

**A Comparative Analysis of a Game-Based Mobile Learning Model in Low-Socioeconomic Communities of India**

Paul Kim<sup>1</sup>, Elizabeth Buckner<sup>1</sup>, Hyunkyung Kim<sup>2</sup>, Tamas Makany<sup>1</sup>, Neha Taleja<sup>2</sup>, & Vallabhi Parikh<sup>2</sup>

Corresponding Author: Paul Kim, Ph.D. 520 Gavez Mall #3084, Stanford, CA 94305

<sup>1</sup>Stanford University

<sup>1</sup>Seeds of Empowerment - XRI, Inc.

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### Abstract

This study explores the effectiveness of a game-based mobile learning model for children living in underdeveloped regions with significant contextual variations. Data for this study came from a total of 210 children between the ages of 6 to 14 years old from six marginalized communities in India. The findings reveal that children with little or no previous exposure to technology were able to not only figure out the given mobile learning technology, but also solve a series of incrementally challenging problems by playing math games without specific intervention or instruction by adults. The study also found that various factors, including gender and group size, do affect children's ability to adopt and learn while presenting a unique set of learning interaction patterns. This paper concludes with specific recommendations for future ICT4D (Information and Communication Technology for Development) projects for educational development particularly targeting developing regions.

*Keywords:* Mobile technology, education game, underserved communities, collective intelligence, India

## Introduction

There are over 5 billion mobile subscribers worldwide today – an astounding number considering the world’s current population which is roughly 6.8 billion (ITU 2010). This means that even in very rural areas of the developing world, today’s children are more often than not already exposed to some type of mobile technology, and their exposure is only expected to increase in the coming decades. The rapid proliferation of mobile technologies throughout the world has brought substantial attention to the potential to leverage the power of these new technologies to address decades old problems, including educational inequalities (See Keen & Mackintosh, 2001; Ling, 2004).

Today’s mobile devices, with their increasing affordability and storage, can be equipped with a vast amount of educational content, including mobile videos, learning simulations, and education games targeted to appropriate ages. Moreover, unlike desktop computers or even notebook computers, handheld mobile devices require substantially less infrastructure and electricity, which gives them many advantages over traditional computers. Most importantly, mobile devices are capable of reaching even the most marginalized communities (Attewell, 2005; Kim, 2009), and research has shown mobile learning devices have the potential to widen access and supplement education in remote and underserved areas of the world (Zurita & Nussbaum, 2004).

A number of studies have examined how mobile technologies can be used for both formal and informal literacy development and language learning (Brown 2001; Cabrera 2002; Chinnery 2006; Joseph et al. 2005; Kadyte 2003; Kiernan and Aizawa 2004; Levy and Kennedy 2005; Norbrook and Scott 2003; Ogata and Yano 2004; Paredes et al. 2005; Thornton and Houser 2005). Many others have attempted to leverage mobile technologies for numeracy and math skill development (e.g., Baya & Daher, 2009; Franklin & Peng, 2008; Mathee & Liebenberg, 2007). In addition, several studies have shown that mobile learning devices can be effective educational resources for schools that lack educational resources and places where traditional learning cannot take place (see Attewell, 2005; Sharples et al., 2005; Stead et al., 2006), as well as for underperforming students (Shin et al., 2006).

This interest in mobile technologies is just part of the rapid growth in the number of ICT (Information and Communication Technology) projects for developing regions, often referred to as ICT for Development (ICT4D) (Avgerou, 2008; Prakash & De, 2007; Walsham, 2010). Within education, ICT4D projects aim to help young learners not only reach their full potential through ICT-integration into education system, but also contribute to the larger social, economic, and political development of their communities and nations (Thompson, 2008). However, the real impact of ICT4D reform projects is often hard to measure, and such projects tend to garner mixed reviews.

Among the many issues identified with ICT4D projects, teacher training is an oft-mentioned challenge (Rusten, 2003). In ICT4D and educational development more generally, the idea is to train teachers first so teachers can incorporate technology in their classroom pedagogies, while also helping children learn to leverage technology in their own learning. Although this idea seems ideal, it is not practical in many cases. Teachers in rural villages of underdeveloped regions usually have very little experience with technology (even email or word-processor), and very few own any type computing devices or have any reason to visit an Internet café hours away. The closest thing to a computer many have ever owned or seen is most likely their mobile phone or neighbor's smartphones.

Moreover, we know that children’s aptitude with technology is often much greater than their teachers, and the speed at which children adopt technology can be quite astonishing to many adults. Vail (2003) asserts that, "it is no secret that adults take longer to learn new technology than children do, and that has certainly been the case with teachers." The rapid growth of a whole new array of mobile game technologies such as Nintendo, which children often play without any training by

adults or help from instructional manuals, also suggests that children themselves are perfectly capable of adopting and learning from technology without adult interventions (Kamenetz, 2010).

Considering this conflux of factors, namely, the issues with large-scale ICT4D projects with top-down approaches, challenges with teacher technology training, the recent mobile revolution and its potential impact on education, we wonder why could we not involve young children as partners in the training and implementation stages of ICT4D. It seems that children (especially living in developing regions) could be our best partners in helping us (adults) learn about their use of technology in education. They could even serve as teachers for our teachers and our helpers in figuring out and enhancing new technology tools. It is easy to conceive of how, by simply playing with mobile devices, children can fulfill various roles in the technology design process such as: *user*, *tester*, *informant* and *design partner* (Druin, 2002). Considering the questionable successes of previous ICT4D attempts that employed top-down or teacher-first approach, a new approach that embraces the concept of children as active agents seems worth investigating. This paper researches how children in underdeveloped regions, with low levels of exposure to technology, come to use and learn from mobile technology, while also investigating which factors promote self-directed learning from mobile devices. The study is situated in India, a country with diverse population and low levels of development in both rural villages and urban slum areas; we draw on qualitative observations and quantitative measures of students' success at solving game-based math problems to argue that children can learn to manipulate and learn from mobile devices without adult interventions.

## Research Questions and Rationale

Despite the great promise of mobile technology to help combat educational inequalities worldwide, researchers are still struggling to make mobile learning solutions relevant to the local needs of communities, replicable in a wide range of conditions, and sustainable even in under-resourced regions. For example, in an exploratory study of mobile device usage by children in India, Kumar et al. (2010) have shown that lack of regular electricity and concerns over theft inhibit mobile device adoption. In addition, they find that children's life paths vary substantially across gender, caste and regional lines. They argue that as a result, future mobile-based educational interventions may need to be targeted to certain children's distinct life circumstances. Building off of their research, this study examines how children in different conditions of the developing world adopt mobile devices and learn to play for fun while acquiring basic numeracy skills, with the ultimate aim of better designing and implementing ICT4D educational initiatives. Specifically, this research project asked three major questions:

1. Can children, in developing regions, who may have little or no technology exposure, adopt and teach themselves mobile learning technology without specific interventions by adults?
2. What processes do children go through in figuring out and solving problems presented by mobile devices?
3. What factors contribute to and accelerate children's ability to learn technology?

These inquiries are important steps in our larger research on how to increase access to self-directed learning opportunities for marginalized students; we think that large-scale mobile device interventions might be the only viable solution to many long-standing educational inequalities, and therefore, want to learn what factors make mobile device interventions scalable. However, this process entails two sub-goals as well – first, how to make user-friendly devices, and second, understanding which factors affect technology adoption.

In our current information age, characterized by the rapid development of ICT, the marginalized with the least amount of schooling will find it increasingly more difficult to participate in knowledge-based societies, deepening the social divide (Reimers, 2000). Without innovative

interventions, the gap will only increase, further excluding the poor and uneducated from the connected world, and leaving them without the necessary skills to secure a livelihood and maintain their well being. Therefore, investigation of a highly portable and lower cost mobile learning technology, as a potential means to ignite self-directed and exploratory learning, will be beneficial for future ICT4D planning.

### **Theoretical Framework**

In order to test the effectiveness of various models of child-centered technology adoption, prior studies have suggested three sources of variations:

1) *Group Size*

Prior pilot conducted by the research team in other countries suggest that children will naturally form groups of various sizes when asked to figure out how to use new devices. For example, Kumar et al. (2010) find through ethnographic observations that young people often collaborate to figure out and use mobile devices in their daily lives. Moreover, in a prior pilot studies of mobile device adoption in Mexico and Rwanda, we found that small group formations occurred naturally around 20-30 mobile learning devices distributed to a large group of 40-50 children. We observed that when a few children gathered around a device, they quickly began to share their knowledge and took turns examining the device. However, in most cases, each child wanted to play individually with a device. The tension between the collaborative sharing information in groups and the desire to control the device individually suggested an important line of inquiry. Specifically, we wondered what might be the optimal group size in terms of actual speed and performance at problem solving, as this was not clear from earlier pilot tests in other countries.

2) *Technology Exposure*

We believe that children, in general, with different levels of prior technology exposure would somehow respond differently to educational interventions involving technology. DeBoer (2009) examined the relationship between environmental factors and usage behaviors at 'Hole-in-the-wall' computers (i.e., unattended free computer kiosks with Internet access in the middle of town) and found that user behaviors distinguish themselves clearly along the discrete line of urban versus non-urban communities. Basically, rural children are more likely to use the computers in groups than their counterparts in the urban setting. Nonetheless, Jha and Chatterjee(2005) reported that children were able to achieve a remarkable mastery of computer skills through trial and error and peer instruction in both rural and urban settings.

With mobile technology, there seems to be a noticeable difference between those children who have easy access to technology (e.g., Nintendo DS or smartphones at home and school) in developed countries and those who have very little or no technology exposure (i.e., children even lacking reliable electricity at home or school) in developing regions. In experiments with children, Zhang et al. (2007) found that children with more technical experiences are advantaged in adoption and usage of mobile devices and also took less time in later rounds of use than in the initial exploration stage (i.e., as they quickly gained experiences with mobile technology and built a mental model of the navigation structure). Bay & Ziefle (2005) explains that those who quickly build a correct

mental representation of the allocated functions can efficiently solve tasks on mobile devices.

We acknowledge that in many regions of the developing world, youth may be exposed to cell phones even when they live without running water or consistent electricity. In sum, we hypothesize that children living in regions with some exposure to technology will be in a better position to adopt technology, but are also interested in comparing how substantial the difference between children's technology adoption (also further learning or problem solving) speed may be across regions .

### 3) *Gender*

In many developing countries, including our research site of India, girls and boys have very different life paths. Girls are more likely to be out of school than boys, which may impact their ability to use and learn from technology. For example, National Council of Educational Research and Training of India (as cited in Shah and Veetil, 2006) reports that the gross enrollment rate for girls is 74, compared to 80 for boys.

In addition, prior field studies of mobile technology in India suggest that boys are more likely to be the dominant technology users in mixed-gender groupings, while female children in India are more likely to defer to their male peers. Similarly, Kumar et al. (2010) found that males and females may take different roles. In observations of authentic, unstructured mobile device usage, when working with boys, girls tended to give “direction to the game play without actually sharing the cell phone. On the other hand, if the other participant was a girl, both participants would share the cell phone” (p. 749). For such reasons, we hypothesize that boys may be better able to manipulate mobile learning devices, and may be better positioned to successfully complete mathematical exercises on mobile devices.

In practical terms, knowing how many students form optimal groups is important for designing future interventions and optimal conditions. Although we believe age is an important variable for understanding technology adoption, we found that rural village students in India often do not know their true age, and that learning tends to take place in multi-age groupings. Therefore, we decided to implement the intervention in multi-age groups.

## **Method and Data Collection**

This study explores the effectiveness and adoption of game-based mobile technology solutions for underprivileged children in various locations with significant contextual variations. The research site was India, a country with drastic social and economical variations. Although India has been progressing with a significant economic growth in the past decades, 456 million Indians still live on less than \$1.25 a day (World Bank, 2008).

Moreover, 72% of the population lives in rural areas where resources and educational opportunities are less available (Datta, 2006). For example, Kumar et al. (2010) report that in rural India, 43% of children in rural areas cannot attend school regularly due to required labor in their homes or fields. In total, an estimated 27 million school-aged children do not attend school, making India home to the world's largest number of out-of-school children. Even when Indian children do attend school, however, it is clear that many are not learning much. For example, ASER's (2005) study of fourth graders found that 65% of all students in public schools

did not get passing grades. Even in cities, where access to schooling is generally more common, literacy and numeracy skills are weak. For example, adult literacy rate is only about 58.8% and female literacy rate is about 47.3% in India while there are 18 languages officially recognized (among numerous unofficial regional languages), each having a different character set (Rao, 2009). In short, challenges abound in the Indian education system and therefore innovative solutions to counter the challenges are in dire need. It is in this context that mobile learning technologies have the potential to make such a huge impact.

### A. Participants

Data for this study came from a convenient sample totaling 210 children between the ages of 6 to 14 years old ( $M = 11.12$ ,  $SD = 1.24$ ) from six marginalized communities in India (Figure 1). The children in this study were recruited by partnering local NGOs that were providing social and educational services to the regions where the children were residing at the time of the study. All children participated in the study were familiar with the work of the NGOs and they perceived the study as part of NGOs' efforts to better understand and address the local education needs.



Figure 1. Map of India with the locations of the urban slums (in Mumbai and Bangalore) and the rural villages (Bihar state, Gujarat and Jharkhand).

Two specific types of community settings were selected: urban slums and rural villages. Urban slums were visited in large cities such as Mumbai and Bangalore. In Mumbai, two venues were visited: a privately owned (NGO-operated) school for the underserved and a public school operated by the state. Both served students who were coming from highly dense city slums. In

Bangalore, the students were also from slum areas and the school conditions were inferior to the ones in Mumbai. However, in both cities, Internet cafes and highly reliable mobile wireless network coverage were present.

The rural communities, which consisted of tribal populations, were located in the states of Bihar, Gujarat and Jharkhand. Participating children from Bihar were mostly from the once untouchable Dalit caste, while in Gujarat they were from a nomadic Vadi tribe called Madari (Figure 2). Many of these children did not know how old they were, due to lack of formal birth records and most engaged in child labor as performers in travelling circuses. The rural villages were situated approximately 4-hours from any major city and consequently, electricity, running water, and sewage systems were not present. Mobile wireless network coverage was present in the tribal area of Gujarat state, but not in the rural areas of Bihar and Jharkhand states.

In interviews with NGOs, we learned that families typically lived on less than a combined average income of one dollar per day and that many of the participating children had never been to school or if they did, they attended low-quality, multi-grade classes. Our observations that educational opportunity in rural India is worse than that in urban areas is confirmed by government statistics. The Government of India's 2005 Analytical Report on Elementary Education reports that educational efficiency, defined as the number of years taken to graduate a grade as a proportion of all years taken by the student, is 87.8% for the nation as a whole. However, in Bihar it is 48.8%. In short, Bihar students took twice as long as intended to graduate elementary school.



Figure 2. Madari children in Gujarat state exploring the mobile learning device. This nomadic Vadi tribe moves from one region to another constantly to perform circus shows and the children have never attended any school.

## **B. The Intervention: Mobile Learning Devices with Math Games**

All participants were equipped with TeacherMate, a battery-operated, handheld mobile learning device running Linux as operating system and powered by ARM 9 processor. The device has 512 MB internal memory and an expansion slot for external 4GB memory. The front features a color screen (11cm x 7.5cm), four directional arrow buttons, three colored control buttons above the display screen, a blue enter button, a built-in microphone, and an integrated speaker. The power button, headphone output jack, a mini-USB, and a charger slot are on the side of the device. The device turns on when the power button is pressed and held for three seconds. TeacherMate is a programmable open mobile learning platform that allows anyone to freely create applications with Adobe Flash and run under GNASH, a Flash player, part of the open source GNU project. Flash script programmers can easily map actions on games with any combination of buttons except the power button.

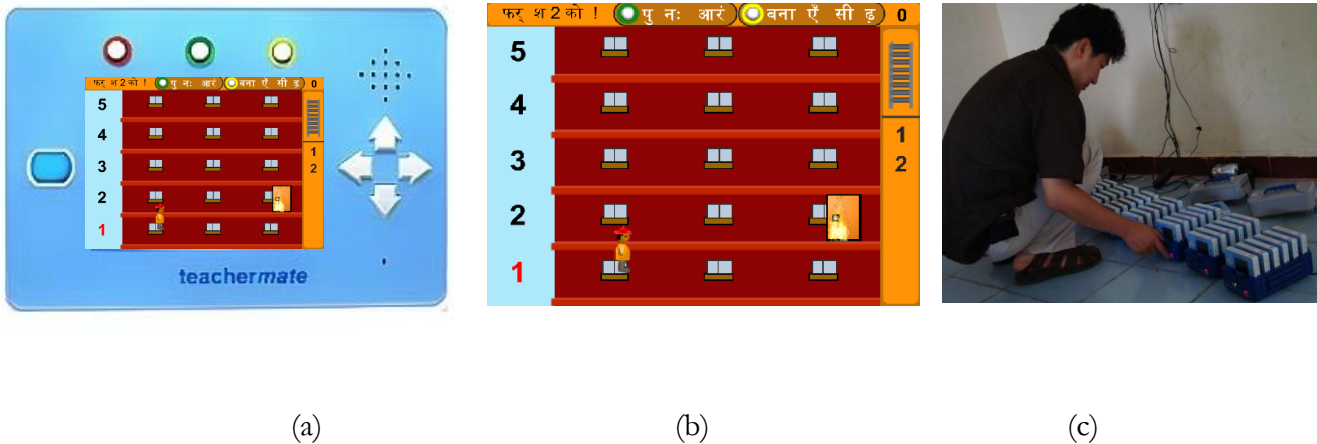


Figure 3.

- (a) TeacherMate mobile learning device
- (b) An enlarged screenshot from the Fire Rescue Math educational game
- (c) Charging the devices in multiple portable storages (daisy-chained) at NGO headquarter offices when electricity was available for a few hours a day.

Because we wanted to explore the potential for child-centered adoption of learning technologies, we chose to use a game-based mobile intervention. Substantial research has suggested that games can be an effective method to both engaging children and teaching educational content. For example, Bennett, Wood, and Rogers (1977) have argued that, "play is considered to be such an educationally powerful process that learning will occur spontaneously, even if an adult is not present." Researchers have recognized the myriad educational benefits of playing games, which include relating learned material to one's immediate context, the acquisition of knowledge and cognitive skills, and the possibility of accomplishing attitudinal change (Aguilera and Mendiz, 2003; BECTA, 2001; Gee, 2003; Gentile, 2009; Hamalainen, 2008; Khoo and Gentile, 2007; Laughlin et al, 2007; Tang et al., 2009; Wouters, 2009). In addition, many researchers have argued that exploring technology, playing games, and learning educational content can take place at the same time. Berson and Berson (2010) explain that, "technology can stimulate students intellectually, incite their creativity, and challenge them to apply developmentally appropriate inquiry approaches that enhance their learning experiences."

For the purposes of this study, a Fire Rescue Math (FRM) educational game was designed for the TeacherMate device. The FRM engages children to recognize the need to rescue people on different floors by picking the right size ladder (e.g., size 2 ladder for climbing 2 floors) to go up or down floors. The logic behind the game is that addition and subtraction with positive and negative numbers require students to know the correct distance and direction in addition to the concept of larger and smaller negative numbers.

The FRM starts with easier problems involving positive numbers with smaller distances (e.g., going up or down 1 floor at a time), but as the player advances in solving these problems, the game offers more difficult ones with larger distances and multiple options (e.g., going to the 15th floor from the 8th floor using size 4, 8 or 11 ladders). An additional challenge in FRM is to avoid a moving fire by either jumping over or extinguishing them with water. Furthermore, there is only a limited amount of water and only a few ladder choices. In order to move between floors, the players are given a few ladders of varying lengths that may be used alone or in tandem to go up or to go down. The added difficulty comes when players realize that no ladder can be used more than once.

The player needs to be nimble in maneuvering the floors, choosing the right ladder size and correct direction to solve increasingly challenging problems.

The game includes multiple reinforcement mechanisms to facilitate numeric skill development. For example, once the player has found the target door, the numeric equivalent of the solution appears on the screen (“ $3 - 4 = -1$ ”) together with an appraisal message (“Great Job!” in their language with congratulatory music). Moreover, when larger distances are climbed with long ladders, the game presents a summary screen of the entire building indicating the floors visited and the difference between them (e.g., “ $18 - 16 = 2$ ”). Since ladders cannot be used more than once, there are limited permutations of the lengths. Therefore, a player must have a good plan before executing the decision.

In short, FRM is designed to be an introduction to mathematical literacy that requires no formal instruction, yet prompts the children to be critical thinkers and strategy planners in the math context. FRM is designed to offer a multi-grade adaptive math game that promotes the development of: (a) algebra and functions; (b) number sense; and, (c) mathematical reasoning.

- a. *Algebra and Functions:* Understand the meaning of the symbols +, -, =. Use the commutative and associative rules to simplify mental calculations and to check results.
- b. *Number Sense:* Use concepts of negative numbers (e.g., on a number line, in counting). Solve addition and subtraction problems, including those arising in concrete situations that use positive and negative integers and combinations of these operations.
- c. *Mathematical Reasoning:* Analyze problems by identifying relationships, distinguishing relevant from irrelevant information, sequencing and prioritizing information, and observing patterns.

Pilot studies have proven this game popular amongst children of this age in underserved regions in other developing countries including Kenya, Rwanda, Burundi, El Salvador, Mexico, Palestine, and Costa Rica. Although multi-story buildings are not present in most rural areas, the children did not seem to be confused with such concept and putting out fire was not an uncommon event. Overall, the concept of helping others or rescuing people was well received by children. We often asked, "How many people have you saved this time?" and they answered with confidence if they actually solved a given problem. When we said, “Great job! Save more,” meaning see if they can solve more and harder problems, they went right back to the problem.

### **C. Implementation Procedure**

In February 2009, six months prior to the study, over 20 education-related NGOs (non-governmental organizations) in 12 different geographic locations in India were contacted to discuss the feasibility of studying and implementing a study on the potential of mobile learning technology to supplement existing educational programs or provide education opportunities to children living in places where regular schooling opportunities are scarce. After discussions about the goals, logistics, procedures, protocols, organizational capabilities, and local conditions, 8 NGOs agreed to participate and coordinate the study. Children’s participation was voluntary, and was determined by parental interest and consent. Each NGO sent out a blanket call for participation to the parents of all of the children participating in its activities. Parents then had to confirm that they wanted their child to participate. In addition, the partnering NGOs and local volunteers coordinated logistics, communication, and transportation.

In each initial meeting with the children at every site, the researcher presented a short skit

with following script to arouse interest and provoke curiosity among children:

Researcher: *"Hi everyone! We heard that you guys are the best scientists in the world. Is that true?"*  
Children: *(Usually respond with) "Yes! We are!" or "Of course!" or just laugh.*  
Researcher: *"We came a very long way to meet you because we need your help!"*  
Researcher: *"We have a problem. Do you see these?" (Showing the mobile learning devices.)*  
Researcher: *"These are gifts from a different world. We have no idea what these are."*  
Researcher: *"We heard that you can figure these out because you are the smartest scientists in the whole world!"*  
Children: *(Usually respond with) "Of course! We can help you!" or just laugh.*  
Researcher: *"Can you figure out what these are and what you can do with these?"*  
Children: *(Usually respond with) "Don't worry. We will figure out!" or "Yes! We will."*  
Researcher: *"Great! Don't ask me or anybody else because none of us know what they are."*

After the skit, children were formed in groups and given the devices. The most important message for the children was that nobody knows what the devices were and therefore, they were on their own to figure them out. Observers or any teachers, if there were any, were advised not to engage in helping or commenting while children were working on the devices. The context of the study is similar to the study described in 'Hole-in-the-wall' computer project (See Deboer, 2009). However, major differences are in that the mobile devices (unlike unattended computer kiosks) were preloaded with specific educational games and the skit-based pedagogy employed in the present study was to maximize experiential learning in an individual or collective problem solving framework.

In order to investigate group assignment at each community, 35 children were randomly selected by a partnering local NGO to participate in the study. The choice of 35 was essentially made out of necessity, due to space and device limitations. The children were randomly assigned into one of three groups. There were three group formations: one child per device (G1); three children per device (G3) as shown in Figure 4; and seven children per device (G7). The groups were placed far enough from each other that they could not easily share findings and tips between groups during the sessions.

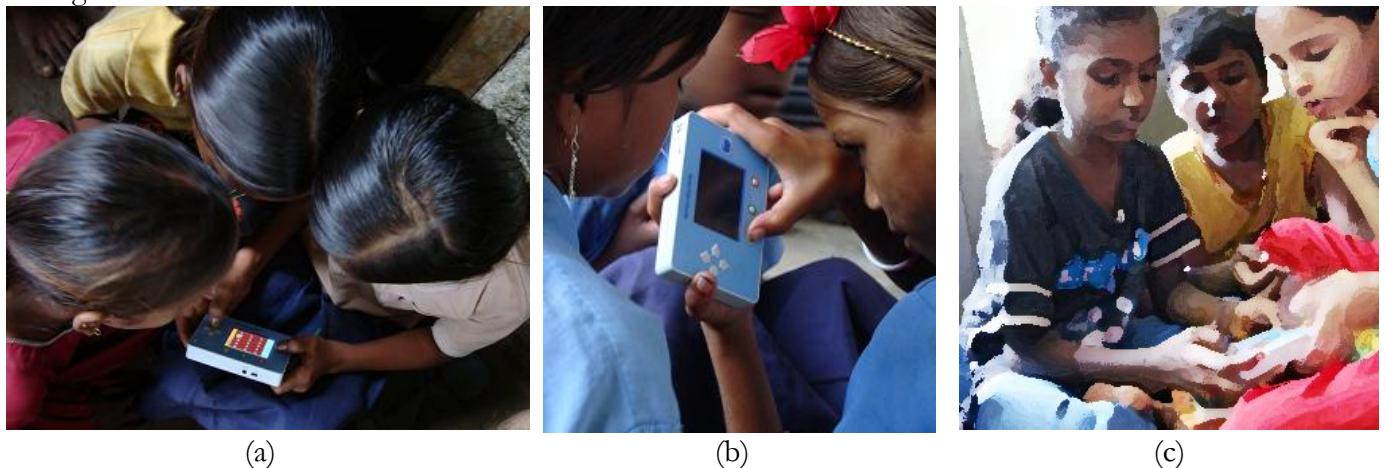


Figure 4.

(a) Dalit children from the former untouchable caste in Bihar state solving tasks in the G3 group formation;

(b) Jharkhand village children exploring the mobile learning device by pushing buttons randomly, but have not figured out what it was or how to turn on the device, yet;

(c) Mumbai urban slum children figuring out how to control the avatar (Two girls were very active while the boy behind was simply suggesting ideas).

Each timed observation lasted for 60 minutes in this study. The choice of 60 minutes was made based on findings from pilot studies. During pilot studies with the devices in other classrooms in India, an average of 25-minute interaction time was needed for most children in groups to figure out how to turn on the device and solve the first problem in the game. By assigning 60 minutes for a session, it was expected that most children would be able to figure out not only how to turn on the device, but also to solve at least one problem. One hour was considered optimal time period due to space and time constraints, while still being sufficient to see differential progress in performance.

At the 60<sup>th</sup> minute mark, the researcher ended the observation. After the experiment, the mobile learning devices were reconfigured to run a variety of additional educational games (e.g., farming simulation game, storymaker, etc.) that were not used in the experiment and handed over to the local NGO to continue to use them for their children. In addition, there were various educational enrichment activities following the experiment. These extra activities included mobile storytelling competitions, puppet shows, and sing-along sessions, however these activities are not discussed here.

#### D. Data Collection

Both quantitative and qualitative data were collected in the study. The mobile devices automatically recorded a time stamped system event log file for each FRM gaming session. This file logged user interactions such as game loads (red button), restarts (green button), ladder selections (yellow button), jumps (up arrow), watering (blue button), correct problem solving, and the number of total problems solved (Figure 5). The logging feature was adopted in this study because it is indispensable for the studies of the human-machine interactions (Bay and Ziefle, 2005), but the analysis of the log is obviously time-consuming task, seriously calling for automated analysis algorithms in the future studies.

```
-----  
0:2.90 mins: Game Loaded  
0:3.84 mins: Yellow  
0:6.69 mins: Red  
0:6.70 mins: Red Button Exit  
-----  
0:2.91 mins: Game Loaded  
0:6.16 mins: Red  
0:6.17 mins: Red Button Exit  
-----  
0:2.91 mins: Game Loaded  
0:6.57 mins: Pressed playButton  
0:50.77 mins: Threw Water  
0:53.05 mins: Threw Water  
0:54.43 mins: Red  
0:54.43 mins: Red Button Exit  
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```

Figure 5. Sample log file (partial). Dotted line denotes game reload event.

In addition to the event logs, three researchers recorded time-stamped observation notes. Prior to observational periods, we had conducted five pilot sessions with different groups of

students, which we used to generate codes for observations. From these pilot sessions, we generated a list of student behaviors and actions, which all three researchers were comfortable with. During the observational period, each researcher jotted notes about what was happening in the group interactions, drawing from the list of developed codes, and adding details when warranted. The same procedure was followed with observational videos. These videos and field notes were also recorded to gain a more comprehensive understanding of children's ongoing learning and gaming experience. Two portable video cameras (shadowed) captured a total of 25 full 60-minute sessions to help us analyze children's initial learning patterns.

### **Data Analysis Strategies**

This mixed-methods study engaged in both qualitative and quantitative analysis to understand how Indian children adopt and learn from mobile devices. The purpose of the qualitative analysis was to identify common patterns of behaviors of the children while engaged in playing and learning with the mobile devices. In our qualitative analysis, we used a grounded-theory approach to analyze video recordings, field notes, and event log files from the mobile devices. Specifically, we coded log file data based on what young people were engaging in, classifying actions into categories such as: randomly pressing buttons, turning on mobile devices, moving an avatar, selecting a ladder, etc. We then reviewed field notes and recoded videos of children's play sessions to examine what types of group interactions or comments children were making while engaging in each of these behaviors. In this way, we were able to link children's initiated actions to their reactions and resulting group dynamics. This qualitative analysis strategy allowed us to not only observe what children were doing while playing with the mobile devices, but also to gain insight into how they interpreted their behaviors and ultimately learned from their play.

In our quantitative analysis, we were interested in ascertaining which attributes facilitate successful learning from mobile devices. Given our three major factors of interest: location, gender and group size, we performed a three-way ANOVA to see if there were differences in the mean number of problems solved across groups or if there were interactions between two or more variables. Given the multiple sub-categories within each independent variable, a 3-way ANOVA is an efficient and intuitive strategy for examining possible mean differences across groups.

### **Findings**

Our first research questions asked whether children, in developing regions, who may have little or no technology exposure, could adopt and teach themselves new technology without specific interventions by adults. Specifically, we wondered what processes children go through in figuring out and solving problems presented by mobile devices.

Based on observational and user interaction data, we identified four distinctive stages of user adoption and mobile game play: Exploration, Recognition, Interaction, and Iteration (Table 1). These stages reflect different levels of user engagement and variations in their rate and intensity of interactions with the devices; however, the stages do constitute a consecutive progression, but are iterative, such that even if a student reaches the Interaction stage with respect to one action, he or she may quickly move back to the Exploration stage in determining the purpose of a new button. Rather, the stages reiterated multiple times during the 60-minute observation session.

Table 1. Iterative phases of learning with the FRM educational game on a mobile device

Stage	Phase	Behavior
<b>Exploration</b>	<i>Rapid</i>	Pushing buttons rapidly to see what happens to the device or the screen.
	<i>Random</i>	Randomly pushing a button without clear purpose.
<b>Recognition</b>	<i>Start</i>	When device turns on, the child says, “Wow” or “Yes!”
	<i>Action</i>	Avatar jumps when a button is pushed, the child smiles and shows the screen to peers.
	<i>Select</i>	Pushing a button to make the avatar jump over fire or pick a ladder.
	<i>Control</i>	Action with a clear intention of controlling an object or solving a problem.
<b>Interaction</b>	<i>Solve</i>	Intentionally applying a series of previously learnt actions to solve a problem and move to the next level.
<b>Iteration</b>	<i>Reload</i>	Pushing a button mistakenly to reload the game over and over.
	<i>Loop</i>	The child is stuck in a loop of making the same action, and cannot advance any further.

**Exploration.** Initially all children in all three groups were in a stage of Exploration. Their user behaviors can largely be considered trial-and-error, as they were exploring the mobile learning devices by pushing all the buttons quickly and randomly. Children in the G3 and G7 groups instantly began to share their knowledge by mimicking the interaction routines of each other. This was regardless of the actual utility of the mimicked behavior. For example, if one child figured out how to pick up a ladder by pushing all the buttons in a sequence, and even though the red button restarted the entire game, the others in the group followed this same and unnecessary button combination. The Individual group showed slower and less effective exploratory behavior than the other two groups. In particular, their engagement dropped suddenly if the device’s response to their initial actions was minimal.

Another typical behavioral marker of this stage was that in the G3 and G7 groups, multiple hands were holding a single device (Figure 6). During this time, each group member was competing for the control over the device; however, this competition seemed to have facilitated the groups to move to the next phase of Recognition. We believe this occurred because when the children were competing for control of the device, they were compelled to prove their worthiness as a group leader by eliciting some response from the devices. When one group leader was unable to make progress, others would try to take over control of the device.



Figure 6. Multiple hands on the device in G3 and G7 group formations during the Exploration stage as each group member was trying to gain control over the device.

**Recognition.** Over time, the groups began to find out about certain phenomena through their routines of exploration. They started to recognize what was a crucial behavior to trigger an event. This Recognition stage began when the group or the individual child accidentally found out about how to turn on the device, make the avatar jump, throw a bucket of water, or select a ladder. This realization was often accompanied by verbal, facial, or bodily gestures to express emotional excitement over the recognition of the new phenomenon. In fact, these were the most joyous moments during the interaction with the game. The attention and engagement of the children spiked again and their consecutive attempts to operate the device became more cautious compared to the rapid and random button pushes of the previous stage. Nevertheless, the rate and intensity of the group's interactions with the device increased as various group members were eager to control the device with their newly learned action.

**Interaction.** In the Interaction stage, the user intentionally applied acquired knowledge of how to control the avatar and solve a problem. For example, the child would jump the avatar multiple times over fire or go up and down on a ladder to find the door. This stage has increased level of engagement, but because it requires focused action, the competitiveness over control would decrease.

**Iteration.** In the Iteration stage, the players were applying their recently learned knowledge, but they were either repeating the same mistake or failed to break away from an incorrect routine. These were the most frustrating moments for the children. During this Iteration stage, they did not try out as many new behaviors or demand to be in control of the device, and sometimes became completely disengaged. For example, if a child mistakenly pressed the red button, the waiting time for the game to reload was often frustrating not only for him, but also for the observing members of the group. If the mistake kept repeating itself, the individual or the group realized that their routine (i.e., pressing the red button) needs to be changed. This change of use, and going back to Exploration stage, in G3 and G7 groups often happened together with a change of the group leader who had the most control over the device. It was also a common marker of this difficult stage that peers would attempt to peek at other groups from a distance.

We believe that progression through these stages represent gains in conceptual understanding about how the devices work. However, that does not mean the goal is simply to reach the Interaction stage; rather, it is through the process of exploring and recognizing multiple facets of the devices that students come to understand the variety of features and actions available.

## Quantitative Analysis

The second aspect of this study investigated what types of factors contributed to children's effective adoption and learning from mobile technologies. To investigate this, we examined three major types of variation: group size, gender and location, which served as a proxy for exposure to technology and level of local development.

### A. Main effects

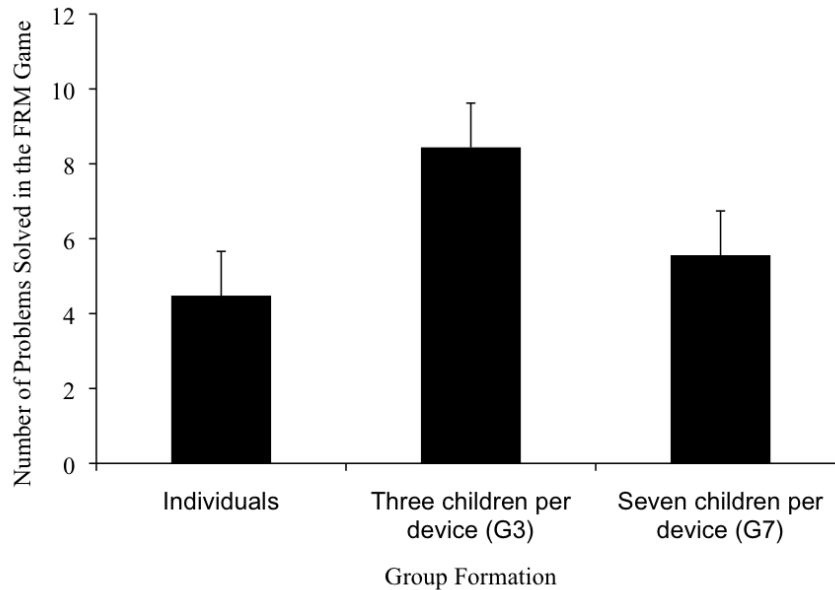
Our quantitative analysis found that within each independent variable, there were statistically significant differences between groups of students. A 3 (Group Formation) x 6 (Location) x 3 (Gender=Boy, Girl, Mixed) univariate Analysis of Variance (ANOVA) revealed a significant main effect of Group Formation,  $F(2, 39) = 6.00, p = .005$ , partial  $\eta^2 = .24$ ; a significant main effect of Location,  $F(5, 39) = 31.78, p < .000$ , partial  $\eta^2 = .80$ ; and a significant main effect of Gender  $F(2, 39) = 11.38, p < .000$ , partial  $\eta^2 = .37$  on the total number of numeracy problems solved. However, the interactions between these main effects were not statistically significant.

### B. Group Formation

Pairwise comparisons with Bonferroni corrections<sup>1</sup> ( $.05 / 3 = .017$ ) on the significant main effect of Group Formation revealed that the average number of solved numeracy problems in the FRM game was greater in the G3 group ( $M = 8.44; SD = 4.59$ ) than the G1 (individual) group ( $M = 4.48; SD = 3.44$ ) at a statistically significant level,  $p < .000$ . Furthermore, the G7 group ( $M = 5.56; SD = 3.29$ ) also solved significantly more problems than the G1 group,  $p = .009$ . However, due to the Bonferroni corrections, the mean difference of 2.88 problems between the G3 to G7 was not significant. This finding strongly suggests that solving numeracy problems with mobile learning technologies is more optimal in a group than individually. However, this study also found that a smaller group (G3) is preferable to a larger group (G7). See Figure 7 for a summary.

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<sup>1</sup> We use Bonferroni corrections to avoid Type I error that is possible from our use of multiple comparisons.



**Figure 7. Game performance main effect in the FRM based on the group formation showing an advantage of smaller groups compared to playing individually or in larger groups.**

An overall comparison of the three groups of the study shows that G3 advances more effectively (i.e., more problems solved) and more efficiently (i.e., faster solutions) than the other two groups during the 60 minutes. We believe that the reason for the superiority of this group size seems to be that the social dynamics in such small groups provides optimal circumstances for balancing levels of competition and engagement. It seems as though a lack of competition prohibits Individuals (G1) from efficiently overcoming the Exploration stage and recognizing the functions of the buttons. In the G7 groups, we hypothesize that perhaps too much competition over who controls the device delays problem solving. Similarly, disengagement is a common phenomenon in the Individual group, whereas in smaller groups (i.e., G3) other group members can take the lead in times when someone is less motivated. In larger groups (i.e., G7), the frustration caused by unsuccessful attempts of the leader and longer waiting times as passive observers could contribute to loss of interest and active involvement. This finding suggests a possible avenue for future research would be to further refine group sizes, concentrating from 2-5, to see if there is an optimal group size for children's learning.

### C. Localities

The next set of six pairwise comparisons of geographical locations with Bonferroni corrections ( $.05 / 6 < .000$ ) showed an interesting pattern (Figure 8). The average number of numeracy problems solved in the FRM mobile game was the highest in the two urban slums of Mumbai ( $M = 10.18$ ,  $SD = 4.56$  and  $M = 8.73$ ,  $SD = 3.35$ , respectively). In contrast, the lowest performers were from the rural villages of Bihar ( $M = 3.27$ ,  $SD = 1.79$ ) and Jharkhand states ( $M = 1.75$ ,  $SD = .89$ ). The third and fourth place on the performance ranking were the communities in rural Gujarat ( $M = 6.00$ ,  $SD = 3.03$ ) and urban Bangalore ( $M = 4.45$ ,  $SD = 2.16$ ) respectively and they did not differ significantly from each other. The mean differences are summarized in Table 2.

Table 2. Mean differences between the six geographical locations. Children in urban slums (Mumbai I [Private NGO school] and II [State school], Bangalore [state school]) in average showed better game performances than in rural villages (Gujarat, Bihar, Jharkhand). Note: \*\*  $p < .000$

	Mumbai I	Mumbai II	Gujarat	Bangalore	Bihar	Jharkhand
<b>Mumbai I</b>						
<b>Mumbai II</b>	1.45					
<b>Gujarat</b>	4.18**	2.73				
<b>Bangalore</b>	5.73**	4.28 **	1.55			
<b>Bihar</b>	6.91**	5.46**	2.73	1.18		
<b>Jharkhand</b>	8.43**	6.98**	4.25**	2.70	1.52	

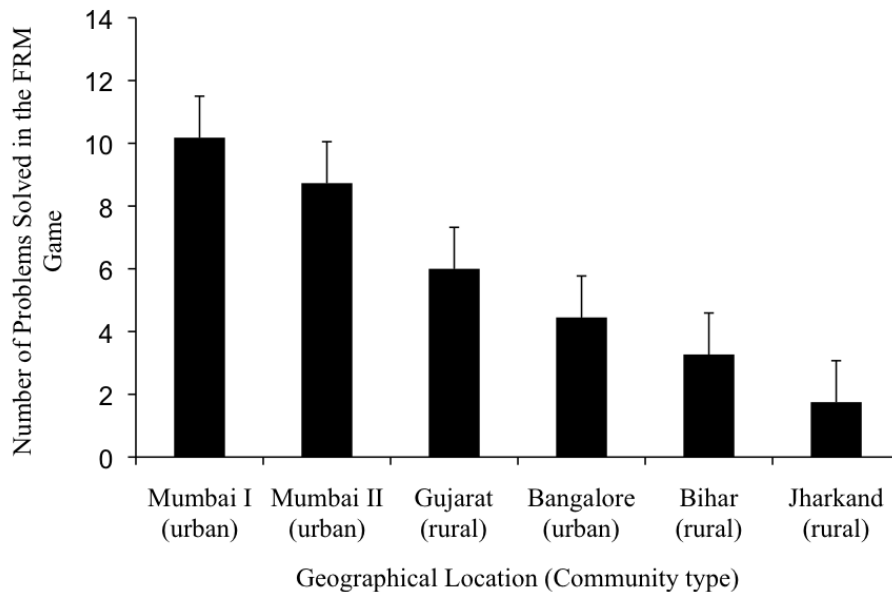


Figure 8. Game performance main effect in the FRM based on the geographical locations demonstrating an advantage of urban slum-type setting over rural villages except Gujarat Madari tribal children versus Bangalore slum children.

#### D. Gender

A pairwise comparison indicated that boys-only groups ( $M = 5.67$ ,  $SD = 4.30$ ) solved more problems in average than girls-only groups ( $M = 3.60$ ,  $SD = 1.81$ ),  $p = .001$ . However, mixed-gender groups outperformed boy-only groups ( $M = 7.09$ ,  $SD = 4.30$ ), although this difference was not statistically significant after Bonferroni corrections ( $p = .153$ ). Also, although prior research suggests that girls take a more passive role and supervisory role in mixed-gender groups, while males tend to be the dominant device manipulators, our research did not find apparent or consistent pattern of division of labor or gendered roles occurring in mixed-gender groups. Our finding that boys are more able to manipulate and learn from mobile devices align with those of Kumar et al. (2010) and

suggest that more research is needed into how gender shapes experiences with technology, and specifically, what social and educational factors are contributing to girls’ poorer performance in mobile device manipulation. Given the current gender differences in school enrollment rates between girls and boys in Indian society, we certainly do not want technology aiming to enhance learning opportunities for children to re-enforce or exacerbate current gender inequalities.

### E. Time distribution

Given that children from different regions, genders and group formations differed significantly in their ability to solve math problems, we wondered if their adoption and learning process may have also differed. Therefore, in the next section, we further analyze how children in different group formations and social settings spent their time at each stage of problem solving.

First, we present a time distribution analysis (i.e., steps and progress in problem solving) for the three group formations. Overall, all children in all groups take some time to understand the device, game logic, and eventually get started with the very first problem, but the G3 took the least amount of time (e.g., around 13 minutes) to understand how to start the game and also the rules of the game. In contrast, individuals (G1) struggle for a long time to get started with the very first problem, but eventually get better as they progress. In addition, as Figure 9 shows, children in groups of three (G3) solved not only more problems with the mobile game than those playing individually (G1) or in larger groups (G7), but they selected the correct ladders and found their ways out of the burning house with shorter times compared to the other two groups. It is also notable that time spent on solving problems get shorter as they get better at manipulating the device and become familiar with the steps to solve a problem.<sup>2</sup>

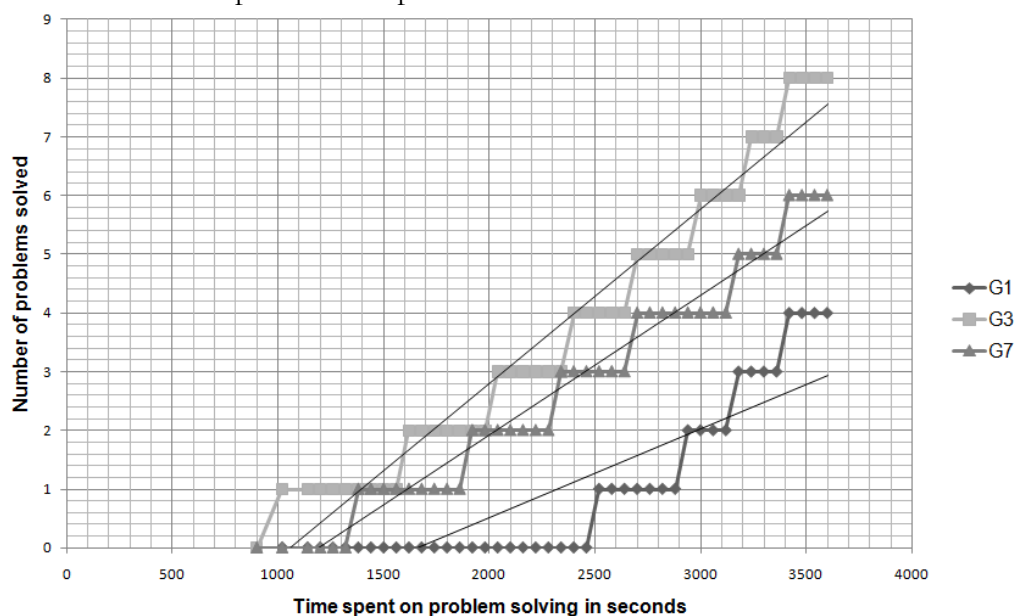


Figure 9. Numerical problem-solving latencies in the FRM mobile educational game for the three group formations.

We also were interested in the effect of location on adoption and time usage. We found that

<sup>2</sup> Although the devices are programmed to provide more difficult problems as children successfully solve the problems, the algorithm preconfigured for this study ensured that difficulty did not increase substantially until after the tenth problem was solved. Most of the low performing groups did not solve ten problems due to the given time limit.

children in urban slum and rural village communities played the game significantly differently. Specifically, we find that children from urban slums outperformed their rural peers both in terms of total solved problems and time took to solve them in all three types of groups. In Figure 10, below, we show this trend for G3, as that group was the most successful at solving problems, however the trend is consistent across all group sizes.

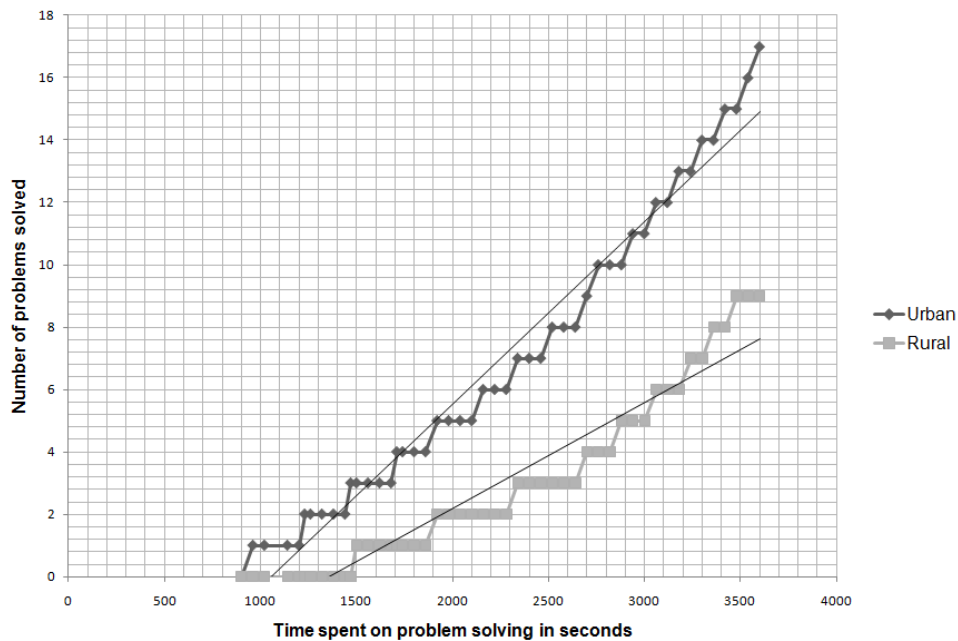


Figure 10. Comparison of gaming performances between the rural versus urban children.

## Discussion

This study found some useful results that could be considered in planning future educational ICT4D projects for marginalized children in developing regions. First, the results resoundingly demonstrate that children with little or no previous exposure to technology were able to not only figure out the given mobile learning technology, but also solve a series of incrementally challenging problems by playing the math game without specific intervention or instruction by adults.

Although children from rural villages in Bihar and Jharkhand did not even own toothbrush or shoes and lived in areas without electricity or running water, when the children figured out the game rule and solved first problem after some time of struggling, it was obvious proof that children can be great explorers and scientists when properly cued, regardless of their origins. While some groups of rural village children could not solve single problem within the 60-minute observation period, and many could not understand the concept of the game; after the 60-minute observation, we found that students (i.e., who were quicker to adopt and solve problems) could successfully disseminate their acquired knowledge of the devices to their peers without adult influence.

Second, results show that children who live in areas where access to technology is prevalent (e.g., Mumbai children) were much better at not only solving more problems, but also in a shorter period. In fact, the Mumbai I group, which had access to a large NGO education program, turned out to be the best performing group. It is probable that high technology exposure coupled with better educational resources at the NGO facilities enabled them to quickly figure out the device and game rules while solving the most problems the quickest.

One exception was that the children from Bangalore city slums were outperformed by Gujarat nomadic children (Madari tribe), although the city children have much better access to technology. We believe it is possible that the nomadic tribe might have been exposed to technology when they were roaming in cities or at least suburban areas for circus performances. Alternatively, interviews with the local NGO and Madari tribal leaders indicated that their children perform circus shows and beg money on the streets and know how to count money and understand how to calculate financial transactions from an early age. We believe that the diverse social settings, direct experience with mathematical calculations, and varied levels of technology exposure seem to have positively influenced their performance. Those with more technology exposure and prior knowledge probably experienced less frustration and errors in their problem solving attempts. In short, the significant main effect of location suggests that all children can learn with handheld mobile technology, yet at a different rate; specifically, rural children require more time in the adoption and use of new technology.

Additionally, we found that various factors, including gender and group size, do affect children's ability to adopt and learn from mobile devices. With respect to group size, results show that G3 outperformed G7 while G1 was the lowest performing group of all. The results also show that mobile learning technology, even with no wireless network feature, can incite collective inquiries (G3, G7), engage them in group problem solving (G3, G7), and most of all certainly stimulate children intellectually (G1, G3, G7). Although it is not clear what the most ideal number of participants may be in order to best accommodate team performance, the results show that in general the G1 group (one device per child) format may be too inefficient in the process of exploration and learning while the large group (G7) format could be too overwhelming. This may be an area for future studies.

This study also advanced our knowledge of how young people interact and engage with unknown mobile devices, ultimately advancing our efforts to design and implement effective ICT4D projects. The data revealed that the "play" sessions consisted of a few distinctive (cyclical and iterative, but not necessarily sequential) stages such as exploration, recognition, interaction, and iteration. From exhilaration to frustration and from anticipation to gratification, the children presented patterns of behaviors valuable for further analyses and considerations for future user interface enhancement.

Similar to findings presented by Schwabe and Göth (2005), we found that the user interface was the most important design issue of the mobile game. As shown in Figure 9 and 10, children obviously took less time to solve later problems as they gained more experience with the device and became familiar with steps to solve the problems. In this regard, we learned many ways to make significant improvements to mobile devices themselves. After analyzing the data, we list just a few here to keep the discussion manageable. First, the target door (which the avatar enters to rescue people) in each problem turned out to be somewhat problematic. Since the door (shown in Figure 11-a) was just not meaningful enough for students to realize that it is the target door, it took quite a while for them to figure out the game rule. In the post-observation period, we quickly reprogrammed the game and replaced the static door with a flash door that constantly blinks. With a simple quick test with a small group of other students in the rural villages, we found that students find the target much quicker with such a visual cue.

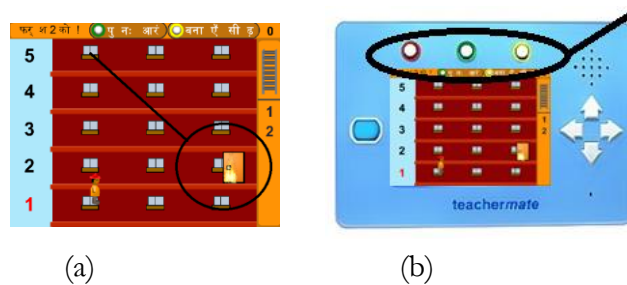


Figure 11. Target door and front buttons

Another area for improvement is with the front buttons. The different color buttons are associated (Figure 11-b) with specific actions for the game. Any flash programmer can map the buttons with different actions as needed for required actions in a game. Since the device was built to accommodate an unlimited variety of educational games, there is no particular sign or label indicating these buttons purposes. Simply because they were there, children pushed them randomly and explored their possible functions. The red button was used to reload the entire game and according to the User log data, the red button was pressed the most among the three available. It is not clear whether it was pressed most because of its location or color. However, it certainly frustrated children when it reloaded the entire game at any point of the game. A visual pop-up message (i.e., asking such as "Are you sure you want to quit?") for literate children or an aural message for illiterate children would have easily avoided such havoc.

In addition, in each distinctive stage (i.e., Exploration, Recognition, Interaction, Iteration), future mobile learning designs should consider ways to maximize Interaction and accommodate Recognition while minimizing Iteration and Exploration if they are simply causing unnecessary cognitive load, interruption, or confusion.

The two above samples are from a long list of ways found to enhance user experience on the mobile device. In the future designs, the user interface issue that has nothing to do with problem solving (e.g., purely the result of poor design) must be addressed accordingly while intended problematic conditions (e.g., moving fire) that can enhance fun, creativity, and curiosity need to be identified and further developed to maximize playful learning.

## Conclusion

Considering the overall impressive attention span demonstrated by the children with the mobile game, the skit played in the beginning (help arousing interest and provoking curiosity) coupled with the incrementally challenging problems might have created somewhat a "play" ground. Obviously, play is considered to be such an ideal process that enables opportunistic learning moments to occur regardless of the presence of teachers or adults (Bennett, et al., 1977). The inquiry-based pedagogies used to introduce the devices, which refrained from telling children what to do or how to do it seems to align with the work of Falbel (1993), who explains that better learning hardly arises through searching for better methods for the teacher to instruct ("instructionism"), but from ways to give the learner better opportunities to construct meaning ("constructionism"). In our study, we found that marginalized children in even disadvantaged settings could not only become self-directed explorers and active problem solvers, but also great scientists or as Wang et al. (2010) call them, "Active Agents!"

We believe that inquiry-based pedagogy coupled with handheld digital tools does not put the children in the passenger seat, but in the scientist's console chair or experimental lab where the

young scientists are sharing cognitive tasks and collectively inquiring and solving problems. Also, the results in the better group formation (i.e., leading to accelerated performance patterns) show the efficiency and power of collective intelligence under such constructionism-based pedagogy.

The findings of the present study, which explored a highly portable and relatively low cost mobile learning technology as a potential means to ignite self-directed and exploratory learning through a child-centered model may be beneficial for future ICT4D planning. This paper discussed only the math problem solving activity, but the children enjoyed other mobile games on the devices and enrichment activities after the observation session, and we expect to analyze results from those activities as well.

Considering the rapid advancement of technology today, mobile learning options for future ICT4D will only increase. Consequently, researchers must continue to investigate their impact; we believe there is a specific need for:

1. More in-depth studies on ICT design variations to meet different challenges of different localities;
2. Further analyses on mobile interface designs for game-based learning scenarios;
3. More studies on potential benefits and possible pitfalls of children-first ICT adoption strategies and how to leverage benefits and address shortcomings of such model;
4. Research on effective ways to involve children as partner in every step of the way in ICT4D projects; and,
5. Best practices in strategizing and implementing sustainable educational ICT4D projects for the disadvantaged children around the world.

In these regards, we hope we have shared at least some useful insights (although on a small scale) for educators to consider in catering and tailoring more contextualized education solutions to learners in different regions and conditions.

## REFERENCES

- Aguilera, M. & Mendiz, A. (2003). Video Games and Education: Education in the face of a 'Parallel school'. *Computers in Entertainment*, 1(1).
- ASER (2005) All India Findings (rural). Retrieved August 23, 2010 from <http://www.asercentre.org/asersurvey/aser05/pdfdata/in-05.pdf>
- Attewell, J. (2005). *From Research and Development to Mobile Learning: Tools for Education and Training Providers and their Learners*. Paper presented at the 4th World Conference on mLearning.
- Avgerou, C. (2008). Information Systems in Developing Countries: A Critical Research Review. *Journal of Information Technology*, 23(3), 133-146.
- Bay, S., and Ziefle, M. (2005). Children using cellular phones. The effects of shortcomings in user interface design. *Human Factors*, 47(1), 158-168.
- Baya'a, N., and Daher, W. (2009). *Students' perceptions of Mathematics learning using mobile phones*. Paper presented at the International Conference on Mible and Computer Aided Learning, Amman, Jordan.
- BECTA. (2001). Computer Games in Education: Aspects. BECTA. Retrieved 18 November, 2009, from <http://partners.becta.org.uk/index.php?section=rh&catcode=&rid=13588>
- Bennett, N., Wood, L. & Rogers, S. (1997). *Teaching through play, teachers' thinking and classroom practice*. Buckingham: Open University Press.
- Berson, I & Berson, M. (2010). High Tech Tots: Childhood in a digital world. Information Age Publishing.
- Birdi, K., Pennington, J., and Zapf, D. (1997). Ageing and errors in computerbased work: an observational field study. *Journal of Occupational and Organizational Psychology*, 70, 35-47.
- Brown, E. (Ed.). (2001). Mobile learning explorations at the Stanford Learning lab. speaking of computers, 55. Stanford, CA: Board of Trustees of the Leland Stanford Junior University.
- Cabrera, J.C. (2002.) "Third Generation Telephony: New Technological Support for Computer Assisted Language Learning." *International Journal of English Studies* 2:167-178.
- Children out of School: Measuring Exclusion from Primary Education. (2006). Retrieved July 6, 2010, from UNESCO Website: [http://www.uis.unesco.org/template/pdf/educgeneral/OOSC\\_EN\\_WEB\\_FINAL.pdf](http://www.uis.unesco.org/template/pdf/educgeneral/OOSC_EN_WEB_FINAL.pdf)
- Chinnery, GM. (2006). "Emerging Technologies going to the MALL: mobile assisted language learning." *Language Learning & Technology* 10:9-16.
- Datta, P. (2006). Urbanisation in India. Retrieved July 2, 2010, from Indian Statistical Institute website: <http://www.infostat.sk/vdc/epc2006/papers/epc2006s60134.pdf>
- DeBoer, J. 2009. The relationship between environmental factors and usage behaviors at 'Hole-in-the-wall' computers. *International Journal of Educational Development*, Vol. 29, no. 1, pp. 91-98
- Druin, A. (1999). *Cooperative inquiry: developing new technologies for children with children*. Paper presented at the ACM CHI 99 Conference on Human Factors in Computing Systems.
- Druin, A. (2002). The role of children in the design of new technology. *Behaviour and Information Technology*, 21(1), 1-25.
- Estrada, R. Q. (2003). Telesecundaria: Students and the Meanings They Attribute to Elements of the Pedagogical Model. *Mexican Journal of Educational Research*, 8(17), 221-243.
- Falbel, A. (1993). *Tools to Build (and Think) With*. Lego Corporation and Massachusetts Institute of Technology.
- Franklin, T., and Peng, L.-W. (2008). Mobile math: math educators and students engage in mobile learning. *Journal of Computing in Higher Education*, 20(2), 69-80.

- Gee, J. P. (2003). *What Video Games Have to Teach Us About Learning and Literacy*. Palgrave Macmillan.
- Gentile, D. (2009). Pathological Video-Game Use Among Youth Ages 8 to 18: A National Study. *Psychological Science*, 20(5), p. 594-602.
- Global literacy challenge. (2008). Retrieved July 5, 2010, from UNESCO website: <http://unesdoc.unesco.org/images/0016/001631/163170e.pdf>
- Government of India (2002). 7th ALL INDIA SCHOOL EDUCATION SURVEY. Retrieved July 14, 2010 from <http://gov.ua.nic.in/aises/>
- Guiding Principles for Mathematics Curriculum and Assessment. (2009). Retrieved March 9, 2010, from National Council for Teachers of Mathematics (NCTM) website: <http://nctm.org/standards/content.aspx?id=23273>
- Hamalainen, R. (2008). Designing and evaluating collaboration in a virtual game environment for vocational learning. *Computers & Education*, 50(1), p. 98-109.
- Hernández, L. H. P., Hernández, M. L., and Alva, M. G. H. A. (2010). Integración de TIC al currículum de telesecundaria. *Investigación*, 15(45), 515-551.
- ITU (2010). Key Global Telecom Indicators for the World Telecommunication Service Sector. Retrieved January 2011 from [http://www.itu.int/ITU-D/ict/statistics/at\\_glance/KeyTelecom.html](http://www.itu.int/ITU-D/ict/statistics/at_glance/KeyTelecom.html)
- Jha, S., Chatterjee, S., 2005. Public-private partnership in a minimally invasive education approach. *International Education Journal* 6 (5), 587-597.
- Joseph, S., K. Binsted, and D. Suthers. (2005). "PhotoStudy: Vocabulary Learning and Collaboration on Fixed and Mobile Devices." Pp. 206-210 in *IEEE International WMTE*.
- Kadyte, V. (2004). "Learning can happen anywhere: a mobile system for language learning." *learning with mobile devices*:73.
- Kamenetz, A. (2010, April 1). A Is for App: How Smartphones, Handheld Computers Sparked an Educational Revolution. *Fastcompany*.
- Kang, N. E., and Yoon, W. C. (2008). Age-and experience-related user behavior differences in the use of complicated electronic devices. *International Journal of Human-Computer Studies*, 66(6), 425-437.
- Keen, P., and Mackintosh, R. (2001). *The Freedom Economy: Gaining the M-commerce Edge in the Era of the Wireless Internet*. Berkeley, CA: McGraw-Hill Company.
- Khoo, A., & Gentile, D. A. (2007). Problem-based Learning in the World of Digital Games. In O. S. Tan and D. Hung (Eds.), *Problem-based Learning and e-Learning Breakthroughs* (pp. 97-129). Singapore: Thomson Learning.
- Kim, P. (2009). "Action research approach on mobile learning design for the underserved." *Educational Technology Research and Development* 57:415-435.
- Kiernan, PJ and K Aizawa. (2004). "Cell phones in task based learning-Are cell phones useful language learning tools?" *ReCALL* 16:71-84.
- Kraemer, K., Dedrick, J., and Sharma, P. (2009). One laptop per child: vision vs. reality. *Communications of the ACM*, 52(6), 66-73.
- Kubeck, J. E., Miller-Albrecht, S. A., and Murphy, M. D. (1999). Finding information on the World Wide Web: exploring older adults' exploration. *Educational Gerontechnology* 25(2), 167-183.
- Kumar, A., Tewari, A., Shroff, G., Chittamuru, D., Kam, M., and Canny, J. (2010). An exploratory study of unsupervised mobile learning in rural India. CHI.
- Laughlin, D., Roper, M., & Howell, K. (2007). NASA eEducation Roadmap: Research Challenges in the Design of Massively Multiplayer Games for Education & Training. Retrieved 18 November, 2009, from [http://www.fas.org/programs/ltp/publications/roadmaps/\\_docs/NASA%20eEducation%](http://www.fas.org/programs/ltp/publications/roadmaps/_docs/NASA%20eEducation%20)

- Levy, M and Kennedy, C. (2005). "Learning Italian via mobile SMS." *Mobile learning: A handbook for educators and trainers*:76-83.
- Ling, C., Hwang, W., and Salvendy, G. (2006). Diversified users' satisfaction with advanced mobile phone features. *Universal Access in the Information Society*, 5(2), 239-249.
- Ling, R. (2004). *The mobile connection*. Amsterdam, Netherlands: Morgan Kaufmann Publishers.
- Matthee, M., and Liebenberg, J. (2007). *Mathematics on the Move: Supporting Mathematics Learners through mobile Learning*, Melbourne, Australia.
- Mead, S. E., Spaulding, V. A., Sit, R. A., Meyer, B., and Walker, N. (1997). *Effects of age and training on World Wide Web navigation strategies*. Paper presented at the Human Factors and Ergonomics Society 41st Annual Meeting.
- MIT Poverty Action Lab. (2006). From schools to learning: meeting the learning needs of marginalized children. MIT Poverty Action Lab. Retrieved October 20, 2009 from <http://www.povertyactionlab.com/papers/BalsakhiJuly2005k.pdf>
- Norbrook, H, BBC English, and Scott, P. (2003). "Motivation in mobile modern foreign language learning." *Further information*:50.
- Ogata, H and Yano, Y. (2004). "Knowledge awareness map for computer-supported ubiquitous language-learning." Pp. 19-26.
- Paredes, RGJ, H Ogata, NA Saito, C Yin, Y Yno, Y Oishi, and T Ueda. (2005). "LOCH: supporting informal language learning outside the classroom with handhelds." Pp. 5.
- Pinkett, R. D. (2002). Creating community connections: Sociocultural constructionism and an asset-based approach to community technology and community building. Unpublished PhD dissertation. Massachusetts Institute of Technology Media Laboratory.
- Pinkett, R. D. (2003). Community technology and community building: Early results from the Creating Community Connections Project. *The Information Society*, 19(5), 365-379.
- Prakash, A., and De, R. (2007). Importance of Development Context in ICT4D Projects: A Study of Computerization of Land Records in India. *Information Technology and People*, 20(3), 262-281.
- Rao, S. S. (2009). Role of ICTS in India Rural Communities. *The Journal of Community Informatics*, 5(1). Retrieved October 20, 2009 from <http://www.ci-journal.net/index.php/ciej/article/view/313/429>
- Reimers, F. (2000). *Unequal Schools, Unequal Chances: The Challenges to Equal Opportunity in the Americas*. Harvard University Press.
- Rusten, E. (2003). Using Computers in Schools. In *Digital Opportunities for Development: A Sourcebook for Access and Applications*. Retrieved June 30, 2010, from [http://learnlink.aed.org/Publications/Sourcebook/chapter4/Computers\\_in\\_Schools\\_model\\_ofuse.pdf](http://learnlink.aed.org/Publications/Sourcebook/chapter4/Computers_in_Schools_model_ofuse.pdf)
- Schwabe, G. & Göth, C. (2005). Mobile learning with a mobile game: Design and motivational effects. *Journal of Computer Assisted Learning*, 21(3), 204–16.
- Schwartz, S. (1998). A comparison of componential and traditional approaches to training reading skills. *Applied Cognitive Psychology*, 2(3), 189-201.
- Shah, P. & Veetil, V. (2006). Private Education for the Poor in India. Retrieved July 14, 2010 from [http://papers.ssrn.com/sol3/papers.cfm?abstract\\_id=950146](http://papers.ssrn.com/sol3/papers.cfm?abstract_id=950146)
- Sharples, M., Taylor, J., and Vavoula, G. N. (2005). *Towards a theory of mobile learning*. Paper presented at the 4th World Conference on mLearning.
- Shin, N., Norris, C., and Soloway, E. (2006). *Effects of handheld games on students learning in mathematics*. Paper presented at the Proceedings of the 7th International Conference on Learning Sciences.

- Sjölinder, M., Höök, K., Nilsson, L.-G., and Andersson, G. (2005). Age differences and the acquisition of spatial knowledge in a three-dimensional environment: evaluating the use of an overview map as a navigation aid. *International Journal of Human-Computer Studies*, 63(6), 537-564.
- Stead, G., Sharpe, B., Anderson, P., Cych, L., and Philpott, M. (2006). *Emerging technologies for learning*. Coventry, UK: Becta.
- Tang, S., Hanneghan, M., & Rhalibi, A. (2009). Introduction to Games-Based Learning. In T. Connolly, M. Stansfield, and L. Boyle (Eds.). *Games-Based Learning Advancements for Multi-Sensory Human Computer Interfaces*. pp. 1-17. Hershey, PA: Information Science Reference.
- Thompson, M. (2008). ICT and Development Studies: Towards Development 2.0. *Journal of International Development*, 20(6), 821-835.
- Thornton, P and C Houser. (2005). "Using mobile phones in English education in Japan." *Journal of Computer Assisted Learning* 21:217-228.
- Towards a knowledge based society: Integrating technology into education. (2003). Retrieved July 6, 2010, from NDP website: <http://www.ndp.org.eg/en/index.aspx>
- Vail, K. (2003). Next generation divide. *American School Board Journal*, 23-25.
- Walsham, G. (2010). ICTS for the Broader Development of India: An analysis of the Literature. *Electronic Journal of Information Systems in Developing Countries*, 41(4), 1-20.
- UNESCO (2009). Who are excluded and why? Retrieved April 23, 2009, from UNESCO website: [http://portal.unesco.org/education/en/ev.php-URL\\_ID=28705&URL\\_DO=DO\\_TOPIC&URL\\_SECTION=201.html](http://portal.unesco.org/education/en/ev.php-URL_ID=28705&URL_DO=DO_TOPIC&URL_SECTION=201.html)
- Wang, X., Berson, I., Jaruszewicz, C., Hartle, L., & Rosen, D. Young children's technology experiences in multiple contexts: Bronfenbrenner's ecological theory reconsidered. In I. Berson & M. Berson (Eds.), *High Tech Tots: Childhood in a digital world*. Information Age Publishing.
- World Bank. (2008). World Development Indicators. Retrieved July 2, 2010, from WorldBank website: <http://siteresources.worldbank.org/DATASTATISTICS/Resources/WDI08supplement1216.pdf>
- Wouters, P., Spek, E., Oostendorp, H. (2009). Current Practices in Serious Game Research: A Review from a Learning Outcomes Perspective. In T. Connolly, M. Stansfield, and L. Boyle (Eds.). *Games-Based Learning Advancements for Multi-Sensory Human Computer Interfaces*. pp. 232-250. Hershey, PA: Information Science Reference.
- Zhang, T., Rau, P. L., & Salvendy, G. (2007). *Developing instrument for handset usability evaluation: a survey study*. Paper presented at the 12th international conference on Human-computer interaction: interaction design and usability table of contents, Beijing, China.
- Ziefle, M. (2009). *Spatial cues in small screen devices: Benefit or handicap?* Paper presented at the 12th IFIP TC13 Conference in Human-Computer Interaction.
- Zurita, G and Nussbaum, G. (2004). "A constructivist mobile learning environment supported by a wireless handheld network." *Journal of Computer Assisted Learning* 20:235-243.