar problems in the field for the participants. Both of them seemed to have spent a significant amount of time familiarizing themselves with the mobile learning applications on our phones – they in fact corresponded to participants 17 and 18 in Figure 4 who had used these applications for the longest duration. On average, power users spent 7 hours and 38 minutes ($\sigma = 1$ hour and 27 minutes) per week with the mobile learning games. In comparison, non-power users spent 35 minutes ($\sigma = 21$ minutes) per week on the games.



Figure 5. The girls hid our cellphones near those places where they worked, e.g., hanging a cellphone from the roof’s beam (left) or hiding it in cupboards in the kitchen (right). Doing so allowed them to finish a household chore and resume gameplay while making it more difficult for their brothers to take the phones while the girls were not using them.

- *Monopolization:* 5 children – 4 girls and 1 boy – told us in the exit interviews that they did not use our phones as much as they wanted because their brothers monopolized the cellphones. Specifically, in the case of the 4 girls, the cellphones had been monopolized by their brothers who were non-participants in our study (2 of their brothers were younger while 2 brothers were older than the girls). The girls were afraid that their brothers would take the cellphones when their use of the phones was interrupted by housework assignments. Hence, the girls tried to hide the phones from their brothers in convenient locations such as the kitchen cupboards while they were occupied with housework (Figure 5). In the case of the boy, we learned that his cellphone was monopolized by his elder brother. (Our interviews with this family revealed that the two brothers devised a scheme to take turns with the cellphone. However, this arrangement often broke down and resulted in fights, whereupon their mother intervened by taking the cellphone and eventually handing it to the elder brother.) We corroborated the above reports against the voice, photo and video recordings that were made on those cellphones, as well as how the title menus had been personalized, all of which suggested that the phones were monopolized by a different boy for most of the time.

- *Mentorship:* From our exit interviews we realized that girls assumed mentorship roles when they played with another participant. The type of mentorship varied by the age, relationship and gender of the other participant. If the other participant was a boy, girls mentored by giving a direction to the gameplay without actually sharing the cellphone. On the other hand, if the other participant was a girl, both participants would share the cellphone. In the latter case, if the girls were friends, either of them could assume the mentors role; whereas in the case of siblings, the elder girl would assume the mentor’s role.

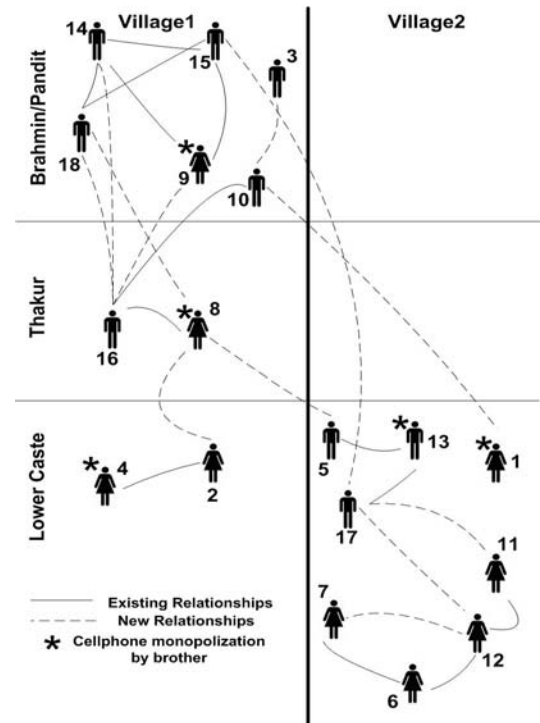


Figure 6. The existing relationships among participations prior to the study, and new relationships that were formed through the gaming activities. Boys and girls among the participants are organized spatially in this diagram based on their village (horizontally) and caste (vertically). The number next to each child stands for his or her participant ID (see Figure 4). An asterisk is placed next to those participants to indicate that the regular user for their cellphones was likely to be a brother who was monopolizing the phones.

Apart from the above roles that children exhibited in interacting with other children, we learned that participants drew closer to one another in the process of interacting with one another to discuss topics about the cellphones or games. The boys who were already friends with one another prior to the study played the educational games in one another’s company and helped their weaker peers to learn the targeted syllabus. Even when there was a significant disparity in the friends’ ability to play the games, they would nevertheless stick together such that the better gamer helped the weaker ones. The above patterns were also observed among girls in the study.

Introducing the e-learning games did not only strengthen existing social relationships, but also facilitated new ties to be formed. More significantly, these new relationships cut across gender, caste and village boundaries. In other words, more children from different castes, genders and villages who were not previously acquainted bonded through the process of helping one another play the e-learning games. In the beginning of phase 2, there were 13 pair-wise relationships between participants (i.e. 3 were between siblings while 10 were between friends) such that only one of them crossed caste divisions. By the end of the study, 10 new pair-wise relationships between friends had developed. Most significantly, 8 and 3 of these 10 new ties took place across caste and village divisions respectively (not mutually exclusive). We illustrate these social changes in Figure 6, which depict the participants according to their castes (vertically) and villages (horizontally).

Most importantly, the social relations that were developed in the context of this gaming community were observed to transfer to the participants' everyday lives, in which they continued to interact more deeply with one another in real-world, non-gaming settings. For example, from our interviews, we learned that the boys who had bonded through the games supported each other when one of them received a scolding at school. Similarly, we observed that boys would wait after school to accompany the girls (and vice-versa) home if they had long distances to walk.

Learning and Persistence

We analyzed the log entries from our mobile applications to assess the extent of learning that occurred. Figure 7 shows the average number of new words that participants covered in each week with our e-learning games, whereas Figure 8 shows the cumulative number of words covered per week by the average participant. From Figure 7, it appeared that the usage patterns were fluctuating until week 9 due to novelty effects and/or our physical presence in the community. As such, for our analysis, we only considered the logs for week 10 and onwards when the study entered "steady state". Furthermore, due to the challenges such as cellphone malfunctioning and battery "swelling" which we describe later, Figure 7 and Figure 8 represents data from 13 participants whose logs we were able to retrieve.

Figure 7 shows that on average, each child covered 3 new vocabulary words per week ($\sigma = 3$ words) in the mobile learning games. Between weeks 10 and 25, each participant covered an average of 46 new words ($\sigma = 113$). Moreover, no new words appeared to have been covered in week 18, i.e. an average of zero words were learned, as opposed to other weeks in which participants covered non-zero new words on average. A plausible explanation is the occurrence of village elections in weeks 18 and 19, during which the majority of villagers participated in pre-election rallies, thereby affecting their levels of cellphone use.

On average, the amount of time that a participant spent on the mobile learning games in one continuous session was

62 minutes ($\sigma = 50$ minutes), and each participant engaged in 2 sessions ($\sigma = 2$ sessions) per week. Within a session, a participant made an average of 4 ($\sigma = 4$) attempts to arrive at a correct response in the games, out of which 3 ($\sigma = 3$) attempts succeeded while 1 ($\sigma = 2$) attempt was not successful. In other words, unsuccessful responses comprise 24% of all attempts. Furthermore, 11% of all sessions ended when the last attempt in the session was an unsuccessful one.

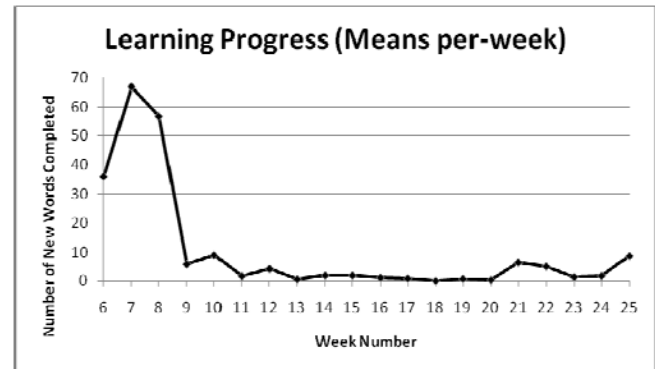


Figure 7. This graph shows the number of new words completed per week. A player is considered as having "completed" a word when he or she gives the correct answer for that word in the mobile applications.

(Even though some of our findings from phase 1 suggested that participants may have shared the cellphones with one another, we do not believe that this is likely to have affected the validity of the statistics in Figure 7 and Figure 8. Here's why: first, only the girls reported in the exit interviews that they had shared the cellphones with someone else. This playmate was always a non-participant. More importantly, since our e-learning games targeted a curriculum that was attainable only for participants, participants would have to mentor their friends to complete the words. As such, Figures 7 and 8 reflected, to a reasonable extent, words that participants completed themselves.)

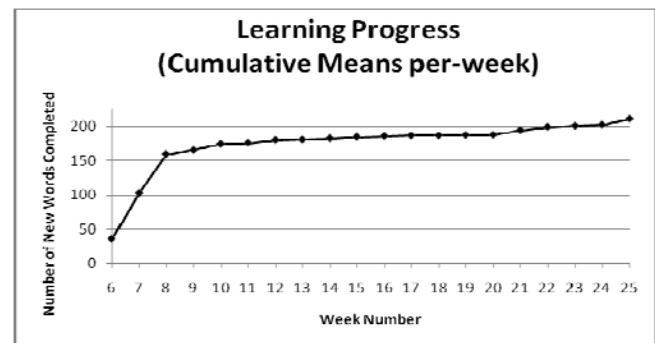


Figure 8. This graph shows the cumulative number of new words completed per week.

It was not practical to seek out parents to interview them on their thoughts about the educational benefits of the mobile learning games. From past experience, we expected them to be predisposed to telling us out of courtesy that the games were indeed educational. However, even though we did not

conduct such interviews, 9 adults approached us voluntarily when they saw us and shared their positive perceptions. 6 of them believed that learning how to use technology is a component of education that should share equal priority with traditional formal schooling. More important, whereas their children used to spend their free time loitering in the rural vicinity, parents observed that their children had been spending more time with the cellphones – presumably for learning English – after the study began. In fact, mothers believed that child participants were benefiting from the mobile applications to the extent that we should also design similar applications for rural adult education:

First woman: *Can we also not learn from this cellphone? Do you have a program to teach women from rural village also?*

Researcher: *Our current study is designed for children only.... Do you think cellphones will help you learn something?*

Second woman: *Yes. We keep sitting idle at home all day. I think we can learn something if you give us the cellphones.*

We found out that several women in the community had to discontinue their schooling when they had to marry at an early age. Mobile learning could therefore empower them to engage in lifelong learning.

Other Challenges

From phase 1, we had learned that variables such as caste, gender and time of the day were likely to influence mobile learning behaviors significantly. We therefore wanted to perform a finer-grain analysis of our log data to understand how mobile learning behaviors varied with these variables. But there was inadequate data to perform this statistical analysis. This was not only due to the fact that 5 phones had malfunctioned to the extent that we could not turn them on at the end of the study to retrieve the logs on them. Instead, the real problem was that the batteries in 6 cellphones had “swelled” after week 10 to the extent that these cellphones could be turned on after their batteries were replaced (which we did only after the exit interviews). Consequently, participants were only able to use the phones up to a certain point in phase 2. The likeliest explanation for the swelling was that the phone batteries had been exposed to extreme heat. We believe that the cause was due to the phones being left in the kitchen when participants tried to hide them from their brothers. This explanation is supported by the fact that these 6 cellphones had all been assigned to girls, including the 4 girls who self-reported that their brothers had been monopolizing their cellphones.

DISCUSSION

Even though the above findings are mixed, we remain cautiously optimistic about the future of mobile learning in the developing world. At the rate that an average participant covered 46 new words over a span of 16 weeks, it seemed reasonable to expect each participant to have covered over 150 words in a calendar year. As a benchmark, research on

second language vocabulary acquisition indicates that “a realistic target for children learning foreign language might be around 500 words a year, given good learning conditions” [4: p.75]. The key is what constitutes “good learning conditions.” In our study, the typical participant achieved this level of learning progress with 2 hours and 23 minutes of mobile learning per week. Furthermore, it does not appear that poor learner motivation was the factor here: only 11% of all mobile learning sessions ended as a result of the participant providing an incorrect response. It seemed that in most of the cases, participants ceased their sessions for reasons other than frustration with their performance.

There seemed to be a combination of social and technical barriers, such that mobile learning in rural, underdeveloped areas could become more prevalent should these obstacles be overcome. The attitudes of rural parents towards their children’s education, especially their bias that educational opportunities should be made more accessible to their sons instead of their daughters, appeared to be at work here. For instance, brothers could not have monopolized the phones that we loaned to their sisters if parents had not given tacit consent to this behavior. It is not clear if and how we could design technology so as to mitigate such effects. We not only plan to investigate designs in which the cellphones and mobile learning applications were designed to appeal only to girls and not boys. We also plan to explore game designs that encourage those group sharing behaviors exhibited in some of the scenarios from phase 1, such that girls could play an explicit mentoring role and learn something in the process, even if the actual cellphone user might be a boy. We have found that gender attitudes remain a significant challenge, and this topic will be a major emphasis in future research.

In comparison, the electricity barrier appears to be more amenable. Multimedia mobile applications for cellphones in developing regions could be designed so as to perform less energy-intensive computations that drain their batteries less quickly. Likewise, cellphones for emerging markets could be sold with hand-operated power generators (i.e. hand-cranked). Most importantly, our findings regarding power users suggest that more reliable electricity is associated with greater phone use, which could potentially translate into higher learning gains from mobile learning. In addition, better quality batteries that are more resistant to “swelling” under extreme heat conditions are also more likely to yield more robust devices that promote a greater extent of mobile learning.

Most of all, we learned that our mobile learning games have created a shared context that encouraged the formation of new social ties across caste and village boundaries, which were less likely to have developed otherwise. Our findings have also pointed to a new opportunity for mobile learning that has not yet been pursued in our research community, namely, mobile learning to promote lifelong learning for mothers.

CONCLUSION

Despite the hype around how mobile learning can make education more accessible in the developing world, more rigorous research is clearly called for. This paper presents an important step towards this goal. We have identified opportunities for mobile learning in the everyday lives of rural Indian children. Based on these insights, we have investigated the extent to which rural children voluntarily engaged in mobile learning when they are unsupervised, and have carried out this study on a sufficient duration that novelty effects were likely to have worn off. Our results not only show that some degree of academic learning occurred, but that the extent of such learning could potentially be increased if barriers owing to limited electricity and gender attitudes could be overcome.

More broadly, the cellphone is viewed as the “personal computer” of the developing world given its increasing pervasiveness there. Our experiences and the challenges we have encountered will be beneficial to our colleagues who seek to conduct more rigorous, longer-term evaluations of cellphone applications under naturalistic conditions in these highly difficult environments.

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