EXPLORING APPLICATION, INTERACTION AND INTERFACE DESIGN FOR EDUCATIONAL USE OF MOBILE PHONES IN SCHOOLS IN PANAMA

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Abstract

Mobile phones have become the most ubiqutious computing devices worldwide. In developing countries, mobile phones have been adopted much faster than conventional desktop computers and in some regions mobile phones are the only kind of computer available. In fact, current mobile phones have well integrated multimedia capabailities, are equipped with multiple sensors, offer a wide range network capabilities, and many offer a good usability. These features, together with the ubiquity of mobile phones makes these devices a versitile and powerful tool to be used for supporting education in developing countries.

Over the last decade researchers have explored the potential of using mobile phones for learning in school in developing countries around the world. So far, most research focused on the use of customized applications that were designed to support specific tasks within a single school subject or to support a particular learning task. The research reported in this dissertation followed a human-centered design approach. In contrasts to previous research the approach taken was more holisitic than previous studies, included longitudinal studies, and investigated how ordinary off-the-shelf mobile phones can be used as a tool to assist teaching and self-directed learning across different classes in elementary schools in Panama.

The first and exploratory research steps incluced an analysis of the current accesiblity, atittude and use of computers and mobile phones by teachers and students in elementary schools in Panama. Following a participatory design process with the teachers, potential scenarios and use cases where mobile phones might be beneficial for education were identified.

This dissertation includes a set of field studies in elementary public schools in the countryside of Panama. Teachers identified relevant use cases for their situation, and were free to integrate and use mobile phones in whatever way they considered best to support the pupils they were teaching at that moment. To automate the long term data collection a screenshot logger mobile application was developed. This applications runs in the background and provides textual and visual data of the use and interaction across the different applications and function of the mobile phones and was used during the field studies. Using this tool these studies provided a rich dataset. An analysis of the data provided a comprehensive understanding on the usage of mobile phones by children both at school and at home.

One area that was investigated in depth was how technologies impact drawing and writing skills. It was studied how children of different ages wrote words by hand and how they drew simple shapes on paper and different touchscreen phones.

The research conducted and presented in this dissertation, provides evidence that there is a strong potential for educational use of mobile phones in elementary schools in Panama. This dissertation presents a set of recommendations on how mobile applications and more general phone user interface should be improved to better support a variety of individual teaching approaches and learning styles.

Zusammenfassung

Mobiltelefone sind weltweit zu den am meistgenutzten digitalen Kommunikationsgeräten geworden. In Entwicklungsländern wurden Mobiltelefone viel schneller eingeführt als klassische PCs und in manchen Regionen sind sie das einzige verfügbare digitale Kommunikationsgerät. In der Tat besitzen die aktuellsten Mobiltelefone vielfältige Multimedia-Eigenschaften, sind mit einer Vielzahl von Sensoren ausgestattet, verfügen über große Netzwerkkapazitäten und erlauben eine einfache Bedienung. Diese Funktionen, zusammengenommen mit der Verfügbarkeit der Mobiltelefone, lassen diese Geräte zu einem vielseitigen und mächtigen Arbeitsgerät werden, das das Unterrichten in Entwicklungsländern unterstützen kann.

Im letzten Jahrzehnt haben Forscher aus verschiedenen Ländern das Potential vom Gebrauch von Mobiltelefonen zum Lernen an Schulen in Entwicklungsländern untersucht. Bisher konzentrierten sich die meisten Untersuchungen auf den Gebrauch von maßgeschneiderten Anwendungen, die speziell für bestimmte Aufgaben innerhalb eines einzelnen Schulfachs oder zur Unterstützung einzelner Lernaufgaben konzipiert wurden. Die Untersuchungen, die in dieser Doktorarbeit präsentiert werden folgten dem Konzept des Human Centered Designs. Jedoch sind diese ganzheitlicher als vorherige Studien, beinhalten Langzeitstudien und untersuchten wie gebräuchliche Mobiltelefone als Hilfsmittel zum Unterrichten und zum Selbststudium in verschiedenen Fächern in Panamas Grundschulen eingesetzt werden können.

Die ersten Forschungsuntersuchungen starteten mit einer Analyse der aktuellen Zugänglichkeit, der Einstellung zum Einsatz von PCs und Mobiltelefonen und deren Verwendung von Lehrern und Schülern in Grundschulen in Panama. Unter Mitwirkung der Lehrer wurden im Gestaltungsprozess potenzielle Szenarien und Fallbeispiele aufgestellt, bei denen Mobiltelefone zum Lernen benutzt werden könnten.

Diese Doktorarbeit beinhaltet eine Reihe von Feldstudien in öffentlichen Grundschulen in den ländlichen Regionen von Panama. Die Lehrer erarbeiteten relevante Anwendungsfälle und konnten die Art und Weise des Gebrauchs und der Integration der Mobiltelefone frei wählen, damit mit ihrer Wahl der grösste Nutzen aus dem Einsatz im Unterricht in den jeweiligen Klassen gezogen werden konnte. Um die automatische Sammlung der Nutzerdaten während den Studien zu ermöglichen, wurde eine mobile Anwendung entwickelt, die im

Hintergrund läuft und die textuellen und visuellen Daten der Nutzung und der Interaktion mit verschiedenen Anwendungen und Fuktionen der Mobiltelefone aufzeichnet. Mit Hilfe der Anwendung konnte eine große Datenmenge aufgezeichnet werden. Durch die Analyse der Daten konnte ein umfassendes Verständnis des Gebrauchs von Mobiltelefonen durch die Kinder sowohl in der Schule als auch Zuhause gewonnen wird.

Ein Fokus lag dabei auf der Frage inwieweit die Technologie die Fähigkeiten des Zeichnens und Schreibens beeinflusst. Es wurde untersucht, welche Unterschiede sich ergeben wenn Kinder verschiedener Altersgruppen auf Papier und auf verschiedenen Telefonen mit Touchscreen Wörter von Hand schreiben und einfache Formen zeichnen.

Die durchgeführten Untersuchungen, die in dieser Doktorarbeit präsentiert werden, liefern Beweise, dass es ein großes Potential für die Verwendung von Mobiltelefonen für pädagogische Zwecke in Grundschulen in Panama gibt. Diese Doktorarbeit spricht zusätzlich eine Reihe von Empfehlungen aus, wie man mobile Anwendungen und die allgemeine Benutzeroberfläche von Mobiltelfonen verbessern sollte, um eine Vielfalt von individuellen Lehrmethoden und Lernstilen besser unterstützen zu können.

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Dedication

To my beloved parents:

Elba del Carmen Bahamóndez Carrizo

and

Maximino Valderrama Quirós

to whom I owe the person who I am now.

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Chapter 1

Introduction

Education is considered a way to reduce poverty [UNESCO, 2014]. Hence, providing good education is a major concern in developing countries. From a governmental perspective, improving education is an investment in the country's future that can result in economic growth and increased global competitiveness. For individuals and families in developing regions, the motivation to participate in education is very high, since education is seen as a way to improve personal living conditions and gain in the long term prosperity. However, to provide a good public education in developing countries is difficult. Shortage of school infrastructure, no roads, lack of basic services, very high youth population, and lack of teachers are among the challenges faced by the government to give an education with quality to all their citizens.

New technologies open means to widen and improve the access to education. However, the use of new technologies to support education is tempting but very challenging at the same time. There is also a very strong cultural influence on how schools are organized and how teaching is conducted. The acceptance within a society about what knowledge and skills are important is deeply rooted and not easily changed. Teaching and the relationship between the teacher and the pupils are strongly dependent on the culture and must be respected when introducing new technologies. If these technologies impose certain teaching/learning paradigms, even if considered superior to the traditional way of teaching, they are likely to fail

Because of cultural, social, and economic aspects the introduction of computers in education in rural settings of developing countries has not succeeded. Even in the case of computers being available in some schools, teachers do not integrate them in their teaching; neither for creating learning material, nor for enhancing their class through multimedia or interactivity. Similarly, students not having access to computers at home cannot take full advantage of them to support their learning in cases they are available at schools.

In contrast to personal computers (PCs), mobile phones have become widely adopted around the world, including developing regions. Even though they are not comparable with conventional computers in screen size and computing power, they offer many opportunities to be used as tools for teaching and learning. To name some of the advantages: phones are affordable; they provide multimedia capabilities (e.g. camera, microphone), and there is an established infrastructure for service and repair established around the world. These points suggest that mobile phones are a valid alternative for learning and teaching.

In our research we evaluate the potential of mobile phones as learning tools. The vision is, that in the near future students and pupils would use mobile phones as educational device that provide them much of the functionality that traditional PCs offer and that phones can be used for learning at school. In contrast to previous research, we explore the design space of inherent capabilities of mobile phones, which enhance generally useful applications (e.g. a drawing application).

Most parts of this research, i.e. the field studies, have focused on Panama. We selected Panama because, similar to most Latin American countries, there is a high adoption of mobile phones; shared language, religion, and idiosyncrasy; it has a cosmopolitan capital, but rural countryside. In addition, few studies have researched the use of mobile phones for learning with children in Latin American and none have been conducted in Panama before.

1.1 Computers, Mobile Phones and Education

Information and communication technologies offer attractive means to provide accessibility to education. For example, although old technologies, television and radio nowadays still play a very important role in the education of children and adults in rural and remote areas in developing countries in Latin America, including Panama [SEP, 2014; Maestro en Casa, n.d.; IPER, n.d.]. Without such technologies that deliver education to some rural and remote areas education is not possible. And the success of these initiatives lies in the wide availability and adoption of these devices by users, especially the radio, even in rural communities.

Computer technologies and the Internet seem to offer easier and wider access to educational materials and means to improve learning efficiency. Computers support education in different ways: they simplify the creation and management of educational content for teachers, the Internet facilitates self-learning, distance and blend learning spaces, multimedia applications and games enhance and make the educational content more attractive for students. In addition, the Internet empowers citizen providing a permanent access to information.

Therefore, educational authorities in developing countries have made efforts to equip schools with computers, following the same model from developed countries. However, this model approach in school has not been fully successful. Among the reasons of failure are: schools in rural and remote areas are not equipped with computers because of the precarious infrastructure they have; few computers available for a large student population limit the time that students can use the computer; access to the Internet and computer maintenance is not available in all schools. In case where computers are provided with costly educational software and educational games, teachers do not integrate them in their teaching style. Teachers neither take advantage of the multimedia features of the computer to create and present educational content.

While the use of personal computers in developing countries is still low, there has been a widespread adoption of mobile phones in recent years [ITU, 2014c]. In comparison to PCs mobile phones are easier to administrate and users have a great interest in keeping the devices functional at all times since they use them as communication devices. Mobile phones have become status symbol [Katz *et al.*, 2005]. People in developing countries are willing to spend their money to acquire a good mobile phone rather than a computer. But in fact, these handheld devices have become small computing platforms that integrate multimedia features and a variety of network capabilities. This issue, together with its wide adoption makes mobile phones attractive for learning.

Despite this potential for education, like many other developed, and developing countries, no school in Panama allows the use of mobile phones in the classroom. Access to inadequate content over the Internet, a disruptive effect in class, and a misuse of the device are among the main reasons to prohibit the use of mobile phones in schools.

For the computer science and the HCI community this topic is current and important. As we better understand how children and teachers in specific cultures use and adapt new technologies (like mobile phones) for learning, computer science researchers can design applications and tools that (1) support teachers to deliver educational content without imposing unfamiliar practices to their teaching style, and (2) enhance education in remote places where traditional ways of learning do not succeed.

1.2 Research Questions

Although there are several examples of mobile phones for supporting education, these approaches have been mainly focused on the development of specific applications for teaching a particular subject. The potential of mobile phones to be used as a tool by educators for teaching in developing countries, independent of the subject, have not been fully explored.

Our goal in this research was to investigate the adoption of mobile phones for education in public elementary schools in the countryside of Panama. We looked at the opportunities that arise from using general multimedia mobile phones as generic learning tools – much like paper and pencil. In order to reach our goal, we identified five research questions.

Table 1. Summary of Research Questions.

No.	Research Question	Chapter
Q_1	*Are mobile phones a useful platform for learning and teaching?*	3, 4, 6,7
Q_2	*What applications and features of the mobile phones support learning and teaching effectively?*	6,7,8
Q_3	*Are there differences regard of gender and age for using mobile phones either as learning tools or as recreation devices?*	8,9
Q_4	*What long term effects have the use of mobile technologies in teaching?*	8
Q_5	*How can current mobile technologies be improved to provide good learning experiences in developing regions?*	10

Our first research question raised was: Are mobile phones a useful platform for learning and teaching (Q_1) in developing countries like Panama.

Modern mobile phones include a variety of network and multimedia capabilities. It is well known that the use of multimedia enhances the learning experience for children. In the thesis we try to understand, from the experience of teachers and students, which of these features and built-in applications support better learning and teaching (Q_2) in Panama.

Cognition, motor skills and behavioral aspects differ strongly during childhood. Similarly, boys and girls usually have different interests and behave distinctly. Are gender and age differences affecting the way children use the mobile phones for learning and for recreation? (Q_3) is another research question we try to answer in the remainder of the thesis.

The adoption of the technology can also be influenced, not only by gender or age, but by the time children and teachers spend with the technology. We also wanted to know what long term effect are observed when using mobile technology for teaching (Q_4). Finally, in the thesis we wanted to know how the mobile technologies can be improved to provide better learning experiences in developing regions (Q_5).

1.3 Research Methodology and Context

The research leading to this doctoral thesis was accomplished over the course of four years, as Ph.D. student in the User Interface Engineering Group at the *University of Duisburg-Essen* and in the Group for Human Computer Interaction of the *University of Stuttgart*. The research has been supported by Nokia. The work contributing to this dissertation was published in conference proceedings. Chapters are based on these publications, which are referenced at the beginning of each chapter. The most outstanding parts of this research were published as a chapter in a book [Valderrama Bahamóndez & Schmidt, 2011c]; work-in-progress, short and full papers at the following conferences: MLearning [Valderrama Bahamondez, *et al.*, 2009], CHI EA 2010 [Pfleging *et al.*, 2010], CHI EA [Valderrama & Schmidt, 2010], CHI 2011 [Valderrama Bahamondez, *et al.*, 2011a], INTERACT 2011 [Valderrama Bahamondez, *et al.*, 2011b], MUM 2012 [Valderrama Bahamondez, *et al.*, 2012], MOBILEHCI 2013 [Valderrama Bahamondez, *et al.*, 2013] and MOBILEHCI 2014 [Valderrama Bahamondez, *et al.*, 2014].

In this thesis, we realized a field research following a user-centered design (UCD) and a participatory design approach. Instead of working in lab environments, we moved out and conducted short and long term field studies with teachers and students in schools in Panama. Surveys, interviews, focus groups, observations, video recordings, prototyping, and logger applications were the methods used to collect information and analyze the real potential of mobile phones as educational tools in real world environments. During the different stages of our research we have worked with 320 teachers, and 709 children, including 135 children who took part in the field studies.

1.3.1 Surveys

Surveys about the access and use of computers and mobile phones by teachers and children in Panama were the initial point in the development of our research. Whereas statistics about the access to computers and mobile phones in Panama exist, this information was holistic and not focused on specific users, like teachers and school students. In this initial survey, teachers evaluated use cases of utilizing mobile phones in the learning context. We also gathered early insights into the attitude of teachers and children towards the use of mobile phones for learning.

1.3.2 Focus Group

Focus groups are used as primary- qualitative data collection method [Khan *et al.*, 1991; Krueger & Casey, 2009]. In our case, we conducted a focus group with teachers to have a better understanding towards the teachers' attitude toward the use of mobile phones in classroom. The focus group was conducted prior to the interviews and the field studies. The main outcome of the focus group was different scenarios where teachers imagine mobile phones to be useful for learning and teaching.

1.3.3. Interviews

During our research, we interviewed children and parents to validate findings of the initial surveys and to gain further insights of the possible design space for learning with mobile phones. The feedback from the teachers across the whole process was very important. We aimed to conduct interviews individually. However, this was not always possible due to the large numbers of participants. The use of paper prototype supported us during the interviews.

1.3.4 Field Studies

We conducted two short term field studies and one long term field study in public schools in rural Panama. The field research helped us to better realize how children and teacher adapt the use of mobile phones in their natural settings. The short field study allowed us to gather insights of the adoption of the mobile devices inside the classroom and the novelty effect; in contrast the long term field study was conducted to understand also the adoption of mobile phones inside and outside the classroom during a long term period. Logger applications taking screenshots provided an unobtrusive way to collect information on how children adopt the use of mobile phone during the field studies.

1.4 Contributions of This Thesis

The contributions of this dissertation are classified in terms of conceptual contributions and applications developed through the research. The contributions of this doctoral thesis can be summarized as follows:

- Design guidelines on how the applications and the user interface of mobile phones should be improved to better support educational tasks.

- One central finding of our research is the validation that mobile phones, even without specific applications, empower teachers to create learning activities that cannot be realized with a PC. Teachers use phones just as any other learning tool. They utilize the devices without disrupting the usual way of teaching and work with their students in the classroom. Furthermore, also children take advantage of using phones as a learning tool (e.g. translator, annotation) without external trigger.

- Design and implementation of a screenshot logger mobile application as supportive tool for research. The logger application logs and takes pictures from the active screen that users work with. It runs transparently in the background. With this tool, researchers can have visual insights how user interact with the mobile phone.

- Thanks to the long term field study, HCI researchers learn how children in rural areas in a Latin American country adopt the use of mobile phones in their environment beyond the educational aspect. The findings provide the researchers with a better understanding on how to create technologies, applications, and design theories that fit to children's life style and social practices.

- The conceptual design and prototype implementation of Mobidev, an application that allows easily prototyping and programming for mobile phones from mobile phones. Our objective with Mobidev was to empower local users –without programming skills– to create user interfaces from paper sketches and develop simple mobile application.

- To the best of our knowledge, this research is the first to provide statistic related to the access and use of IT in Panamanian primary schools by children and teachers. Here we present the findings of a set of surveys to 574 children and 85 teachers. These statistics can give local authorities and educational politics a guide on how children and teachers use IT for learning.

- Across our research we designed and implemented two software prototypes: the MobileMath and Mobislides. MobileMath supports teachers in the creation of arithmetic tasks for low-end mobile phones. The tasks are generated randomly according to the preferences of the teachers. With this tool, teachers can generate their customized math trainer. With the Mobileslides application children can create and illustrate written short stories, that later can be shared via Internet with their peers and teachers. Mobileslides was designed to tackle the low speed of Bluetooth connections for exchanging multiple files simultaneously.

1.5 Thesis Outline

This chapter introduces us to this thesis, describing the motivation, research questions, the research methodology approach followed in this work, and the contribution summary of this thesis. The rest of this thesis is organized in eleven chapters, as follows:

- **Chapter two** starts with a background about mobile learning; we also present the most important research work found in the literature about the use of mobile phones for learning in developed and developing countries.

- **Chapter three** describes an overview of the Panamanian education system including its challenges; the current use of information and communication technologies to improve educational access in both urban and rural areas, and the current access to technologies by their citizens. The potential of mobile phones for learning is also analyzed in this chapter.

- **Chapter four** describes the results of our surveys, interviews and other ethnographic studies conducted with teachers and students from Panamanian elementary schools. This chapter presents the access to IT and its usage by teachers and students; furthermore, potential scenarios where students and teachers welcomed the use of mobile phones for learning is also discussed.

- **Chapter five** presents the tools, prototypes, and applications developed through this research.

- **Chapter six** describes the research methodology and setup, followed by the short as well as the long term field studies. Additionally, in this chapter the use cases, designed by teachers related to the use of multimedia recording and playback for learning with the mobile phones, are presented. The description of the findings of the short and long term field studies realized in Panama continues in the chapters seven and eight.

- **Chapter seven** outlines the usage of mobile phones to support the working with documents during the field studies. The approach followed by teachers was the digitalization of written content with the cameras of the mobile phones, and the edition of it with drawing applications. The chapter also describes how mobile phones were used to better organize information, e.g., summarize lessons, during the field studies. The chapter ends with an evaluation of the features and applications used during the field studies.

- **Chapter eight** analyzes the impact and social behavior of the children when using mobile phones inside and outside the classroom. Gender differences in adopting and using mobile phones are described. An in-depth interview with students, their teachers, and parents who took part in the long term field study is presented.

- **Chapter nine** describes a user study conducted with students across different ages, comparing handwriting using traditional paper and pencil versus stylus and finger with touchscreen phones.

- **Chapter ten** describes recommendations and UI design guidelines to take into consideration for an enhanced development of mobile learning applications and towards a better integration of mobile phones for learning based on the results of our research. This chapter also describes a prototype that allows local populations to develop mobile applications using mobile phones.

- **Chapter eleven** presents the conclusion which summarizes the content and contribution made in this thesis. In addition, it discusses future directions and potential issues for future work.

Chapter 2

Background and Related Work

This chapter starts with the definition of mobile learning from the point of view of different pedagogic researchers, where they described design guidelines in the creation of mobile learning applications, and the potential of mobile phones for learning. Later we present the related work on learning applications using mobile phones in developed countries. Computers and mobile phones approaches for learning in developing regions will also be explored. A discussion and analysis of the different approaches for learning on mobile phones in developing countries complete the chapter.

Part of this chapter is based on the following publications:

[Valderrama Bahamondez & Schmidt, 2011c] Valderrama Bahamondez, E. & Schmidt, A. (2011). Mobile Phones, Developing Countries and Learning. In W. Ng (Ed.), *Mobile Technologies and Handheld Devices for Ubiquitous Learning. Research and Pedagogy* (pp. 120-137). Hershey, PA: Information Science Reference

[Valderrama Bahamondez et al., 2009] Valderrama Bahamondez, E., Döring, T., & Schmidt, A. (2009). Mobile Phone and Learning in Latin America. Proceedings of the IADIS International Conference Mobile Learning, 321-325, IADIS.

2.1 Mobile Learning

Although the term mobile learning is relatively new, learning experiences outside traditional classroom settings without restriction of place and time are not new. Distance learning can be seen as antecessor of a *“mobile”* learning. Distance learning is defined as *“improved capabilities in knowledge and/or behaviours as a result of mediated experiences that are constrained by time and/or distance such that the learner does not share the same situation with what is being learned”* [King *et al.*, 2001, p.10]. Distance learning has its origin in the middle-nineteenth century, when learning content was delivered through the post mail [Sumner, 2000]. It gave an alternative to deliver education to people who were not able to attend regular school or colleges, because they lived in remote areas, or were physically impaired.

In 1901, the Linguaphone Company –a language training provider– recorded audio lessons on wax cylinders and sent them via mail [Burston, 2012]. This can be seen as the first step towards offering a mobile education with further media than only text, which was the standard at that time. With the apparition of Radio broadcast, and later of TV broadcast, both mediums were used to broadcast educational content. These mediums supported mainly learning at any place but not at any time. However, with the development of different audio-and-video record-and-storage devices, it was possible to deliver recorded audio and video lessons through correspondence.

In the middle of the 90s with the popularization of the Internet and the World Wide Web, distance learning experienced a core impulse. Internet played a core role in distance learning. E-learning, defined as *“learning conducted via electronic media, typically on the Internet”* [E-learning, 2014] was born. Learners have through mouse click access to rich multimedia learning content; at the beginning from personal computers on fixed places, like home, Cybercafés, or workstations; but nowadays, from anywhere thanks to the development of mobile computing devices. With the evolution of handheld devices, e.g. smartphones, that include sensors and a variety of network technologies, mobile learning extends the learning experience beyond the mobility feature.

2.1.1 Definition of Mobile Learning

The term mobile learning is composed by the two nouns mobile and learning. The Oxford Dictionary defines mobile as *“able to move or be moved freely or easily”* and learning as “*the acquisition of knowledge or skills through study, experience, or been taught*”. In the literature, we found several attempts to define the concept of mobile learning as a whole. Already in the year 2000, Quinn defined mobile learning as *"e-learning through mobile computational devices: Palm, Windows CE machines, even your digital cell phone"* [Quinn, 2000], a similar description was found in [Pinkwart & Perez, 2003] who defined mobile learning as "*e-learning that uses mobile devices and wireless transmission"*. Traxler defined mobile learning as *"any educational provision where the sole or dominant technologies are handheld or palmtop devices"* [Traxler, 2005], whereas Wood defined it as *"the use of mobile and handheld IT devices, such as PDAs, mobile phones laptops and tablet PCs in teaching and learning"* [Wood *et al.*, 2003]. Sharma and Kitchens defined mobile learning as *"learning supported by mobile devices, ubiquitous communication and intelligent user interfaces*" [Sharma & Kitchenns, 2004].

Most of the definitions of mobile learning, found in the literature, are techno-centric. However, other researchers have tried to define mobile learning not only from the use of portable devices, but considering the mobility of the learner and learning itself [O´Malley *et al.*, 2005; Leung & Chan., 2003]. For instance, Leung and Chan described mobile learning as "*the point at which mobile computing and electronic learning intersect to produce an anytime, anywhere learning experience"* [Leung & Chan, 2003]. In contrast some researchers defined mobile learning in relation to the communication between the learners; Nyiri considered mobile learning as *"learning that arises in the course of person-to-person mobile communication"* [Nyri, 2002], while Sharples affirms that the *"new mobile and context-aware technology can enable young people to learn by exploring their world, in continual communication with and through technology ... conversation between learning real and virtual worlds"* [Sharples *et al.*, 2002].

In search of a wider definition of mobile learning which included not only the technological and mobility aspect of mobile learning, but also all the variables involved in learning in such mobile environments, researchers as [Laouris & Eteokleous, 2005] propose the following definition:

$$\boldsymbol{m - Learning} = \boldsymbol{f}\{\boldsymbol{t}, \boldsymbol{s}, \boldsymbol{LE}, \boldsymbol{c}, \boldsymbol{IT}, \boldsymbol{MM}, \boldsymbol{m}\}$$

Where t = *time, which for m-Learning can be continuous or discontinuous*
s = *space or location where the learning take place.*
LE = *learning environment defined as all the agents involved in the learning*
c = *content*
IT = *technology*
MM = *learner's mental abilities*
m = *method, the way the content is delivered and how the learner interact with*

For a complete description of all the component of this definition please look up in [Laouris & Eteokleous 2005]. More recently, researchers like Shih and Mills [Shih & Mills, 2007] established a set of core features of mobile learning: *(a) the capabilities for learning anytime and anywhere (b) with the use of multimedia and (c) a variety of types of communication.*

While most authors considered mobile learning simply either as the extension of E-Learning [Mostakhdemin & Tuimala, 2005; Georgiev *et al.*, 2004], other authors claimed although m-learning and e-learning share common aspects, they should be considered as two different learning disciplines [Sharma & Kitchenns, 2004; Laouris & Eteokleous, 2005; Traxler, 2005]. However, due the fact that the development of computing technology is going more and more towards mobile and ubiquitous; and that there is Internet infrastructure in developed countries, the slight line that differentiates e-learning and m-learning is blurring.

From all the reviewed definitions, we can summarize that researchers defined mobile learning mainly from two perspectives: the mobility of the learner to study at anytime and anyplace; and the use of computing portable devices to learn. Finally, a consensual definition of mobile learning, which considers both the mobility and the technology to use for learning, is found in [O´Malley *et al.*, 2005]:

> *"Any sort of learning that happens when the learner is not at a fixed, predetermined location, or learning that happens when the learner takes advantage of the learning opportunities offered by mobile technologies"* [O'Malley, *et al.*, 2005, p. 7]

For our purposes, we agree with the definition proposed by O'Malley *et. al.*, from our point of view, this definition embraces and summarizes the two main aspects of mobile learning, the mobility and the novel learning spaces that the new handheld computing devices are creating.

2.1.2 Design Guidelines for Mobile Learning

Vaouvula *et al.* [Vavoula *et al.*, 2004] defined guidelines as *"rules of principles for action, encapsulating some combination of practitioner-determined best practices in a domain and research-based insights into factors relevant in that domain".* Overall the general HCI guidelines and principles should be considered when designing good interactive applications including m-learning ones. As the mobile learning discipline has evolved, guidelines for the creation of mobile learning applications have also been developed. Levert [Levert, 2006] adopted the six Clark and Mayer's design principles for multimedia learning accordingly to the screen and input size limitation of handheld devices: *(a) Multimedia Principle e.g. break long text into chunks of text; (b) Modality Principle, e.g. keep narration short; (c) Contiguity principle, e.g. do not separate related text and images (d) Redundancy principle, e.g. use duplicate narration for language learning; (e) Coherence principle, e.g. avoid irrelevant videos, images, audios, or texts; and (f) Personalization principle, e.g. create a conversation with the user.*

Design guidelines for mobile learning applications were also proposed by other authors [O´Malley *et al.*, 2005; Seong, 2006], while O'Malley *et al.* focused on mobile learning applications in general; in contrast Seong suggested a set of usability guidelines on how to create mobile learning web applications in particular. Usability is defined as *"the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use"* (ISO 9241-11); usability guidelines from the International Standardization Organization described under the ISO 9241-11 are the main reference in usability. In general, design guidelines for mobile learning can be grouped as follow:

(a) User Analysis: know the learners [O'Malley, *et al.*, 2005; Seong, 2006] considering not only biological aspects (gender, age), but also cultural background and different cognitive skills [Gelderblom & Kotzé, 2009];

(b) Analysis and choice of the technology, including both hardware and software according to the infrastructure available, costs and goals [O'Malley *et al.*, 2005];

(c) Mobile-human interaction: context-awareness, and the personalization of the learning contents [Clark & Mayer, 2011; Seong, 2006];

(d) General HCI guidelines: like Mapping to the real world, consistency, coherence [Clark & Mayer, 2011], minimize human cognitive load, give informative feedback, to help learners to prevent errors and to recover from them;

(e) Guidelines related to the limited screen size of the devices e.g. including only relevant texts or divide long text in smaller chunks, use simple hierarchies for navigation or avoid extensive scrolling are some examples [O'Malley *et al.*, 2005];

(f) Guidelines for questioning for general, completion and multiple choice exercises [O’Malley *et al.*, 2005].

Guidelines for developers of mobile learning environment are found in [Jönsson & Gjedde, 2009]. These guidelines are summarized in three sections: *(a) presentation of the content, (b) game design and collaborative learning and (c) integration of the learning environment in school systems.* An adequate integration between fun and educational content should be considered when we create learning application for children, [Gelderblom & Kotzé, 2009; Jönsson & Gjedde, 2009] espeically when developing learning games. Understanding the users well [Gelderblom & Kotzé, 2009; Seong, 2006; O'Malley, *et al.*, 2005], i.e. teachers and learners is the most important recommendation. Furthermore, the culture and social background is an important aspect to consider when developing learning contents [Kam *et al.* 2009a; Gelderblom & Kotzé, 2009]. It is important in the way how to present the content or to teach may be different across diferent cultures.

2.1.3 Potential of Mobile Phones for Learning

From all the different mobile devices, mobile phones are acknowledged as the handheld computing device with the most potential for the realization of mobile learning [Nyiri 2002; Sharples, *et al.*, 2005]. First, mobile phones not only have been adopted worldwide, but they are considered as an extension of the self [Laouris & Eteokleous, 2005]. People carry them usually all the time; making them a sort of wearable and ubiquitous computer [Nyiri 2002; Laouris & Eteokleous, 2005].

Table 2. Convergence between Learning and Technology [Sharples et al., 2007].

Learning	Technology
Personalized	*Personal*
Learner centered	*User centered*
Situated	*Mobile*
Collaborative	*Networked*
Ubiquitous	*Ubiquitous*
Lifelong	*Durable*

According to [Sharples *et al.*, 2007] *"there is a relation between learning and technology to the point that both terms have converged".* Table 2 shows the common features of learning and technology, where we can see that mobile phones fully support this learning-technology convergence proposed in [Sharples *et al.*, 2007].

Second reason is that modern mobile phones and smartphones are equipped with enriched multimedia and network capabilities. The wide range of technologies to select includes [Attewell, 2005]: transport options (GPRS, Bluetooth, etc.); delivery option (HTTP, SMS, MMS, etc.); media options (video, audio files, TV broadcast, etc.); platform options; and development language options. These capabilities give room to the development of a great variety of learning approaches. On one hand, developers together with pedagogues can create customized learning applications that later can be utilized by learners. Furthermore all these multimedia and network features of modern mobile phones can be used as tools to create content, without the need of any customized learning applications, just with the proprietary features of mobile phones. In addition, students can program their own mobile applications. The vision that computers can support education with the three roles as tutor, tool and tutee support education [Taylor, 1980], is also fully applicable to smartphones.

2.1.3.1 Overview about the History of Mobile Phones

Since Alexander Graham Bell invented the telephone in 1876, almost 200 years passed until the mobile phone was invented such as the way we know. Naturally, the development of the mobile phone was the result of the effort of many researchers over time. The timeline illustrated in

Since the first radio speech transmission done by Fessenden in 1900, there has been advances in radio telephony. In Germany, around 1918, wireless telephony was tried on military trains and in 1924 on public train services [DeutschesTelefonMuseum, n.d.]. Due to the Second World War, the development of radio telephony got a great impulse. At the beginning of the 1940s, the backpacked Motorola SCR-300 was the first radio receiver/transmitter which allowed mobile communication among soldiers [Magnuski, 2005; Meyers, 2011]. In 1942, Motorola presented the model SCR-536 a handheld transceiver, informally called *"hand-talkie"* [Motorola Solutions, 2014; Meyers, 2011].

In 1946 Bell System introduced the Mobile Telephone System (MTS) a VHF radio system, which allowed its users to receive and make calls from automobiles but with the intermediation of an operator [Meyers, 2011; IEEE, 2013]. Later, in 1964, the Improved Mobile Telephone System (IMTS) was developed. It offered a direct connection without the need of operators, allowed more simultaneous calls and the devices weighted up half less than their predecessors [Meyers, 2011; IEEE, 2013].

The cell phone network was conceived by Ring from Bell Labs in 1947 [IEEE, 2013], but it was not developed by end of the 1960s by Frenkiel, Porter and Engel [IEEE, 2013]. The cell phone network technology opened the door to the rapid development of the modern mobile phones. In 1973, Dr. Cooper from Motorola made the first cell phone [DiscoveryChannel, 2014; IEEE, 2013, CBCNews, 2013]. However, it was not commercially available as DynaTac 8000x until 1983. In 1993, IBM introduced the model Simon considered as the first smartphone; that also included a touchscreen [CBCNews, 2013; Meyers, 2011].

Mobile phones that worked over analog cellular network are known as 1G of mobile phones, while the mobile radio telephony is known as 0G. In 1991, GSM introduced a protocol for digital cellular network telephony, called 2G of mobile phones [GSMA, 2014].

Over the time mobile phones have evolved, integrating additional features that go beyond a telephone. The short messaging service (SMS) was introduced in 1992 [GSMA, 2014; DiscoveryChannel, 2014]. In 1999, Kyocera introduced the model VP-210, the first mobile phone with camera phone offering video telephony [Peres, 2007]. Nokia introduced in 1999 the model 7110, the first mobile phone that included access to the Internet through the protocol WAP [Meyers, 2011]. In the middle of the 2000s several mobile phones that incorporated computing capabilities, wide network capabilities and multimedia features were introduced. The most outstanding one was the iPhone introduced in 2007, which made a milestone in the smartphones era.

1876 Roughly at the same time Alexander Graham Bell and Elisha Gray invented the telephone

1900 Fessenden made the first radio speech transmission

1918 Test of wireless telephony in military trains in Germany

1924 Public Trains between Berlin and Hamburg implemented wireless telephony

(a) SCR 536

1940 Motorola developed the Backpacked Motorola SCR-300, the first receiver/transmitter to be used by soldiers

1942 Motorola developed for the US Army the Motorola Model SCR-536 transceiver, the "handy talkie"

(b) Trigild Gemini 2

1946 Bell System introduced the Mobile Telephone System MTS, which allow phone call through an operator.

1947 Douglas Ring and W. Rae Young from Bell Labs designed the concept of Cellular Phone technology

1964 The Improved Mobile Telephone System was introduced, allows mobile telephone calls without operator

Late 1960s Bell Labs developed and implemented the cellular phone network

1973 Martin Cooper from Motorola invented the first handheld mobile phone.

1978 Bell Labs introduced the Advanced Mobile Phone System AMPS, in North America, an analog cell phone system (1G)

1983 Motorola introduced the DynaTac 8000x as the first commercially mobile phone

(c) DynaTAC 8000x

1991 The digital cell phone system (2G) was developed by GSM and CDMA

1992 The Short Message Service was introduced

1997 Siemens launched the first mobile phone color screen.

1999
- Kyocera introduced the first mobile phone with an integrated camera in Japan
- Samsung introduced the SPH-M100 Uproar the first cell phone having MP3 music player

2000
- Nokia 711, the first mobile phone integrated WAP Internet Browser
- Benefon Esc was the first cell phone that included a GPS navigator system
- NTT DoCoMo in Japan, offered the first commercial 3G mobile telephony services

2001 Ericsson T39 was the first cell phone with Bluetooth capabilities

2006 Nokia introduced the first NFC phone the Nokia 631

2007 Apple introduced the iPhone

2008 The first mobile phone with Android OS, the HTC Dream, was invented

Figure 1. Timeline of Mobile Phones Based on the Information Found on the Internet [Skipworth, 2013; DiscoveryChannel, 2014; IEEE, 2013; GSMA, 2014; Meyers, 2011; Simon, 2010; ATT, 2014; WebDesignerDepot, 2009; DeutschesTelefonMuseum, 2014]. Photos sources are: (a) US Federal Government; (b)Techie 111; (c) Redrum0486

2.2 ICT for Learning in the Developing World

Along the history there are several examples on how technologies have been used to support education. In the following sections, we present some approaches on how broadcast and computer support learning in developing countries.

2.2.1 Broadcast for Learning in Developing Countries

Radio Broadcast has been explored as a medium for learning since the late 1940s [ACPO, n.d.; Colin & Estrada, 2001], TV broadcast since the early 1960s [Hilmes, 2010]. Nowadays, both Radio and TV broadcasts are widely used in many countries in Latin America as a medium to support education on rural settings. Furthermore, despite the high penetration of mobile telephony worldwide, radio penetration is still higher in rural settings.

2.2.1.1 Radio for Education

Pioneers in the school radio are found in Latin America [Colin & Estrada, 2001]. In 1947, the priest José Joaquin Salcedo started in the village of Sutatenza, Colombia, a radio educational program addressed to peasants living in rural areas [ACPO, n.d]. The program, called Acción Cultural Popular ACPO (Popular Cultural Action), covered topics from literacy and numeracy to other important themes like health, family relationships, and other topics to improve the life quality of the people. Peasants gathered together, in the evening, to listen to the classes on the radio assisted by one monitor. A monitor was one person of the same community who knew little more than their peers, who voluntarily assisted the rest of the group when listening to the lessons. Booklets and mail interchange complemented the radio lessons; in the mails participants presented their advances or problems with the lessons to teachers. In the full sense, ACPO was not part of a regular education system.

In the 1960's at the Dominican Republic the Santa Maria radio launched a literacy program [White, 1976]. In 1965, inspired by ACPO program from Colombia, on the Canarian Islands the Radio ECCA was launched (for its acronym in Spanish Emisora Cultural de Canarias). ECCA extended the education beyond literacy, offering programs to allow adults to finish primary and middle school. In this model pupils also have regular meetings with teachers who guide their learning and clarify doubts [ECCA, n.d.]. In 1971 the first radio school program was launched in the Dominican Republic, based in the ECCA model, which is known nowadays as the program “Teacher at home”. Today El

Maestro en Casa Network (Teacher at Home Network) is integrated by the radio schools in Dominican Republic, Costa Rica, Nicaragua, Honduras, Panama and Guatemala [Maestro en Casa, n.d.]. Further details of this radio education system in Panama are described in section 3.4.2 of this thesis.

2.2.1.2 TV for Education

The broadcast of educational programs on TV, can be dated back to the early 1960s; when there was a reform to include educational documentary as part of the TV programs in the USA [Hilmes, 2010]. In 1968, Mexico launched Telesecundaria as a model of middle school, where the lessons were taught through TV broadcasts [SEP, 2014]. This model rose as an alternative to allow children living in remote rural areas to continue their education. Telesecundaria officially started in Mexico in 1968, as public middle school (7^{th} - 9^{th}) in unprivileged areas where secondary schools were scarce. In 1996, the Mexican government started the High School Distance Learning as an alternative for teenagers and adults living in remote areas to initiate, to continue and to finish their high school education.

In 1995, the government of Mexico launched EduSat, an educational satellite network to transmit the content of Telesecundaria. The EduSat Network covered the whole American continent, except Brazil. EduSat included 16 channels and was transmitted to more than 35000 receptors in whole Mexico. Since 2003 they were also available online whereas nowadays, Telesecundaria is supported with additional interactive material over the Internet.

2.2.2 Computers in Educational Settings in Developing Countries

Most researchers [Taylor, 1980; Lowe, 2002; Bentley, 2007] agree that computers enhance the learning process. Indeed, most developing countries have made great efforts to implement the traditional computer lab model. However, this model has failed in many of these countries because, among other reasons, the precarious infrastructure, the low access ability to PCs at home, the lack of budget, teacher with no IT knowledge, and a high number of schoolchildren. These issues have led researchers to look for an alternative to the computer lab model at school. Over recent years, several research efforts have been undertaken to improve the access to computing technologies in educational settings in the developing world. We will now look at two representative examples of these research efforts: *(a) the idea of having one laptop especially* *designed for children in unprivileged regions, and (b) the use of a classroom computer with a shared interface.* The most outstanding project is the first approach with OLPC Laptops [OLPC, n.d.].

2.2.2.1 Low-Cost Laptop for Children

In 2005, Negroponte launched the One Laptop per Child (OLPC) project, which had as goal to develop a low-cost (100 USD) multimedia laptop equipped with educational software and a matching pedagogic concept especially designed to improve learning for children in developing countries Laptops [OLPC, n.d.]. The OLPC laptop, also called XO-1 laptop, runs on the operating system Sugar OS[1], which was developed especially for the OLPC. Sugar is an open-source GUI based on Linux and it was designed to be easy to use, and it has many innovative concepts in comparison to standard systems. The operating systems provide a collaborative work environment where interaction with nearby users is made easy through the utilization of meshed networks. The Sugar OS works like a Journal, which keeps a record of all activities (applications) that children have opened; this journal is what in Windows OS is called file explorer.

Figure 2. XO-1 Laptop. Image author: Mike McGregor

[1] *http://sugarlabs.org, last accessed on September 30, 2014.*

The OLPC laptop also introduced relevant improvement in hardware. Dual-mode monitor (monochrome in sunlight, otherwise multicolor), flash memory instead of hard memory, Wi-Fi integrated with a mesh network. However some usability and design UI problems are reported [Hourcade *et al.*, 2008; Flores & Hourcade; 2009; Yeh *et al.*, 2010]. The activities on the OLPC laptop and the Sugar OS are based on the constructionism theory. In this theory, children *"learn by doing"*, while they are exploring in a collaborative environment where they get feedback from peers, not just from teachers [OLPC, n.d.]. Figure 2 shows a photo of the XO-1 laptop.

Despite its special design for children, its low price and novel teaching approach, the XO-1 laptop has not been adopted in developing countries as it was expected [Kraemer *et al.* 2009; Purington 2010]. There have been concerns that this learning model would not fit the educational curriculum, requirements and policies of some developing countries [Kraemer *et al.*, 2009]. Authors of OLPC claim that children learn mainly by creating and sharing with their peers using only the laptops. It leaves the teachers' role in the learning process of the children in the background. This model has led to some criticism from the education community [Bentley, 2007; Prington, 2010; Warshauer & Ames, 2010; Warshauer *et al.*, 2012]. First, not all children learn in the same way: some need to be guided and motivated more than others. Second, there is a need to ensure that children have learned the necessary knowledge and skills that will prepare them for higher education or to join the work force. In the context of education in Panama (and many other developing countries), this novel approach to teaching does not fit well into the established curricula and would lead to a revolution in the educational system instead of an evolution towards an information society.

> *"Laptops do not translate simply into education. Without learning fundamentals, such as being taught to read, a child can hardly be expected to receive a proper education by freely browsing the Internet"* [Prington, 2010, p. 31].

In addition, the Sugar OS is also a barrier in the embracement of the XO-1 laptop [Kraemer *et al.*, 2009] in developing countries. Globally, the Windows GUI approach is the operating system prevalent in most developing countries, so therefore educational authorities are not interested investing in a device so that at the end, students will not have the skills to use the IT available in the market. In the same direction, as Sugar is mainly exclusively for the XO-laptop[2], teacher should also be trained in how to use the OLPC laptop. Furthermore the OLPC laptop while is suitable in terms of size and hardware specifications for children,

[2] *Currently Sugar OS is free and can be installed in almost any computer.*

it is too small for teachers. Finally, government has to train potential programmers in Sugar OS, so that they are able to develop educational software for the OLPC laptops. Without the development of the adecuate social and technical infrastructure, the deployment of laptops, like the OLPC, to students will not fullfill the expectatives [Cervantes *et al.*, 2011].

Nevertheless, a positive consequence of the XO-laptops was that they were the starting point to a wide adoption of netbooks (non-educational targeted) with less functionalities, lower performance, smaller sizes, and lower prices than laptops.

2.2.2.2 Single Shared Display

The second approach is the use of a single display and a larger set of input devices. Pawar [Pawar *et al.*, 2007] proposes an individual mouse cursor assigned to each child, which allows them to interact simultaneously over the same computer. In this approach children worked in pairs; i.e. at one PC worked two children. Meanwhile, in Mischief [Moraveji *et al.*, 2008] proposed simultaneous interaction of the whole classroom using a large shared display, i.e. projector.

Initial studies [Moraveji *et al.*, 2008; Pawar *et al.*, 2007] concluded that when the learning tasks are well designed: *(a) there is added value to collaborative learning as long as the children's tasks support learning, and (b) the effect of learning is similar to that achieved when using one computer per student.* The strength of this approach is that it supports the collaboration among students, which is important for child development. This is a suitable alternative for overcoming the shortage of computers in traditional schools, where all the children in a classroom are in the same grade. These children are at the same educational level and have to learn the same curriculum.

However, the reality in many developing countries is that multigrade classrooms in primary schools are the norm rather than the exception. In Panama, where most of schools are multi-grade schools, as described in section 3.2.1.2, such an approach is less effective. Learning content differs significantly from student to student, and it would be extremely difficult to develop educational software that supports multiple simultaneous users with different learning goals on a shared PC and screen. For classrooms in developing countries, individual tasks or devices for each child or group of children with similar learning levels would be more appropriate.

Different than the OLPC laptop, this approach does not address mobile use while on the way to and from school nor individual learning at home. In addition, in a large audience [Moraveji *et al.*, 2009], it seems to be difficult to visualize all mice on screen.

2.3 Mobile Learning in Developed Countries

In the literature several research projects in the domain of mobile learning can be found, some of them explored the use of mobile phones in schools. Experiments and research on mobile tools have often been designed especially to take advantage of the portability and ultimate features of the platform.

Although the use of mobile phones as learning tools is still nascent, already a number of projects integrating mobile technology with teaching exist like, e.g., [Rogers *et al.*, 2004; Mitchell & Race, 2005; Hansen *et al.*, 2010]. Mobility can be exploited for out-of-classroom teaching, e.g., for annotating and learning about the locations in the real world, as reported in the HyCon project [Bouvin *et al.*, 2005], or for retrieving contextually relevant information in situ by using 2D barcodes that are read by a mobile phone camera [Mitchell & Race, 2005].

2.3.1 In-Classroom

There are several examples of using mobile phones for in-classroom learning purposes. Vihavainen *et al.* [Vihavainen *et al.*, 2010] have conducted a study where traditional learning equipment, *i.e.* schoolbooks, was used in conjunction with mobile phones in a class of twelve-year-old pupils. By using the mobile phone application, the children took a photo of a page of the printed book, sent it to a server, and received exercises on their mobile phone related to the specific chapter of the book. The authors utilized an application specifically designed for this purpose.

Several projects [Häkkilä & Beekhuyzen, 2006; Mitchell & Race, 2005] adopt the approach of using existing mobile phone applications when using phones as teaching instruments. The camera and messaging capabilities of mobile phones have been used in educational use cases targeting to provide immersion and glimpses to the world outside of the classroom [Mitchell & Race, 2005]. Encouraging results have been achieved for student mentoring where a mentor sends photos and messages of his/her day at work to an undergraduate university student in order to provide some tacit knowledge of the profession [Häkkilä & Beekhuyzen, 2006].

Text messaging has been also explored for learning inside the classroom [Linquidst *et al.* 2007]. Lindquist *et al.* explored the use of text and multimedia messaging for answer and solve exercises in undergraduate computer sciences students. The researchers found out that for short answers and quizzes the use of

SMS is preferred, however for long or complex answers the approach of taking photos of the answer and send them via MMS is desired. However the cost for messaging discourages students to adopt SMS and MMS.

Zhang [Zhang Y. *et al.*, 2006] explored the use of mobile phones for active learning in university settings. The authors implement the application using Bluetooth as communication channel between mobile phones and computer. Students can answer lively questions raised by professors, give immediately feedback of the lecture, who can read the responses of the students in their computers.

2.3.2 Out-Side the Classroom Environments

The use of mobile technology sometimes has been integrated with storytelling and a broader, more technical setup, as done for outdoors learning experiences as in Mobile Urban Drama [Hansen *et al.* 2010], and Ambient Wood [Rogers *et al.* 2004]. The former employs, e.g., phone-readable tags placed on the surrounding while the latter augments the environment with other digital instruments, such as loud speakers and stand-alone video viewing tools. While these setups open interesting windows to dramatic learning utilizing mobile technology, they are not the main focus of our research due to their complexity and the use of special arrangements, which are not feasible in rural places in developing countries.

Noise Detective [Wyeth & MacColl, 2010] is an application implemented on iPod touch that measures the noise of the environment from different locations throughout the school. Although the study was conducted on iPod touch devices, the application can easily run on iPhones.

The use of mobile phones in schools has also been tested for purposes other than direct learning. In [Ervasti *et al.,* 2009] children's school attendance was monitored with NFC-enhanced mobile phones and a reader that the children used to register when arriving at school. Bamford et al. [Bamford *et al.*, 2008] describe a project where pupils' school journeys were investigated with the help of mobile phones and where for example GPS tracking was used in conjunction with air pollution data in order to investigate the risks for exposure. Although these projects do not contribute directly to the development of m-Learning tools, they demonstrate the potentials of mobile phones if they are integrated into school life.

The use of mobile phones to enhance outdoor visits has been widely explored [Vavoula *et al.*, 2009]. The authors implemented MyArtSpace where children can view videos from the expositions, take photos; allow audio and written annotation which later are uploaded to a webserver from the mobile phones. Pupils can also see what other students have seen in the museum.

2.4 Mobile Phones for Learning in Developing Countries

Although mobile phones offer an interesting educational platform across countries with different economic and cultural profiles, in developing countries their attractiveness is emphasized due to several factors. The lack of computing equipment available for schools as well as a general shortage of computing infrastructure (e.g., repair network, internet access); together with the higher access to mobile phones than computers are among the reasons why using mobile phones instead of traditional computers is an appealing alternative. The potential of mobile phones for education in developing countries has already been recognized [Kam *et al.,* 2009a; Kam *et al.*, 2009b], although the deployments have so far been rather scarce. Earlier research has explored the possibilities of mobile phones mainly through case studies where the design and impacts of a specific application have been investigated. Most of the works here presented have conducted studies in India and Africa, while in Latin America the work has been scarce. In the following sections we present the most outstanding research found in literature, about the use of mobile phones for learning in unprivileged and/or developing regions settings.

2.4.1 Edutainment Application — Educational Games

Most of the researchers found in the literature implemented educational games for analyzing their use cases. Only [Kam *et al.,* 2009a] focused on the potential of traditional games for learning. With the exception of EducaMovil [Frías-Martínez *et al.,* 2012], whose use case was Mathematics, the rest of the approaches here presented created mobile learning games for training English. Similarly, EducaMovil is the only research not conducted in India, but in LatinAmerica.

2.4.1.1 Exploring the Traditional Games Applications for Out-of-School Settings

Kumar *et al.* [Kumar *et al.,* 2010), have investigated how mobile phones could be utilized in out-of-school learning situations in India, and therefore provided mobile phones with educational games to rural children. The games were designed to resemble traditional village games, as reported in [Kam *et al.,* 2009a], as the influence of the traditional game design provided children with familiarity and eased the adoption of the learning applications. With regard to learning, the technology was found to motivate children [Kumar *et al.,* 2010]. The researchers also report that local game practices should be well understood and taken into account when designing the content in order to develop useful educational games to which the children can easily relate to [Kam *et al*., 2009b; Kam *et al.,* 2009a].

2.4.1.2 Exploring the Speech Recognition

[Kumar *et al.,* 2012] created games for training English vocabulary as a foreign language in school settings in India. The authors designed these learning games based on the guidelines for developing digital games in rural India [Kam *et al.,* 2008; Kam *et al.,* 2009a]. However, in contrast to them, in [Kumar *et al.,* 2012] the educational games developed included speech recognition. Children have to pronounce correctly the object requested in the game in order to pass to the next task. The speech recognition accuracy was about 91%. The authors considered that the inclusion of speech recognition in learning games, supported and improved the school children's English reading and pronunciation's skills.

2.4.1.3 Exploring Collaborative Learning

Jain *et al.* explored collaborative learning using the mobile phones and pico proyectors [Jain *et al.,* 2011]. The authors adapted a version of the Boggle™ game for English learning in two collaborative settings as single display groupware SDG [Stewart & Bederson, 1999] and as a multiple display groupware MDG. In the first condition, a mobile phone projector is used for display the game, where each child uses a Bluetooth joystick for interacting with the game. In contrast, in the second condition, each child used a mobile phone connected over Bluetooth to interact with the game, where the game ran in each handset. In both approaches the study was conducted in teams of two children. In order to evaluate both conditions, two studies were conducted: one in formal learning setting inside the classroom and the other in an informal out-side school program. Although, no significant learning difference among both techniques was found, initial findings suggests that SDG may support better the formal classroom settings.

2.4.1.4 Computers for the Creation of Content for Mobile Phones

EducaMovil is a learning tool that allows teachers create their own content on a computer for delivery on children's mobile phones [Frías-Martínez *et al.,* 2012].

The authors evaluated the tool in rural schools in Peru, during lessons inside the classrooms and the breaks. In the computers, teachers create lessons, and quizzes, which are later embedded in open source mobile games such as the Snake® or Tetris®. Quizzes were rose when children complete a task of the game. Researchers showed that using the tool for a short time improved the performance of average students [Frías-Martínez *et al.*, 2012]

2.4.2. The Use of Multimedia for the Creation of Content

The combination of multimedia features of the mobile phones allows the easy creation of content. Videos, images and texts [Mathur *et al.,* 2011], but especially audio [Ford & Leinonen, 2009; Leinonen *et al.,* 2006] and audio with images [Frohlich *et al.,* 2009; Reitmar *et al*., 2010; Bidwell *et al.,* 2010; Frohlich *et al.*, 2012] are the main features of mobile phones that have been explored by researchers for the creation of content. Audio capturing and playback capabilities of mobile phones have been recognized to be a useful feature for learning in developing countries where the literacy level is often rather low.

2.4.2.1 Audio Recording and Playback

Frohlich *et al.* describe a story-telling project in an Indian village for non-textual information sharing with the help of camera phones [Frohlich *et al.,* 2009]. Similarly, Reitmar *et al.* and Bidwell *et al.* developed and tested an audio-visual story-telling application in African settings [Bidwell *et al.,* 2010; Reitmaier *et al.*, 2010; Frohlich *et al.,* 2012]. However, the studies were conducted with only adults.

In MobilEd [Leinonen *et al.,* 2006; Ford & Leinonen, 2009] the researchers developed an audio Wikipedia application. The users can access and edit an article on Wikipedia using their mobile phones. The application works as follows: the user sends a SMS to the server with the term to search on the Wikipedia; then, the server calls the user and reads out the article found in the Wikipedia using a speech synthesizer. In case no article was found, the user can create an article dictating it to the system. The researchers conducted a user study in a private and public high school in South Africa, where students worked in small groups. The students created voice content about HIV/AIDS which was later retrieved by other students. The researchers reported a fast adoption of the application as well as a high engagement by the participants. Further quantitative findings were not reported.

2.4.2.2 Multimedia for Annotation

In [Mathur *et al.*, 2011], the authors developed an annotation prototype application that allowed teachers to customize content. Teachers can record images and videos, add and delete hand-written notes, as well as add audio notes to the images and videos on a touchscreen mobile phone. Teachers can take their own pictures, record videos or upload images and videos for external sources and then use the annotation application to add notes. With this tool teachers were able to create digital content, for example take picture of books or real object and adding their own digital content. The notes were written with a digital stylus. This content created by teachers can be displayed as a slideshow to the students in the classroom connecting a pico projector to the mobile phone.

2.4.3 Educational Curriculum

Mobile phones have also been explored to be used as a medium for teaching the complete educational curriculum of a subject [Masperi & Hollow, 2009; Nokia, 2011; SchoolNet, 2014; Otter, 2007]. In Malawi, a trial with 520 custom-made handheld devices was carried out in schools where children had access to different audio-visual lessons installed on the mobile devices [Masperi & Hollow, 2009]. The audio-visual lessons were explained by cartoons and were interactive by means of multiple-choice tests. Children could not move on to the next lesson until they answered the tests correctly.

In South Africa, for example –where the student performance in Mathematics in high school is low– several initiatives to support students to learn Mathematics using mobile phones has been implemented like MyMobi[3] [Otter, 2007] and MoMaths[4] [Nokia, 2011; SchoolNet, 2014] . The MyMobi application [Otter, 2007] is tailored to the South African mathematics curriculum for grades 10 to 12 and can be accessed using WAP or a web browser. MoMaths started like a pilot project from Nokia with the support of the South African Ministry of Education [Nokia, 2011; SchoolNet, 2014]. The application contains explanations of Mathematical concepts, examples, exercises, tests and individual progress report, following the Mathematical educational curriculum. MoMath is accessible using the local social network MXit and also from a web browser.

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[3] http://www.mymobi.co.za/, last accessed on September 30, 2014.

[4] http://momaths.nokia.com/, last accessed on September 30, 2014.

2.4.4 Social Network Platforms

In Africa, there have been several approaches which explored the use of MXit [Mxit, n.d.] for learning. MXit is the most popular social network platform for mobile phones in South Africa; which includes a chat application. In this section we present three learning applications approaches with MXit. The first example is Boot [Tangkuampien, 2009]. Tangkuampien take advantage of the waiting reply time when students chat in MXit, he implemented short quizzes which popped up ring these waiting times. Students seem to like the application, however, no formal evaluation was made.

A second example is Dr. Math [DrMath, 2012], a mobile tutoring service. Students can send their question about a Mathematic problem (e.g. equation, formulae) through MXit to a set of university students, teachers or other tutors who answer the message. Similar to Boot [Tangkuampien, 2009] no evaluation has been made.

The last example is Yoza [Yoza, 2010; Shuttleworth Foundation, 2009], a project initiative to encourage students to read more and to overcome the lack of access to leisure books in South Africa. The researchers create m-novel –a novel intended to be read on mobile phones– for teenage audience. Students can access the m-novel using MXit, and comment with their peer about them. The project has been welcomed by teachers and students, and early findings are promising.

2.5 Analysis of the Mobile Learning Approaches for Developing Countries

Table 1 shows a comparison among the mobile learning approaches for developing countries presented in the related work. Despite the mobility feature of mobile phones, that can be used everywhere, not all mobile learning approaches take advantage of the mobility feature. Many mobile learning applications were built to be used at fixed locations like schools; however most of the approaches presented can be used also everywhere and anytime.

Different to the mobile learning approaches for developed regions, described in section 2.3, there was no learning approach for developing countries focused on enhancing and supporting field trips or experiences outside schools. Almost all mobile learning approaches explored in developing countries were focused on delivery learning content, for example for delivering education to children who cannot attend school [Kumar *et al.*, 2010], to support children to individual learning through lessons, examples and quizzes [Nokia, 2011.; SchoolNet, 2014; DrMath, 2012; Otter, 2007], exploration of collaborative learning like in [Leinonen *et al.*, 2006; Ford & Leinonen, 2009; Jain *et al.*, 2011]. We can summarize the trends in the research of learning applications for mobile phones in the following:

(1) Most learning applications for mobile phones, focused on one learning goal i.e. Mathematics, or English. In addition to the storytelling approaches [Frohlich *et al.*, 2009; Reitmar *et al*., 2010], that were not aimed for children, only one approach [Mathur *et al.*, 2011] presented a use case that allowed the creation of own content on mobile phones to teachers, but not to learners. EduMovil [Frías-Martínez *et al.*, 2012] also allows customization of Mathematics content, but this personalization of content is created on a desktop computer and not on a mobile phone.

(2) Most learning applications give learners a passive role, as answering quizzes or playing games, but do not allow them to create content. Only MobilED [Leinonen *et al.*, 2006; Ford & Leinonen, 2009] and Yoza [Yoza, 2010; Shuttleworth Foundation, 2009] allow learners to create audio content and write feedback about novel respectively.

(3) Local technologies practices, like the social network MXit in South Africa, support the widespread and popularity of mobile learning projects.

(4) Mobile learning game applications where preferred for teaching and learning English [Kam *et al.*, 2009a; Kumar *et al.*, 2010; Kumar *et al.*, 2012; Jain *et al.*, 2011].

(5) Educational curriculum was considered in some of the mobile learning application approaches like the projects MyMobi [Otter, 2007] and MoMaths [Nokia, 2011; SchoolNet, 2014], supported by Educational authorities and mobile phone practitioners.

(6) With exception of MXit, no application included the use of Internet in their approaches.

Table 3. Analysis of the Research on Mobile Learning Applications for Mobile Phones in Developing Countries.

Name	Subject	Directed to	Phones featured used	Location	Content Creation	Learning Resource	Place
[Kam et al., 2009a]	English	-Children	✓ Audio ✓ Images ✓ Text	School	No	-Educational Game	India
[Kumar et al., 2010]	English	-Children	✓ Audio ✓ Images	Out-School	No	-Educational Game	India
EducaMovil [Frías Martínez *et al.*, 2012]	Topics in Mathematics	-Teachers -High School Students	✓ Text ✓ Images	School	Yes, include a PC application that allow teacher create written lesson and quizzes to be installed on learners phones	-Informative text -Quizzes embedded in common games	Peru
[Kumar *et al.*, 2012]	English	-Children	✓ Audio record and playback ✓ Images and text ✓ Speech recognition	School	No	-Educational Game	India
[Mathur *et al.*, 2011]	Any Subject	-Teachers	✓ Video and images ✓ Handwriting text ✓ Projector, Phone Camera	School	Yes, an annotation tool which allow teacher the free creation of content like slides	-Video/Slide show	India
[Jain *et al.*, 2011]	English	-Children	✓ Bluetooth ✓ Phone projector	School	No	-Educational Game -Collaborative learning in SDG and MDG mode	India
[Frohlich, *et al.*, 2009]	Variety	-Illiterate Adults	✓ Camera phone ✓ Audio + Image	-Rural communities	Yes, free creation of content with pictures and audio	-Story Telling	India
[Reitmaier, *et al.*, 2010; Bidwell et al., 2010; Frohlich et al. 2012]	Variety	-Illiterate Adults	✓ Camera phone ✓ Audio + Image	-Rural communities	Yes, free creation of content with pictures and audio	-Story Telling	Africa
[Masperi & Hollow, 2009]	Variety	Students	✓ Custom-made handheld devices: Audio and video	-School	No	-Quizzes -Educational videos with cartoons	Africa
MobilEd [Leinonen *et al.*, 2006; Ford & Leinonen, 2009]	Variety	-Children -Illiterate	✓ Voice Phone ✓ SMS	School	Yes, creation and edition of audio content for a Wiki	-Audio Wiki	Africa
MoMaths [Nokia, 2011; SchoolNet, 2014] and MyMobi [Otter, 2007]	-High school Mathematics curriculum	-High school students	✓ Internet access: WAP, Web Browser, MXit	-Everyplace	No	-Written lessons -Exercises and tests -Individual progress report	Africa
Dr. Math [DrMath, 2012]	Mathematics	-Students	✓ MXit	Everyplace	No	-Tutoring online service	Africa
Boot [Tangkuampien, 2009]	Variety	-Students	✓ MXit	Everyplace	No	-Quizzes	Africa
Yoza [Yoza, 2010]	Motivate reading	-Teenagers	✓ Access to novel using the phone and MXit	Everyplace	Yes, student can write feedback about the m-novel	Improve the reading	Africa

2.6 Summary and Discussion

Researchers defined mobile learning from three perspectives: technocentric, user mobility and communication. Although there is not a full consensus among experts, we can summarize it in two aspects the use of mobile devices for learning and the new learning spaces that such devices are creating [O´Malley *et al.*, 2005]. Mobile phones integrate a widely variety of network connection, delivery and media options [Attewell, 2005], and at the same time that people carry it always with them make them a personal and ubiquitous device. Currently, the mobile phone is the main device that takes advantage of the complete mobile learning experience: mobility and communication. While in the developed countries the direction of the research has been mainly to enhance the learning experience with outdoors field trips like augmented reality, or other activities to complement the learning experience, but not directly related to delivering learning contents; in developing countries the trend is different. In developing countries, researchers are focused on delivering learning contents, reaching children outside school, and taking the advantage of multimedia to support and improve the quality of education.

Whereas examples of using mobile phones at schools to support teaching and learning exist, we believe that the full potential of mobile phones has not yet been used. Typically, earlier studies with mobile phone-assisted learning report on the use of a specific phone application that has been designed and used for learning purposes. Our approach differs from these, as the starting point is the use of ordinary off-the-shelf phones with applications that are not customized for educational purposes. Former research typically concentrates on specific tasks within one school subject, and lacks a holistic perspective where a device can be a general tool to assist teaching across different classes. Consequently, related work does not concentrate on reporting user interface (UI) issues that could be useful for a mobile phone application design so that it could support learning throughout the whole learning cycle.

Chapter 3

Availability of Technologies in Education in Panama

In this chapter we describe the current availability of technologies in Panama, within its society but also in the educational area. The chapter starts with a brief overview of Panama as country, the educational system and situation there that help the reader to better understand the context where we conducted our research. This chapter also includes how the educational authorities have integrated technology to improve and deliver education in underprivileged areas. At the end of the chapter, we discuss about the potential of the use of mobile phones over computers for learning in Panama, which is also applicable in Latin America and other developing regions.

3.1. An Overview of the Republic of Panama

Panama is a country located in Central America. It has an extension of 75,517 km^2 and a population of 3,405,813 habitants. Panama is divided in 9 provinces and 4 Comarcas[5]. The capital of the country is Panama City with a population of 430,299 habitants. However, the population living in Panama City and its metropolitan area estimates in 1,195,710 habitants [Contraloria, 2010].

Panama has a tropical maritime weather. The yearly temperatures range from 25 and 33 degree Celsius and high humidity above 70%. In Panama there are two seasons. The dry season starts between December and January, and the rainy season starts from May.

Most of the population is concentrated in the urban areas (65%). 35% of the Panamanians live in rural areas including ca. 6% of the population who lives in the Comarcas. The population of Panama is still relatively young, the mean age is 27. More than half of the population (54%) is under 30 years old. The rate of

[5] *Comarcas: term used in Panama to refer the autonomy territories where exclusive indigenous live.*

children per woman is 2.3, even higher in the Comarcas. Furthermore 38% of the Panamanians are 19 years or below. In Panama about 10% of the population is indigenous, and it is composed by seven groups: Guna, Emberá, Wounaan, Ngäbe-Bugle, Bri Bri, Teribe and Bokota. [UN-Panama, 2009, p.20].

There is no global convention of how to classify a country in a developed or in a developing one. The United Nations classifies Panama as a developing country [UN, 2013]. The gross national income (GNI), and the human development index (HDI) have been introduced as an effort for grouping the countries accordingly.

The World Bank classifies the countries according the GNI per capita in low, middle and high income economies [WorldBank, 2014a]. Usually, countries with low and middle-income economies are adduced as developing countries. Low-income economies are those countries with a GNI per capita below U$1035; lower middle income economy are those between U$1026 and U$4085; upper middle income those between U$4,086 and U$12,615 and high income economies those above U$12,616 [WorldBank, 2014a]. According to the World Bank, Panama is classified as an upper middle income [WorldBank, 2014a; WorldBank, 2014b].

The Human Development Index (HDI) was developed as an alternative approach to the GNI country's classification [UNDP, n.d.(a)]. The HDI measures the progress of a country in terms of health, education and wealth of the population, and not only by income like the GNI. The values of the HDI are between 0 and 1, where a HDI below 0.535 means a low human development, 0.536 to 0.710 a medium human development, 0.711 to 0.799 a high development, and 0.800 to 1.00 a very high development [UNDP, 2013a]. Panama has a Human Development Index of 0.780 [UNDP, 2013a], however most of the Comarcas present a Human Development Index HDI below 0,535 [UNDP, 2014, p.128].

Nonetheless, the HDI did not consider the inequality distribution of the three HDI dimensions across the population; then the inequality-adjusted HDI (IHDI) was created [UNDP, n.d. (b)]. The inequality-adjusted HDI for Panama is 0.588 [UNDP, 2013]. These results reflect the situation in Latin America where one of the highest levels of income inequality takes place [UNDP, 2013b; Ruble, 2010].

3.2. Education System in Panama

The Ministry of Education organizes and supervises the education in Panama, which is regulated by law [Organic Law of Education, 1946; Law 50, 2002; Law 60, 2003]. The education consists in 14 school years. The education is compulsory until the 9th grade; the public education is free until the 12th grade. The school-year starts the first week of March and ends the second week of December. It is divided in three trimesters with one week break at the end of the first and second trimester. The education system in Panama is divided in three levels to know: Elementary, Middle Education and Higher Education.

a) *Elementary Education:* also called Compulsory Education consists of 11 years of education. It is divided in the three following stages:
   - ***Pre-school*** is target for children between 4 and 6 years old. Pre-school comprises two years. In Panama the grades are known as pre-kinder and kinder. Since 1995 pre-kinder is compulsory.
   - ***Primary School*** is attended by children between 6 and 11 years old. The Primary Education is 6 years. It comprises the grades between 1st and 6th.
   - ***Pre-middle School*** is for children between 11 and 15 years old. It has duration of 3 years, which includes the grade 7th, 8th and 9th. Since 1995 the pre-middle education is compulsory.

b) Middle Education: The length of middle education is 3 years, it is also known as high school. It comprises the grades 10th, 11th and 12th. The students can select between general high school, pedagogic high school and technical high school. Students who finish a technical school are usually prepared professionally to join the work force or to be self-independent (e.g. plumber, open a Beauty Saloon, etc.).

c) *Higher Education:* After the 12th grade, students can continue higher studies in the University or in Institutes of Higher Education. In Panama there are 5 public universities. The two largest public universities, University of Panama and the Technological University of Panama, have in most of the provinces a seat; where many careers are being offered for those students that live outside the metropolitan area.

Table 4 shows the number of students who attended the school and university (undergraduate degree) during the year 2010.

Table 4. Number of Students Attending Education System in Panama during 2010 [Contraloria, 2010; MEDUCA, 2010].

Education	*Number of Students*
Pre-School	92,667
Primary School	433,746
Pre-Middle School (7^{th} – 9^{th})	182,114
Middle School (10^{th} -12^{th})	101,633
Higher Education (only undergraduate programs)	84,157

3.2.1 Form of Schools

The school system is divided in private and public education. Most of the pupils in primary education age (88.4%) attended public schools and only 11.6% private schools[6]. Table 5 shows further details about the amount and percentage of children attending both public and private primary schools (1^{st} to 6^{th} grade) according to their location. In addition to the public and private school classification, public schools are further organized according to (a) their location, and (b) the number of pupils attending related with the school building capacity. A further categorization is the adult school or adult education. In our research work, we focus on the children attending public primary school.

Table 5. Number and Percentage of Students Enrolled in Primary School (1st to 6th grade) in Public and Private Primary Schools according to Their Location [MEDUCA, 2010].

Type of School	Total Children Enrolled in Primary School		Children enrolled in Public Schools		Children enrolled in Private Schools	
	Number	Percentage	Number	Percentage	Number	Percentage
Urban	**216 948**	**38.5%**	**167 202**	**77.1%**	**49 746**	**22.9%**
Rural	154 626	**35.5%**	154 129	**99.7%**	497	**0.3%**
Indigenous	68 172	**15.7%**	68 062	**99.8%**	110	**0.2%**
Total	**433 746**	**100.0%**	**383 393**	**88.4%**	**50 353**	**11.6%**

3.2.1.1 According to its Accessibility and Location

The Ministry of Education in Panama classified the schools in relation to location where they are built. Power supply, water supply, hospitals nearby, transportation mean and availability of streets are some of the factors to take into consideration for the arrangement. The schools are divided according to its

[6] *In the thesis "we" refers to public schools simply as schools, when we want to refer to private schools we explicitly state it.*

location in: urban, rural and indigenous schools; and simultaneously according to its travel accessibility: in difficult access areas and not difficult access regions schools.

From the 2971 public primary schools national wide, around 70% of the schools are located in rural areas; 21% are located in indigenous areas and only ca. 9% in urban areas. However, the number of children attending urban and rural schools is roughly similar, as we can see on Table 6. All the schools located in two provinces and most of the schools in Indigenous area are classified as difficult access regions [MEDUCA, 2010].

Table 6. Number and Percentage of Public Primary Schools and Pupils Attending Them according to Its Location and Travel Accessibility [MEDUCA, 2010].

Total		Classification of Schools				
		According to its location			According to its travel accessibility	
		Urban	Rural	Indigenous	Difficult Access Regions	Accessible Region
Number of schools	2 971	282	2 070	619	1 401	1 570
Number of Pupils	383 393	167 202	154 129	68 062	112 174	271 219
Percentage of Schools		21%	70%	9%	47%	53%
Percentage of Pupils		43%	40%	17%	29%	71%

3.2.1.2 According to the Number of Students Attending

In traditional schools usually pupils attend the school in a single shift and share the classroom only with same age –and grade peers. This model can be implemented where *(a) there is a good school infrastructure to attend the pupils population enrolled; (b) the amount of pupils enrolled are suitable for the capacity of the school; (c) it is economically feasible to have a teacher for each grade and (d) there is a shortage of teachers.* However in many developing countries, like Panama, this school model cannot fully be applied in the public education especially because it is highly costly. The shift-school model and the multi-grade model have been implemented instead.

3.2.1.2.1 Double-Shift Schools

When the amount of pupils is high and there is a shortage of building and money, the use of a same school building for two or more shift schools is preferred. Although higher numbers of shift-schools approaches exist in developing countries, the most common shift-school model is the double-shift school [Bray, 2008]. Mark Bray defines double-shift school as:

> *"In a double-shift system, schools cater for two entirely separate groups of pupils during a school day. The first group of pupils usually attends school from early morning until mid-day, and the second group usually attends from mid-day to late afternoon. Each group uses the same buildings, equipment and other facilities."* Bray [Bray, 2008, p.17]

The double-shift school or double-session school is mostly adopted in urban areas, where there is a higher concentration of people. In Table 6, we can easily observe the high amount of students and the limited school availability in urban areas compared to rural areas for example.

Furthermore many of the pre-middle and middle schools even in some rural areas settlements also follow the double-shift school model [MEDUCA, 2010]. Private schools use only the single-shift or one-session school approach. In Panamá, the duration in each shift in Primary Schools is 5 hours, thus is seven school-hours of 40 minutes with a 20 minutes break. The morning-shift school is scheduled from 7 a.m. to 12 p.m. and the afternoon-shift school is from 12:30 p.m. to 5:30 p.m.

3.2.1.2.2 Multigrade Schools

Multigrade schools can be defined as a school where children of two or more grades share the same classroom space and have the same teacher. Therefore in a single classroom, the same teacher teaches two, three, four, five or even six grades together. This model is widely implemented in developing countries, especially in the rural areas. It is also adopted in some progressive schools in developed countries like Finland [Kalaoja & Pietarinen, 2009]. In Panama, no private school follows the multi-grade approach.

Table 7. Amount and Percentage of Public Primary School Buildings, Schools with a Grade per Classroom and Schools with Multigrade per Classroom according to Their Location [MEDUCA, 2010].

Type of School	School Buildings		One-grade per Classroom		Multigrade per Classroom	
	Number	Percentage	Number	Percentage	Number	Percentage
Total	**2 971**	**100%**	**792**	**27%**	**2 179**	**73%**
Urban	282	9%	254	90%	28	10%
Rural	2 070	70%	379	18%	1 691	82%
Indigenous	619	21%	159	27%	460	73%

Table 7 shows the amount and percentage of multi-grade schools in Panama in rural, urban and indigenous areas. It can be noticed that 73% of the primary schools are arranged as multi-grade schools [MEDUCA, 2010]. Most of the rural and indigenous schools are organized as multi-grade schools, and most of the urban schools are arranged as one-grade classroom school, as Table 7 reveals. About 30% of the students in Panama attend a multigrade elementary school.

Among the reasons, to open a multi-grade school, are *(a) when there is a low number of children enrolled in the school; (b) the school has a reduced number of classrooms; and (c) there is shortage of teachers.* Similarly to the double-shift school model, the multi-grade school model supports the idea to have a better use of the school infrastructures and facilities minimizing costs.

3.3. Challenges for Education in Panama

Social and cultural context influence the development of education policies and practices in developing regions. Limited budget and high demand obligate to government to make tradeoffs in education in terms of costs, priorities versus quality. Circumstances differ from country to country. Furthermore, it differs even inside the country itself. However, most of the developing regions face similar challenges with respect to education. Below we present our list of the common problems faced for the goal to educate children in equal conditions.

3.3.1 Poverty

About 21% of the world population lives with less than 1.25 USD a day [WorldBank, 2014c], thus 1.22 billion of person worldwide live in extreme poverty. Poverty can be found in rural areas as well as in big cities like Mumbai or Rio de Janeiro. In Panama, about one fourth of the population (25.8%) lives in poverty and about one tenth of the population (10.4) lives in extreme poverty. Hunger and scarce access to the health services are direct consequences of poverty.

By 2012, in Panama a person lives in poverty when he/she has a monthly income below 132 USD in urban areas, and 98 USD in rural areas [MEF, 2012]; and in extreme poverty when he/she earns less than 63 USD in urban areas, and 53 USD in rural areas [MEF, 2012].According to the last census of 2010, the monthly average income per Panamanian worker was USD 408, and the average monthly family income was around USD 576 [Contraloria, 2010]. The basic food basket[7] cost by February 2014 was USD 333.42 [MEF, 2014]. Thus means that on average, half of the monthly income of a family is used for buying basic food. Housing rent, transportation, basic public services, gas, cleaning articles and personal cleaning items are not consider in this basic food basket. About one fourth of the population in Panama lives in poverty [UN - Panama, 2009]. However the distribution of the poverty varies significantly by geographic areas.

3.3.2 Inequity between Urban, Rural and Indigenous Areas

According to the last census 2010 [Contraloria, 2010; MEF, 2012], 2 216 559 persons live in urban areas (representing the 65% of the population) and 1 189 254 live in rural areas including 199 857 who live in the Comarcas). There is a huge difference between those people living in rural areas, indigenous areas and urban areas. Poverty and extreme poverty is mainly settled in rural and indigenous areas. In rural areas poverty reaches the 50.2% of the population and extreme poverty reaches the 24.3% of the Panamanians. But in the indigenous areas the situation is dramatic, about 89.8% of the population who live in the Comarcas are poor. Furthermore, above two-thirds that means 68.5% live in extreme poverty. The poverty affects mainly the rural areas and the extreme poverty the indigenous population living in the Comarcas.

[7] *Basic food basket: is the minimal monthly cost of the basic food requirement for the individual well development. In Panama it is calculated for 3.5 persons and it is equivalent to 58 items for a daily diet of 2338 kilocalories [MEF, 2014].*

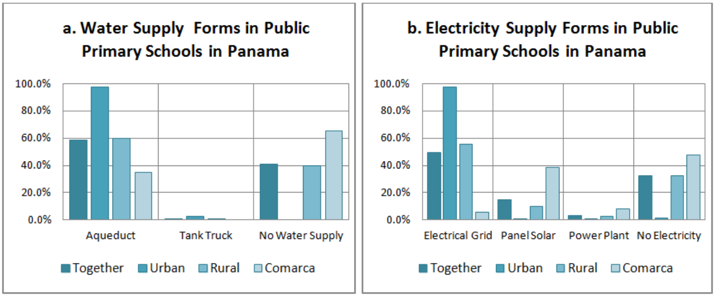

Figure 3. Percentage of Public Primary Schools in Panama, according Water Supply (a) and Electricity Supply (b) by region [MEDUCA, 2010]

In the remote rural areas and in the Comarcas, there is no road that allows motorized traffic, and to travel to the nearest town people need to use at least two means of transportation. These areas are usually located in the mountains and in the jungle. The communities are mostly off-grid, therefore schools are also off-grid as shown on Figure 3. There are no hospitals, and no high school nearby. As people live dispersed, most of the time the children have to walk long distances to attend the elementary school. Primary schools implement the multigrade approach (section 3.2.1.2.2); middle schools are extremely seldom. Distance learning alternatives, supported by technologies, have emerged to help teaching in these rural areas, like Telebasica (section 3.4.1) and El Maestro en Casa (section 3.4.2).

3.3.3 Children labor

UNICEF estimates that around 115 billion children are out of the primary school, where 82% of those children live in rural areas [UNESCO, 2005]. In places where there are no wars, poverty and child labor are the main causes children do not attend school. The double-shift school approach (section 3.2.1.2.1) allows children to attend school and work part time. In Panama, 7.1% of children between 5 and 17 years old work [OIT, 2012], thus 60,702 children in school age work. Around 31% of the children who work do not attend school, whereas ca. 12% of the children who work between 13 and 15 years old have not finished the primary school [OIT, 2012].

The percentage of children labor is also higher in Comarcas than the rest of Panama. About 26% of the school age children living in the Comarcas work, compared to only roughly 8% and 3% in rural and urban areas respectively [OIT, 2012].

3.3.4 Very High Youth Population and Limited Infrastructure

Developing countries have a relative young population. This implies a high number of children in school age, who have to attend the school system. In Panama, about 35% of the population is between 5 and 17 years old [Contraloria, 2010]. School infrastructure, –including buildings, resources and supplies–, are insufficient to satisfy this high demand. In their effort to offer education to their children, educational authorities in developing countries implement different measures to reach out to the most number of children. Here quantity, –number of children reached–, of course impose over quality. Two common approaches in developing countries to target this problem are the double-shift school and the multigrade school described in section 3.2.1.2.

3.3.5 Low Performance in the World-Spoken Language by Native Population

In this point we have two portraits in Panama. On the one hand, we have the low performance of the indigenous population in speaking Spanish –the official language of Panama– and on the other hand the low performance in English by the Panamanian population in general.

Aborigine people, –who usually live in remote rural areas and are the poorest in the country–, speak their own dialect and have problems adopting the official language of the country. Children living within this context usually have lower performance in the primary school and have problems to advance in upper grades as their skill to speak the official language is weak. The situation is common especially in former colonies in Latin America, Africa and some countries in Asia, where Spanish, English or French is the official language. Contrary to this, in developed regions it is usually not the native but foreign minorities which have some problems to adopt the official language of the country. Four native dialects are spoken in Panama.

Skills in a foreign language, like English, open the doors to a much better job and further opportunities research/academic formation in comparison to those who do not speak English. This has been made clear by the Educational authorities, who have included English as a foreign language in the educational curriculum in the Panamanian public schools starting from the 4th class and since 2005 from 1st class, until the 12th. Despite these efforts the results got are discouraging.

3.3.6 Low Schooling Years of the Parents and its Influence in their Siblings

Only about 5% and 6% of men and women above 10 years in Panama are illiterate [MEDUCA, 2010]. Panamanian women and men above 15 years old have in average 8.2 and 8.6 years of schooling respectively, while in remote rural areas and Comarcas, the education level is even below 5 years of schooling [MEDUCA, 2010]. It is well known that there is a relation between the level of education of the parents and the level of education that their siblings will achieve. As higher the education of the parents is, especially the mothers, children will achieve the same education level or higher. In Panama this is being reflected in the very high attendance to primary school, in comparison to a decrease of attending afterwards. Almost all children who correspond to attend primary school are enrolled, and the school dropout is under 1% [MEDUCA, 2010]. However the desertion in the pre-middle and middle school reaches about 12% [OIT, 2012].

3.4 Use of Technology for Education in Panama

In this section we will introduce how currently information and communication technologies as radio, TV, video and computer is adopted by Educational authorities in Panama for delivering education in places where conventional schools are not available.

3.4.1 Education per Television: Telebasica Approach

Based in the Telesecundaria project in Mexico [SEP, 2014], the Ministry of Education started the program Telebásica. We interviewed Lic. Aleika Lopez, from the Ministry of Edcucation, who was involved in the project Telebásica since its beginning. We asked her to explain us about Telebásica, the following are the extracts of her answer with this respect:

> *"Telebásica is an educative model that arrives in Panama between 1993 and 1994, as an agreement between the Mexican and the Panamanian government. It is addressed to people*

> *living in remote rural areas. Mexico transmitted via satellite at specific schedules in channel 11 [public channel] the [video] classes. At that time channel 11 only was available in the Panama province. We started with 6 schools, and at the beginning the experts from Mexico travelled to Panama to teach the docents about the methodology. We attend groups from 7th through 9th grade. The main goal of this program is that students living in remote rural areas that do not have access to attend pre-middle school can finish their basic studies to pursue later high school"* (A. López, personal communication, August 8, 2011).

The initial project was a success, which was officially created in 2003, whereas since 2004, Telebásica is implemented as a pre-middle school modality within the public education system [Executive Order 11, 2007]. We also asked Lic. Lopez about how the Telebásica is arranged:

> *"One teacher is in charge of one school grade [7th, 8th or 9th] and he/she is in charge to teach all the subjects in that grade… however in some cases according to the strength of each docent, teachers support each other. For example, the teacher who is more skilled with Mathematics teaches this topic to all the courses, while the teacher who is more skilled in History gives this subject across the subjects. In this way teachers decided the best approach that allows students to learn better and more; and they can compete with the students in the city. Each school receives a TV per classroom, the school books for self-learning, DVD player, DVDs with the video recorded lessons and a guide book for the teacher. The community as well as parents support strong the docents. The schools participants are selected after an evaluation, the main requirements are that they are located in difficult access areas and that they have electricity or solar panels"* (A. López, personal communication, August 8, 2011).

Currently in Panama there are 122 schools enrolled in the Telebásica program. Table 8 shows the number of school, docents and students by region participants of the Telebásica program during 2010. Telebásica implements the same school-year calendar as the rest of the regular public schools [Executive Order 11, 2007, §6]. Currently pupils who attend in Telebásica have to take between 11 and 12 compulsory subjects by year [Executive Order 11, 2007, §5]. In addition the subject of technologies and recreation activities complete the study plan for the pupils. The subject of Technologies, —in Panama i.e. Informatics, Agriculture, or Cuisine—, are optional according to the interest of the participants, and the availability of the resources and infrastructure of each participant school [Executive Order 11, 2007, §5]. With respect to the learning material and the methodology, Lic. López stated:

> *"Although at the beginning of the project, the lessons were broadcast through the national open TV signal, nowadays the schools used recorded videos to present the lessons to the students. In addition to the videos, pupils work with text books which present the courses as modules. These module books contain the instructions and all the material children have to learn for the course, as well as, the school-and-home works. The study requires self-discipline by pupils; there are periods where students have to learn alone. The students before entering to the Telebásica receive an introduction to the learning methodology used"* (A. López, personal communication, August 8, 2011).

A difference between the regular middle school and Telebásica is the number of teacher by grade and their role. In the former, each group has multiple teachers where each teacher dictates the subject of his/her specialization. In Telebásica one single teacher supervises the advances of the pupils in all the subjects. Here the role of the teacher is more like a facilitator that guides and clarifies doubts while children work on the module books. Teachers who participate in Telebásica live in the community where the school is based, every three weeks they have one free week where teachers leave the remote rural area and go back to their families. Pupils continue working with the module book during the time teachers are absent.

Table 8. Number of Schools, Docents and Student in Telebásica in 2010 [MEDUCA, 2010].

Area	Number of Schools	Number of Docents	Number of pupils (7^{th} – 9^{th} class)
Total	***122***	***400***	***7516***
Urban	1	3	36
Rural	104	232	6212
Indigenous	17	65	1268

Telebásica has been an important advance allowing children in remote rural areas to continue pre-middle school. During 2010, about 8 over 10 students finished successfully the Telebásica [MEDUCA, 2010]. Differently to Telesecundaria [SEP, 2014] in Mexico, Telebásica do have neither Internet website nor social network available in Panama.

3.4.2 Education per Radio: El Maestro en Casa Approach

Other program that takes advantage of a broadcast medium is the *El Maestro en Casa (Teacher at Home)* [Maestro en Casa, n.d.]. It is a program of distance learning, through the radio [IPER, n.d.]. Different to Telebásica, El Maestro en Casa (EMC) program is not addressed to children but to youth and adults, who want to be literate or finish primary and middle education. It also a program supported and managed by the Panamanian Institute for Radio Education [IPER, n.d.] as part of the Catholic Church in Panama. We interviewed the Lic. Zuleyka Cordoba who work for the EMC; she explains us about the students who attend the EMC:

> *"Most of our students are adults who did not have the chance to study and people with very low income who cannot attend other kind of school. We also have students that because of their work schedule cannot attend traditional school forms. Although we accept students of 15 years and above, most our students are adults. The student enrolled [in EMC] requires a very high discipline, as this is a self-learning approach. Students below 15 needed to be highly motivated and are therefore not suitable for our program. In very seldom cases we allow youth under 15 years old. We have more female students than males, about two third of our students are females. As an example in this year [2012] 64% of the students enrolled were woman"* (Z. Córdoba, personal communication, June 22, 2012.

In Panama, EMC began in May, 2001, [IPER, n.d.] but it has its roots in the Escuelas Radiofonicas Santa Maria (Radio School Santa Maria) in the Dominican Republic [RSM, n.d.]. The content of the courses corresponds to the educational curriculum of the Ministry of Education.

> *"Across Panama, we have 5 regional centers, which are in charge to distribute and collect the exams to the students, which later each center has to correct the exams and send to the headquarters in Panama City. Apart from the radio lesson,*

> *once a week students can meet the facilitator. The facilitators are volunteers who preferably live in the own communities of the students who clarify doubts. Each book includes self-evaluation tests that each student has to solve before meeting the facilitator. In addition to the radio, all the lessons are also available to purchase by CDs. Students have the option to follow the class only through the radio, only with the CDs or both"* (Z. Córdoba, personal communication, June 22, 2012).

Students have to pay a minimum fee between 10 and 25 USD, but in cases the students cannot afford this fees, they can study for free. EMC offers the primary, middle and high school level. A person can finish the primary education, including literacy, in two years, the pre-middle school in two years and the middle school in three years as shown in Table 9. The classes are transmitted by radio with duration of half an hour daily. The lessons are audio recorded by volunteers' teachers. Participants receive textbooks with all the learning material and a self-evaluation test. The classes are transmitted by 15 different broadcasting radios, who offer freely 1 to 2 half-hour block broadcast time.

During the first trimester 2012, there were 1395 participants enrolled in EMC, from those only 14% attended literacy and primary school education, while 86% attended middle school education, data of the high school were not available, since it was just implemented this year.

Table 9. Educational Curriculum Structure of the Program Maestro en Casa.

Level	Subjects	Duration
1st, 2nd and 3rd class	Not available	3 months each level
4th, 5th, and 6th class	5 subjects each grade: *Mathematics, Spanish, Social Sciences, Nature Science and Values*	3 months each level
7th, 8th and 9th class	12 subject each: *Values, Civic, Mathematics, Geography, History, Technology, Spanish, Nature Science, Arts, English, Community Development, and Mental and Physical Health.*	6 months each level
10th, 11th and 12th class	11 Subjects each grade. Common subject across the grades are *Spanish, English, Mathematics, Accounting, Business Management, Ethics, and TICs. Other subjects are History, Work Law, Politics, Geography, Art and a practical training in entrepreneurship.*	One year each level

Every participant has to pass one exam in each subject, in order to go to the next level. The facilitators are usually volunteers from the same or near community, most of them former teachers. All facilitators are trained in the EMC methodology. In 2011, 230 facilitators were attending 1000 students in 210 communities. Pupils who follow the program using the CD have the advantage that can join the program in any trimester. Those who only use the radio can join the program only when the trimester with their school-level is offered.

Different to Radio ECCA in Canarias Islands [ECCA, n.d.], Maestro en Casa Network in Latin America do not offer interactive or complement material over Internet. Depending if each broadcasting radio participant has online transmission, the audio classes are also available online under the broadcasting radio webpage if it is the case.

3.4.3 Use of the Computer in Education: Computer Lab

In Panama only 29% of the public primary schools are equipped with computer labs, and only 16% with Internet access, as shown on Table 10. In each case, approximately 12 children share a computer in primary [MEDUCA, 2010]. But not only had the Ministry of Education equipped the schools with computer labs. Thanks to initiative and efforts of the parents and community many schools are equipped with computer lab (A. López, personal communication, August 8, 2011). In any case, the maintenance of the equipment is the exclusive responsibility of each school, there is no support by the Ministry. According to the last available statistics in 2010 [MEDUCA, 2010] only 18,256 computers were available to attend all the students in primary public school.

Table 10. Number and Percentage of Schools with Computer Lab and Schools with Internet Access in the Public Primary School by Location in 2010 [MEDUCA, 2010).

Type of School	Number Total of Schools	Schools with Computer Lab		Schools with Internet Access	
		Number	*Percentage*	*Number*	*Percentage*
All Together	**2 971**	**858**	**29%**	**462**	**16%**
Urban	282	255	90%	193	68%
Rural	2 070	563	27%	263	13%
Indigenous	619	40	6%	6	1%

According to MEDUCA almost 73% of the pupils attending primary school are benefiting from the computer lab approach [MEDUCA, 2010]. Nevertheless, in order to maximize the use of the computers due to high school population, school authorities are obligated to limit the access to the computer lab. Different arrangements are implemented, like visits the computer lab once a week, twice a month or even in some schools children attend the computer lab one school term of the year, giving the chance that all students can visit the computer lab at the end of the year.

Connect to the Knowledge Project

Conectate al Conocimiento – *Connect to the Knowledge* [Rodríguez Rojas & De Coloma, 2006] was a governmental project among the National Secretary of Science and Technology SENACYT and the Ministry of Education of Panama started in 2005. The project was targeted for pupils from 4^{th} to 6^{th} grade. For the realization of this project, 1,000 public primary schools were equipped with computer lab with Internet access. The CmapLite[8] was installed to each computer. This tool is a light version of IHMC CmapTools[9] customized for Panama's schools for creating conceptual maps. Conceptual maps are very common practices used in Panamanian schools for present information summarized with the key points learnt.

After children create their conceptual maps, they can share it with the other pupils. Children upload to a webserver the conceptual maps created, which was only available in the schools participating in the project. The project was discontinued in 2009 by the new government.

Figure 4 shows an example of conceptual map created by a child in the project Conectate. However, each child has very limited access to the lab (e.g., once a week), since schools are only equipped with one lab each. Also, even though the computers provide access to the Internet, most of the time children were not allowed to go online due to concerns about security and distraction. Since most children in Panama have no access to computers at home, their computer use and education are limited to lab sessions in school.

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[8] *http://cmap.ihmc.us/download/cmaplite.php, last accessed on September 30, 2014.*

[9] *http://cmap.ihmc.us/, last accessed on September 30, 2014.*

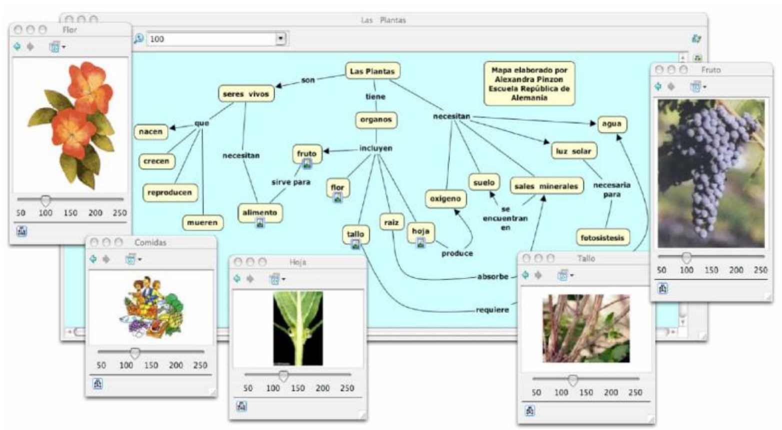

Figure 4. An example of a Conceptual Map Done under the Project Conectate [Tarté, 2006]

Deliver computer to Students of High School

In 2009, the government gave to the students attending 12th class a Dell laptop. At end of the school-year students have to return the laptop. The aim was that the new students attending 12th class reuse the laptop. However the program only run that year, and was discontinued by the new government. There are no statistics in how many laptops were not returned, lost or broken. In 2012, the new government gives to every student in 10th to 12th class an IntelClassmate PC. This netbooks have installed Windows 7 as operating system. Until this date, no study has been conducted to evaluate the efficiency of the inclusion of the laptops in the classroom.

3.5 Access and Use of Technology

Mobile phones are the most popular ICT adopted globally, as it shown in Figure 5. Already in 2013, the number of mobile-phone subscriptions worldwide is about 93%, 88% and 119% in developing and developed countries respectively [ITU, 2014a]. By 2013, there are about 6.6 billion mobile-cellular subscriptions [ITU, 2014a], and by end 2014 mobile-phone subscriptions will reach almost 7 billion [ITU, 2014c]. Already in 2012, the access to mobile phones is much higher compared to the access to Internet and owner of computer as shown in Figure 5.

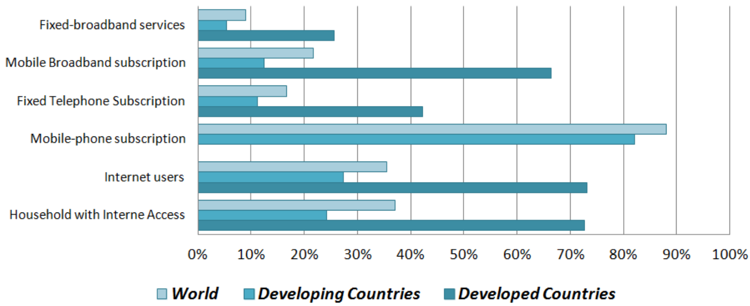

Figure 5. Access to Information and Communication Technology Worldwide, Developing and Developed Countries during 2012 [ITU, 2014a]

In 109 countries including Panama and other developing countries, there are more mobile phone subscriptions than population [ITU, 2014b]. Never before, a technology has impacted the society on developing countries as mobile phones do. Computers have been on sale at an affordable price by the end of the 1980s, pocket sized mobile phones have become affordable by the middle of the 1990s. The popularity and adoption of mobile phones in developing regions has grown much faster than compared to the other technologies, as it is shown on Figure 6.

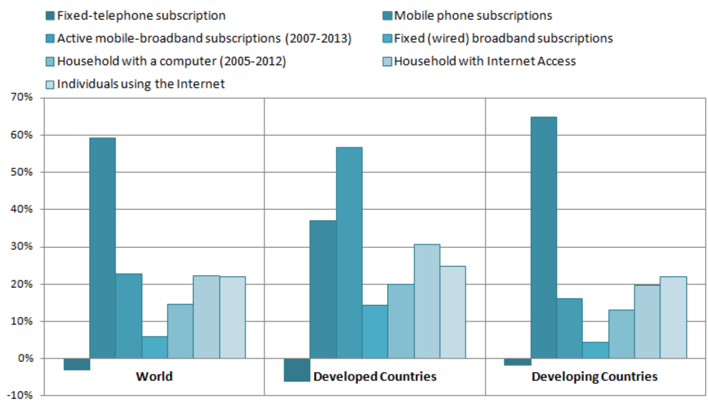

Figure 6. Growth Rate of the Use of the ICT in the World, Developed Countries and Developing Countries between 2005 and 2013 [ITU, 2014a].

In developed countries, 75.1% of the population was subscribed to mobile broadband service in 2013, compared to only 16.8% on developing countries [ITU, 2014a]. Nonetheless, from the analysis of the data available in ITU [ITU, 2014a], there was a total growth rate in the developing countries of 16% versus a 4.5% growth of fixed wire broadband subscription in the last seven years. The Americas[10] region has the second highest penetration levels, with 59%, and with an annual growth of over 15% in 2013 [ITU, 2014c]. By the end of 2014 there will be about half a billion of new mobile-broadband subscriptions in the Americas. Furthermore, mobile-broadband annual growth in Africa will be about 40% whereas the penetration in Africa will reach almost 20% by the end of 2014 [ITU, 2014c].

3.5.1 Access to Information and Communication Technology in Panama

In Panama, similar to global trends [ITU, 2014a; ITU, 2014c] in developing regions where have a higher access to mobile phones over computers, even more than traditional mediums like radio and television. The cell phone network covers 37.71% of the Panamanian territory and 95.75% of the population [ASEP, 2013a]. In 2013, the number of mobile phones subscriptions reached 6.3 million almost twice the population of Panama [ASEP, 2013a]. However, this number may consider the clients who have more than one phone as well as clients who change phones and stop to use their older phone. Since November 2011, the mobile phone number portability exists in Panama.

The last census in 2010, could give us a better picture of the access to mobile phones by Panamanians. In Panama, unlike other large populated countries, the whole population is censed every 10 years. In the last census in 2010, about 85% of the Panamanian household has a mobile phone, compare to roughly 28% who has a computer at home, as shown in Figure 7. Most of the mobile phone users, about 90%, use a prepaid card rather than the contract system [ASEP, 2013a].

The percentage of the population using the Internet in Panama –considering those who access from at home, the working place or a cybercafé– is approximately 41.5% [ASEP, 2013b]. Roughly 98% of the Internet clients have broadband access (≥ 256 Kbps) [ASEP, 2013b]. ADSL and Cable Modem are the most popular Internet access technology by Panamanians, with a 39.6% and 52.9% of clients using this technology respectively; while the percentage of

[10] *Americas region: include the whole American continent.*

client using WIMAX and WIFI technology were below roughly 7.5% together [ASEP, 2013b].

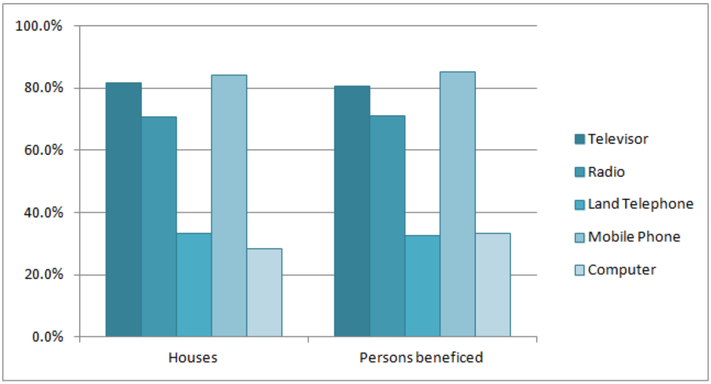

Figure 7. Access to Communication and Information Technology in Panama in 2010. Percentage of households and persons with access to Information and Communication Technologies [Contraloria, 2010]

3.6. Summary and Discussion: Potential of Mobile Phones as Learning Tool

We have seen radiography of Panama in relation to its Primary Public Education and the accessibility to technology by Panamanian, teachers and children. Although pedagogic researchers share antagonist opinions about whether with technology children learn better, no one can negate the support of the ICT in learning. The Internet allowed people access to an amount of information never seen before; it facilitates the distance formal learning, where people can follow courses and even do a degree through an E-learning platform or a teacher can complement their courses through virtual learning environment applications like Moodle. Students can watch educational videos on YouTube; language software facilitates the learning of foreign languages, as pupils have a full multimedia experience under a mouse click.

But not only the computer and Internet support education. Programs like Telebásica (section 3.4.1) or El Maestro en Casa (section 3.4.2) demonstrate that older ICTs like Radio, Television, audio and video players are still playing an important role in bring education to remote rural areas in the developing countries where computers are unknown. Modern mobile phones combine all of this, and are day by day more popular in developing countries. There have been several projects seen in chapter two that prove that mobile phone can be used also to support education. The following are the main reasons we argue why mobile phones are a more suitable learning tool than a laptop or PC in the context of developing countries.

The failed Computer Lab Model at Schools

Although there has been the effort of the educational authorities in equipped schools with computers, this model has failed. First, the time that children used the computers is very limited (section 3.4.3). Furthermore pupils have to work in pairs, which lead usually to a dominant child controlling the computer [Pawar *et al.*, 2007]. And when the child has no computer at home, the device is unfamiliar to him/her. When the student visits the computer lab next time, the student again has to take time to refresh her/his skills in using the machine.

In the schools where there is a computer lab, most teachers do not integrate the computer in their classes to enrich their lessons. Mainly students use the computer only for looking up information and working with text processor, which again is interrupted because of the limited time for the use of the computer. But for example English classes are not enhanced with the support of the online multimedia resources available.

The machines on the computer lab are not updated. Schools do not employ technicians who can repair the computers, and have to wait long periods until the Ministry of Education sends one to check the machine, which in some cases can take the whole academic year. In addition, in the schools where the parents build and equip the computer lab, the parents are also in charge to repair the computers (A. López, personal communication, August 8, 2011).

Computer Maintenance Availability and Tropical Weather

While in the cities and urban areas there are many locals to repair computers, in the rural areas the locals to repair computers if exist are seldom. Computer owners have to go to the cities and urban areas to get their computers repaired. In contrast, kiosks to equip, maintain and repair mobile phones in the country side and rural areas are widely available.

Besides, it is known, that computers are sensible to extreme conditions like heat and humidity. Panama is a tropical country with high temperatures and high humidity. In optimal conditions computers are located in rooms with air condition. That is the case of the computer lab in schools, however at home most of the Panamanians do not have such a setting. It could be thought that it is a trivial issue but it is not. The expecting life of a computer under such extreme heat and humidity conditions is lower than a computer placed in an air condition room. On the other hand, mobile phones are much more resistible to extreme weather than computers. They do not need to be in an air condition.

Low Access to Computer at Home and High Popularity of Mobile Phones

The access to computers at home is very low, only one third of the houses have a computer. Although we have no statistics, it is sure that this number is much lower in indigenous and remote regions. On the other hand, mobile phones are much more popular than computers in developing countries, including Panama, as we described in this chapter. People want to be communicate, and are willingly to afford the cost of having a mobile phone. A mobile phone is seen as a necessity but at the same time like a symbol of status. Whichever is their motivation, in many cases people are able to save money by weeks and even months to buy a mobile phone. Nevertheless, in most cases, except with some new smartphones, the price of a multimedia integrated mobile phone is accessible in comparison with computers. It is not uncommon also to see in developing countries including Panama, shops selling second hand mobile phones.

Modern Mobile Phones are Computers

Current mobile phones have a higher performance than the personal computers available fifteen years ago. Several smartphone models are provided with storage capacity, in some models up to 64 GB, and with the SD slots the storage can be extended even further. There are several low cost smartphones specially targeted for developing countries [Ford, 2011; McEnaney, 2014; Luna, 2014]. All the new main OS platforms –iPhone OS, Android, Symbian, and Windows 8– are friendly low-end programmable with a robust architecture.

Even middle-end phones are integrated with enriched multimedia features like a photo camera and audio. In the mobile phones this multimedia integration is better than on computers. Additionally, it integrates a wide communication channel from phoning, text messaging SMS, multimedia messaging MMS, Bluetooth and Internet access. The most modern phones include Wi-Fi, accelerators and GPS.

Mobile phones are portable; children can bring them wherever they are: at home, in their classroom, on field trips, on their way home, etc. Children can learn and record experiences at any moment and at any time.

Natural User Interface

Children in primary school are used to write by hand. Keyboards are not affordable; they do not follow the natural interaction children have when writing with a pen and paper. Younger children show low skills in using the keyboard skill [Ing & Wild, 1994]. Touchscreens are more affordable to use with children as they can write on it, in a similar way children write on paper. Currently, the mobile phone trend is toward touchscreen.

Chapter 4

Scenarios for Using ICT for Education in Panama

New technologies try to offer easier and wider access to educational materials and improve learning efficiency. But at the same time, new technologies often enable or impose new ways of teaching and learning. If the needs of users are not met in a meaningful way, then their acceptance of the new learning technologies will fail.

Teachers are the key in the integration and use of technology for learning [Vanatta & Fordham, 2004; Becket *et al.*, 2003; Gorder, 2008]. The mode that teachers perceive the technology implies the use or not of technology in classrooms [Gorder, 2008]. This predisposition will depend on how the educator thinks about the benefits of using technology in class [Ertmer, 2005; Baylor & Ritchie, 2002], the overload of work, as well as the grade of skills using the technology [Baylor & Ritchie, 2002; Mumtaz, 2000].

Therefore, we carried out surveys and interviews to assess the status quo of technology use, as well as the rough potential of using mobile phones in the context of school education. Especially, we focused on the perception of teachers towards the use of mobile phones for teaching. The studies can be grouped in:

(1) surveys to analyze the access and use of technology by teachers and children to get initial clues where and how mobile phones could support the learning and teaching process.

(2) focus groups, interviews, and paper prototyping to discuss about benefits and concerns of using mobile phones in class and extract teachers' ideas and opinions for using mobile phones as educational tools.

Part of this chapter is based on the following publications:

[Valderrama Bahamondez & Schmidt, 2010] Valderrama Bahamondez, E., & Schmidt, A. (2010). A Survey to Assess the Potential of Mobile Phones as a Learning Platform for Panama. *Extended Abstracts in the SIGCHI Conference on Human Factors in Computing Systems* (CHI EA‘ 2010), 3667-3672, ACM. DOI: http://dx.doi.org/10.1145/1753846.1754036

[Valderrama Bahamondez, *et al.* 2011a] Valderrama Bahamondez, E., Winkler, C., & Schmidt, A. (2011). Utilizing Multimedia Capabilities of Mobile Phones to Support Teaching in Schools in Rural Panama. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI ’11),* 935-944, ACM.
DOI: http://dx.doi.org/10.1145/1978942.1979081

4.1 Access and Use of Technology by Teachers and Students in Public Schools in Panama

In order to assess the potential of mobile phones as learning tools, we conducted a large survey to better understand: *how mobile technologies are currently used and how widespread access to mobile phones is for children; where in the current educational systems students and teachers see a need for support; and how mobile technologies could fit into the learning context in urban as well as rural Panama*.

The survey was conducted in three public schools in Panama in 2009. Two of the schools were urban schools located in Panama City and the other one was a rural school located in Panama East. The survey was conducted to analyze the educational situation in Panama with regard to the use of and access to technology by children and teachers. In Panama, as in Latin America in general and in other developing regions, there exists an internal digital division between schools situated in urban areas and school situated in rural areas. We wanted to capture this division as well in the survey.

The survey for the schoolchildren contained 26 questions. The suitability of the questionnaires was tested on two occasions with a total of 13 children to make sure they were easy to understand. The survey for the teacher had 24 questions, which were also tested for comprehensibility with 12 teachers. For both surveys the initial testing phase was very useful and helped us clarify confusing questions.

In total 300 children were interviewed, 150 from urban schools and 150 from rural schools. The ages of children were between 9 and 17 years old, with an average age of 12.4 years. 52.2% of children were male. Participants attended from 5th to 9th class. Parallel to this study, we also conducted a survey to 85 teachers, who work in public schools in rural, urban and also indigenous schools. These findings were reported in [Valderrama Bahamondez *et al*., 2011a]. The findings showed that children and teacher have a higher access to mobile phones rather than computers. This is similar to the result of the last worldwide ICT statistics trends in developing countries [ITU, 2014a; ITU, 2014c], and the national ICT access [Contraloría, 2010]. The survey was realized during spring 2009.

Government Perspective on Technological Challenges in Education

Before planning the survey, we met with the Secretary of State for Education, the Head of National Education, and Head of Primary Education of Panama. During these meetings, they explained to us the situation and their opinions on implementing new technologies in the schools, i.e. computers in Panamanian schools. With the high number of students and a lack of human resources and infrastructure, their limited budget is often used to fulfill other priorities. In rural areas that are difficult to access, the existence of computer labs is almost zero. Overpopulation of children in classrooms and the multigrade system both limit the children's access to computers. *"In the luckiest schools, two children share a PC during 40 minutes once a week. [For] many, the visits to computer lab [are] once a month or even more seldom"*. Another concern is the security of the equipment. In some areas, computers have been "lost". A further worry is allowing children access to the Internet. They do not want children to visit unsuitable sites. (Some schools have solved this by restricting Internet access for students). Another problem is computer maintenance. As one teacher that we interviewed pointed out, *"in our school there are 1000 students, 20 machines of which only 5 work"*.

4.1.1 Access to Technology

There was a much higher access to mobile phones than computers. Almost all teachers, 82 of the 85 teachers that represent the 97% reported to have a mobile phone, and around 80.3% of children have access to a mobile phone, as it is shown in Figure 8. This is in accordance with the worldwide trend [ITU, 2014] of mobile phone penetration developed as well as in developing countries. In contrast, 129 students, representing 43% of the 300 children surveyed have access to a personal computer. Of those with access to computer, about 73% have access to the Internet, whereas 27% do not have access to the Internet Figure 8 makes it clear that children from rural areas have significantly lower access to computers and Internet than their urban peers. Both children attending urban and rural areas had a relatively high access to mobile phones.

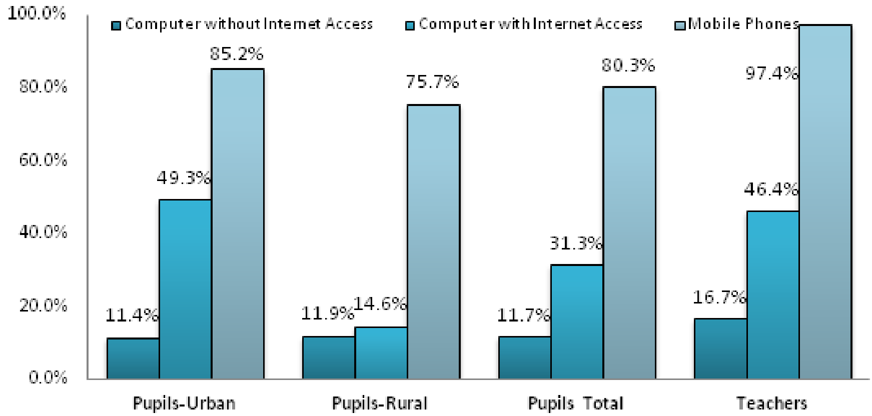

Figure 8. Access to Computers, Internet and Mobile Phones for Children and Teachers in Panama in 2009. The percentages presented are taken considering the whole sample of the 300 children.

Although not all children have their own mobile phone, most of them had access to one at home. Furthermore, in 72.4% of the households, there are three or more mobile phones.

Children have a high access to TV: Accordingly 92.6% of the children interviewed reported to have a Color TV at home; 1.4% a grayscale Black and White TV and 6% do not have a TV set.

4.1.1.1 Access to Computers in Schools

Most of the children reported to have access to computers in their schools: 67% of them with Internet access and 14% without Internet access. About 19% of the children reported do not have access to computers in the school.

We also asked children about the frequency in which they visit the computer lab. Most students have access to a computer weekly, however 20% of the students reported do not have weekly access to a computer at school, furthermore 10% do not have access to computers at all in their school.

Figure 9 presents a further description of the results. Fourteen children who represent the 5% of the interviewees did not answer this question.

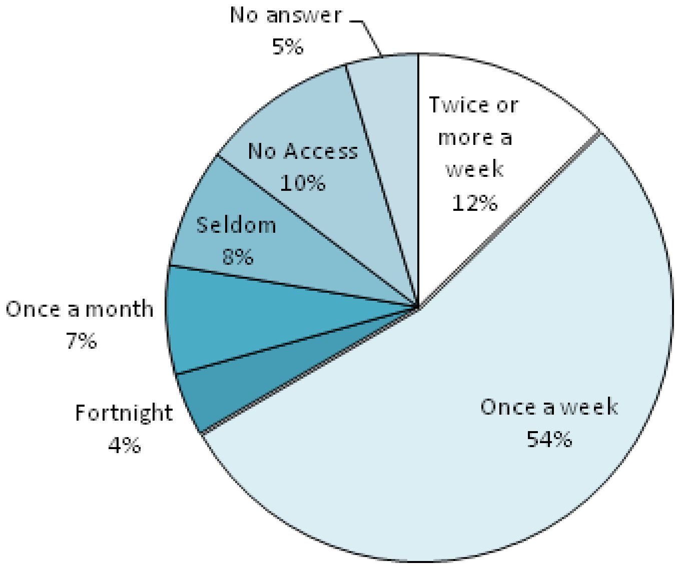

Figure 9. Frequency of children visiting the computer lab

One of the teachers' participants from the urban school in the survey stated that in her school, because of the lack of computers, the students alternate the visit to the computer lab. Students that do not have access to the computer lab during one school quarter should have the right to visit it in the next school quarter.

4.1.1.2 Computer Applications used by Teachers

Most of the teachers are familiar to use computers, but they considered themselves not skilled in using them. Only 6.1% of the teachers have never used a computer before. Microsoft Word® is the software most used by teachers. Approximately 88% of the teachers have used MS Word. About 67.1% of the teachers stated to have used MS PowerPoint®, and approximately 49.7% reported to have used MS Excel®. Most teachers have used the Internet. The percentage of male teachers reported to use or have used those applications was slightly higher than their female peers. Microsoft Windows was the OS that all teachers who have some computer experience, worked with. We asked teachers for what school activities they used the computer. Teachers could select more than one answer. Most teachers consult the Internet (81%), calculate grade (46%), school planning (40%) and prepare lectures (31%).

4.1.2 Second Survey

In 2012, we conducted a second survey to observe changes in the adoption and use of technology by children in a primary school in Panama. This second survey included a subset of the questions related to the access to technology as during our first survey in 2009, plus questions related to touchscreens and mobile Internet. The children's survey had a total of 11 questions.

This second survey was conducted in two public schools, one located in Panama East and the other in Cocle. Both schools are categorized as rural schools; however children who attend the school in Cocle come from a lower income family than those in the first school. Altogether 274 students were interviewed with quite an equitable gender distribution: 51.5% of students were girls and 48.5% of students were boys. Participants were between 8 and 15 years old and attended 4^{th} to 7^{th} class. The average age was 11 years.

4.1.2.1 Access to Mobile Phones and Computers

Figure 10 presents the comparison in the access to computer and mobile phones at home during the years 2009 and 2012. We found out that the percentage of children having a mobile phone at home increased by almost 15%. Almost in 95% of the student's household there are mobile phones, compare to ca. 80% during 2009. While the percentage of students, who has access to a computer at home, had increased ca. 4%, from 43% to 47%.

Furthermore, 30% of the students reported to have access to Computer with Internet, whereas 17% have no Internet access. Compared to the survey in 2009, the percentage of students who reported having access to a computer with Internet is slightly lower. This is due to the fact that we excluded the urban school in Panama City in the new survey.

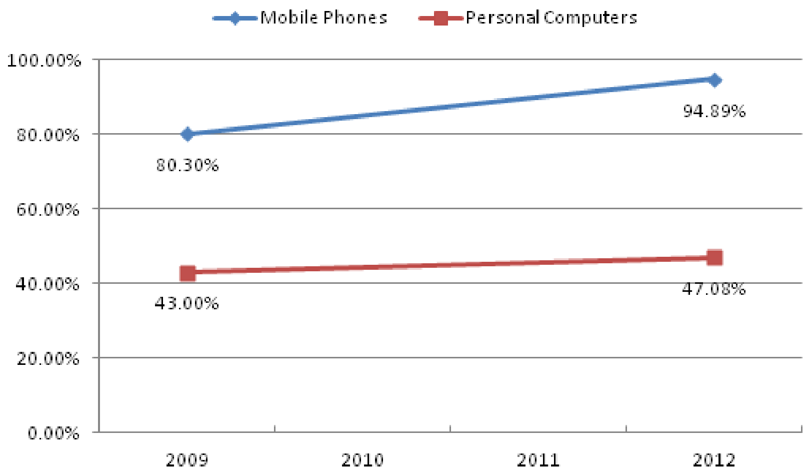

Figure 10. Comparison of access to Mobile Phones and Computers among students in Public School

Furthermore, 48% of the students reported to own a mobile phone. Similarly to other studies, the number of students who own a mobile phone is higher in older students than younger ones. In our case, we found out that 68% of students between 12 and 15 years old own a mobile phone, while 37% of the students with an age between 8 and 11 years old own a mobile phone.

4.1.2.2 Types of Internet Access Used by Children

During 2012, we also asked the type of access to the Internet by students. Roughly half of the students declared having Internet access. Three over ten students (30.6%) reported to have access to the Internet on their computers, and 2 out of 10 students (20.4%) have access to the Internet through mobile phones. Figure 11 shows these findings. The students who reported to have access to the Internet on computers connected either use ADSL/Modem or a USB stick Mobile Internet.

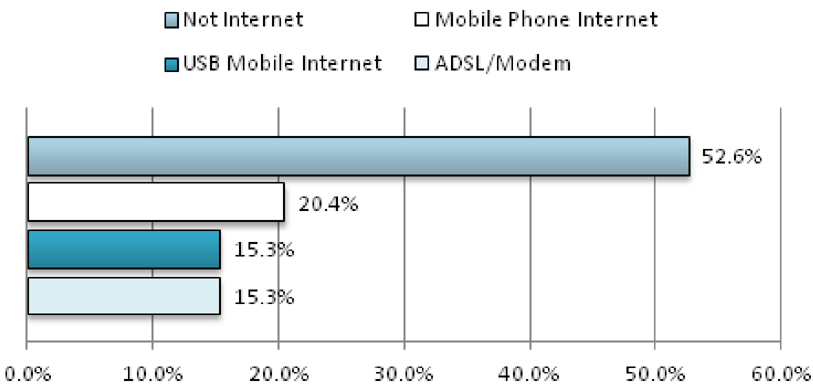

Figure 11. Kind of Internet Access Reported by Students

4.1.3 Mobile Phone Adoption and Use

In the survey conducted during 2012, there were in average 3.5 mobile phones per household. A high percentage of children have access to modern telephones at home[11]. At least about 71% of the students reported to have access to mobile phones integrated with a photo camera and Internet access. Only 21% of the students reported to have a low-end mobile phone at home which only allows calling, and text messaging SMS. In the survey in 2009, about 60% of the teachers and 77% of the students reported to have a mobile phone with Internet access and/or an integrated camera.

Additionally, about 55% of the students reported in 2012 to have access to smartphones at home with integrated photo/video camera, video-and-audio player, and Internet access. In Panama, touchscreen phones are quite adopted. In our 2012 survey, there was at least one touchscreen phone in about 47% of the students' homes.

[11] *Students were asked to specify the different phone available at home.*

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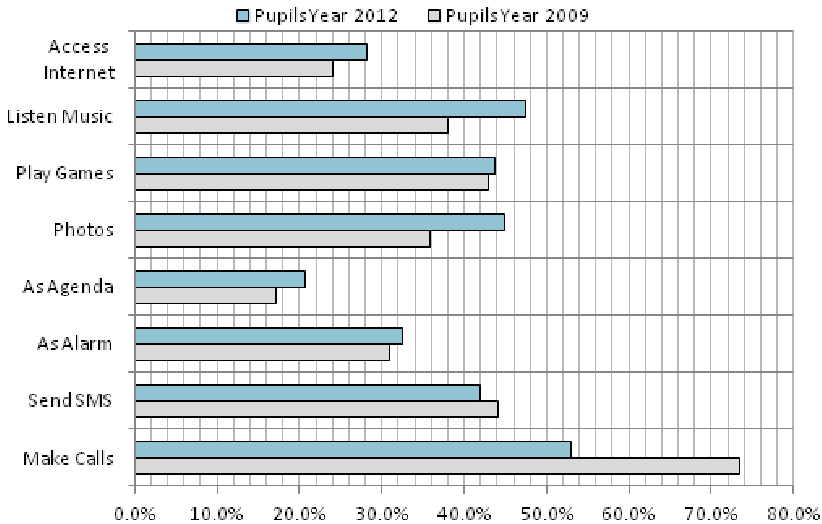

Figure 12. Use of Mobile Phone by Children in Panama in 2009 and 2012.

As a consequence of a wider access to modern phones, the usage of mobile phones has changed from 2009 to 2012. In 2009, making calls, sending SMS and playing games were the top functions that children and teachers used on the mobile phone. However, in 2012 making calls, listening to music and taking photos are the top functions children used on their mobile phones. Figure 12 shows this comparison and trends in the use of mobile phones by students.

Whereas teachers, during 2009, used the mobile phone mainly for making calls (93%), send SMS and as alarm (80% each), take photos (56%), as agenda (52%), playing games (45%) and listening music (37%). In contrast only 8% of the teacher accessed Internet from their mobile phones.

4.1.4 Information Gathering

We also asked the students about their preferred medium of information gathering for doing the school assignments. Participants were free to select more than one option. The results showed that students used a variety of sources of information, mainly digital but also many students used books to look for information, as shown in the Table 11.

Table 11. Approach Used by the Children to Look Up Information for their School Assignments. Years 2009 and 2012.

Year	DIGITAL MEDIUM				PRINTED MEDIUM		
	Online			Offline			
	Internet on Computer	*Internet on Mobile Phones*	*Wikipedia*	*Software-Encyclopedia*	*Encyclopedia*	*School Library*	*Public Library*
2012	*58.1%*	*37.9%*	*45.1%*	*5.9%*	*45.1%*	*12.6%*	*16.6%*
2009	*65.8%#*		*14.7%*	*4.9%*	*29.6%*	*22.8%*	*4.9%*

**In this survey children did not specify the Internet medium used*

Search information on the Internet was the form used by the majority of the students in both surveys. In 2009, more than 65% of the students used the Internet to search information. Based on these findings, in 2012 the survey was extended and we asked children to specify the medium where they use the Internet from –i.e. computer or mobile phone. The results showed that ca. 58% and ca. 38% of the students used the Internet from computer and mobile phones respectively.

In both surveys, more children used the Internet for gathering information from a computer – see Table 11 – than those children who reported to have a computer with Internet access at home. Some of them can use the computer in their schools; other options are the Cybercafés, and Infoplazas. Infoplazas [SENACYT, 2011] are computer centers located in margined areas which offer access to the Internet and other multimedia resources at a lower price than the market. Infoplazas are supported by the government of Panama through the National Secretary of Sciences and Technology[12] (SENACYT). Figure 13 showed one Infoplaza in a rural town in Cocle.

[12] *http://www.senacyt.gob.pa/, last accessed on September 30, 2014.*

Figure 13. A photo of an Infoplaza in the Village El Caño, Coclé.

Interesting to note is that 37.9% of the children interviewed in 2012 reported to use mobile phones to search information (see Table 11), while only 20.4% stated to have Internet access on their mobile phones. A possible explanation is that children do not consider information gathering for their school assignments as a real use of Internet. Children see in the Internet a place to play online games, watch online movies (YouTube), listening music, share photos and experience synchronously (Chat rooms), and asynchronously (e.g. Social Networks, Emails). It can also be that students use the Internet on their mobile phones to search information only when the information is not available in the additional means, like printed medium. Therefore as students do not connect and use the Internet in a continuum, but in seldom cases, the students did not consider the Internet access in the whole sense.

During 2009, although Internet was the main source of information gathering, most of the children apparently did not know nor use Wikipedia. From the whole sample only 14.7% used Wikipedia for solving their homework. In 2012 this percentage increased almost three times.

4.2 Potential Context for Mobile Learning Platforms

During the surveys conducted in 2009, we also asked teachers and children about the subjects they think can be benefited from with a mobile learning application. In addition, location and time where children can make more benefit of potential mobile learning applications were also explored.

4.2.1 Subjects that Can Be Supported by Mobile Learning Applications

We asked the children which subject they would like to have help with e.g. through learning games. The answers indicate that many children (44.2%) would like to receive help with Mathematics. They seemed to be open to having more practice with multiplication. Some children felt that they *"*cannot learn the multiplication table*"* or do *"not [have] much time to practice"*.

A more detailed analysis is shown in Table 12. Although Mathematics is the subject where most children have problems and wanted more support with, the overall responses differed greatly between rural and urban areas. Students in rural areas wanted support in a more diverse set of subjects, whereas students in urban areas were largely concerned with Mathematics. These results are consistent with reports from the Ministry of Education of Panama [MEDUCA, 2010], which showed that Math, Science and Spanish were the subjects with the highest fail rates.

Table 12. Academic Subjects Where Children Have Difficulties and Would Welcome Additional Support.

Subjects	Total (in percentage)	Urban Schools (in percentage)	Rural Schools (in percentage)
Mathematics	44.2%	59.5%	28.9%
English	15.6%	8.1%	23.0%
Spanish	6.0%	6.1%	5.9%
Nature Sciences	15.2%	6.1%	24.3%
Social Sciences	13.3%	6.7%	13.8%

We also asked teachers which subjects they felt children struggled and could benefit from the use of technology (computer and/or mobile phones). The majority of teachers considered Mathematics (94.8%), English (35.1%), and

Spanish (25.6%) as the most difficult subjects[13]. Teachers stated that children in primary schools *"do not know the multiplication table"* and those in middle schools exhibit a "*lack of basic mathematical principles"* and *"do not know the four basic arithmetic operations"*.

The teachers were asked about their opinions of educational applications on mobile phones. In particular, we asked about the suitability of applications for mathematical exercises (e.g. basic Arithmetic) and exercises in English vocabulary. 71.6% see a value in the idea of using mobile applications to reinforce mathematics learning and 54.1% support the idea for English language learning.

4.2.2 Location for Using Mobile Learning Applications

The teachers were asked to evaluate the use of mobile phones versus laptops for supporting learning in Mathematics and English. They were asked to rate the devices from not useful to very useful (on a 5-Point Likert scale). Figure 14 shows the results. The phone and laptop are rated similarly with a marginal preference for the laptop. A large majority of teachers rated the mobile phone as a good learning platform for practicing Mathematics and English at home, as we expected that the primary usage context would be in mobile situations (e.g. on the bus).

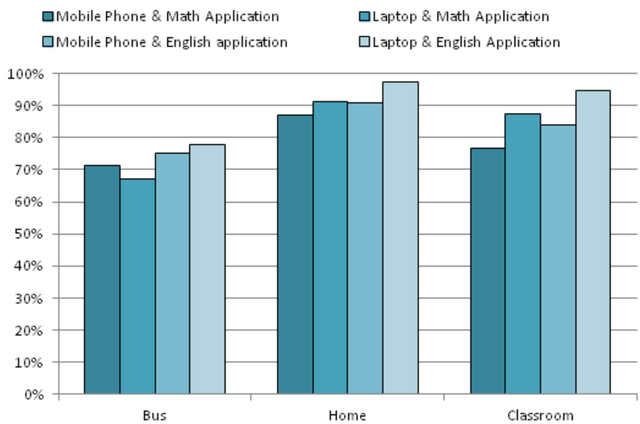

Figure 14. Acceptance of the Use of Mobile Phones and Laptops for Solving Mathematics and English Exercises.

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[13] *Teachers could name more than one subject.*

4.2.2.1 Traveling Time by Children to/from School

For the majority of rural children the travel time to school is fairly short (82% of the children need less than 30 minutes). In urban areas about half of the students (49%) have a travel time to school of more than 30 minutes. Most children in primary school (78.5%) use the bus to go to school. Overall age groups about 42% of the children and 80.5% in rural areas go to school by foot. Besides talking to friends, revising for exams was the main activity on the way from home to school (stated by 47.5% of the children). On the way back from school students stated they wanted to relax.

4.3 Scenarios of Using Mobile Phones in Classrooms

Based on findings from our previous survey, we wanted to explore some concrete ideas how teachers think mobile phones can be used in class. In the section we presented scenarios and design space for mobile learning applications resulted from the research with teachers in Panama.

4.3.1 Methodology

We conducted focus groups and a large interview with a paper prototype. Focus group is one of the most used techniques to conduct qualitative research in order to understand social behavior [Debus, 1988] and gather opinions [Krueger & Casey, 2009]. With the utilization of focus groups, researchers can *"obtain participants' perceptions on a defined area of interest in a permissive, nonthreatening environment"* [Krueger & Cassidy, 2009, p.2]. The focus group, section 4.3.2, helped us to have better understanding of the attitudes, and perceptions of teachers toward the use of mobile phones for learning.

To the focus group additionally, we conducted a set of group interviews. Because of time and other external constraints, we realized a set of large interviews with 190 teachers, as described in section 4.3.3. For these interviews we supported on paper prototypes, as shown on Figure 16. Paper prototyping is widely used in the context of human centered design, as a method for *"designing, testing and refining user interfaces"* [Snyder, 2003], furthermore it leads to generation, discussion and evaluation of ideas [Hanington, 2006; Greenberg *et al.*, 2012].

4.3.2 Results of the Focus Groups

In December 2009, we realized three focus groups with a total of 37 teachers in 3 different schools, two urban and one rural school. There were 28 male and 9 females with an average of 42.9 years old. We asked the participants regarding their expertise using PCs and mobile phones. The rating scale was from 1 to 5, where 1 meant no experience and 5 meant expert user. Participants have had an average expertise of 2.94 using a computer and an expertise of 3.6 in the use of mobile phones. This implies that 82% of participants were more experts using mobile phones than computers.

We also asked the teachers which applications they have used[14]. MS Word (29), Internet (27), E-Mail (18), MS Excel (17) and MS PowerPoint (15) were the main software and applications mentioned that teachers had used. Windows OS® together with its MS Office® tool are the most popular OS and office application respectively; Windows is the only OS that teachers know. Despite the high usage of Internet, social network (7) and chat (5) applications were not so popular among teachers at that time[15]. Teachers reported to use the computer in the following scholar activities: look up information (27), write exams (23), prepare tasks (21), calculate students' grades (16) and create slides (13).

Most teachers liked the idea of using mobile phones for supporting teaching: "*They (children) really like this thing and are more expert than me"; "I think with mobile phones children will be very enthusiastic*". But two teachers were strongly against using mobile phones in classroom, "*I do not agree using mobile phones for learning especially in Mathematics because (they) lead children to be more dumb and dependent… computers do everything*".

According to the teachers, main concerns with the use of mobile phones are the security, distraction, and behavior problems among students, as one student commented: "*Imagine large classes of 30 and even 40 students with mobile phones, how I control that (they) use it properly?*"

Two teachers had already used mobile phones in class with their students *"I was tired that my students were filming me all the time and put me on the Internet… I am a cabinetmaking teacher and because of the limited class time I have not enough time to review their work, … so one day I tell them open your (mobile phone) camera and take a picture of your work … they were so enthusiastic and*

[14] *Teachers can give more than one answer*

[15] *As nowadays the popularity of social networks has increased, it is probable that these numbers have changed by the time this thesis gets published.*

concentrated taking the pictures… the next day everyone wanted to show me and explain their work… since then I do not experience such bad behavior anymore and I continue using the phone in my class from time to time.”

Many teachers agreed upon the *key being the multimodal usage, especially combining audio, pictures and text*. As well as to design applications as games to prevent children from becoming bored. All teachers considered the SMS exchange as a strong problem for learning Spanish. The shortness and incorrect writing of the words are their main concerns, as one teacher states: “*writing SMS worsens the orthography and writing of the students”*. In general, they welcomed the help of mobile phones for Math, Spanish and English and perhaps also other subjects.

4.3.2.1 Paper Early Design

After the initial feedback from the focus group with teachers, we asked them to draw a concrete example on paper of how they envisage a mobile learning. This activity was conducted only in two of the three focus group sessions, so only 25 teachers did this task. Teachers grouped in 4 to 6, and in their drawing they used both audio and text modalities as input.

Figure 15. Learning Applications Designed by Teachers. From left to right: A mathematics game learning, support to distinguish homophonic words, and as a way to verify if children understand the reading.

The use cases drawn are shown on Figure 15. The first design (left) was a game where children practice addition; kids type the number and receive an award (star) in case the answer was correct. The second example (center) was an application where children have to complete blanks (similar to the books) in this occasion to distinguish homophonic words. The last drawing (right) represents an application for reinforcing the reading comprehension, here the idea behind was that children have to arrange scenes related on what they read.

Initially, the last scenario (Figure 15 right) was thought for Spanish. In the discussion, teachers stated that it can be extended to other areas like Nature Science and History. Another scenario depicted by teachers was the creation of an audio story based on an image displayed on the mobile phone.

4.3.3 Results of the Group Interview

During three weeks of February 2010 we had the chance to interview around 190 teachers, which represented 1% of the teacher population in Panama. The teachers interviewed were representatives of urban, rural and difficult access areas and we met them in groups of 30-40 each. We presented them a big paper prototype with an example of two mobile learning platforms, where teachers would be able to create tasks and send them to their students. Figure 16 shows the presentation of the paper prototype to one group of teachers.

The content of the paper prototype was based on the results of our previous focus groups. In total, we presented four (2x2) paper prototypes: one pair that would allow the creation of mathematics tasks and another pair for science tasks, each pair consisting of one prototype representing a child's phone and the other a teacher's phone. Annex B shows images of the paper prototypes used during the interview.

Figure 16. Presentation of Paper Prototypes during the interview with Teachers

The majority of the teachers (80%) liked the idea of using mobile phones in class. Teachers stated that students are very good with new technologies and are able to work with it. However, they think "*if we ever work with such phones… we have to receive good training on how to use it or otherwise children will know more than us*".

4.4 Summary and Discussion

In Panama access to mobile phones is much higher than to traditional computers. We were surprised of how many of the currently used phones had cameras and multimedia capabilities, suggesting that many people have mid-range phones.

Both children living in urban areas and rural areas had low access to computers but high access to mobile phones. In addition, a considerable percentage of teachers and students reportedly have access to modern mobile phones that include multimedia and networking features, i.e. integrated audio player, integrated camera and Internet access. This would allow them to run rich, interactive learning applications on these phones.

Additionally, students and educators would seemingly welcome edutainment applications on their handsets, especially for basic Mathematics and Languages. Their responses suggest that there would be a high acceptance of educational games designed for the mobile phone that would reinforce concepts learned in class.

Although mobile phones can be used virtually anywhere, most educators felt that the home is the most feasible place where children would benefit from learning with their mobile phones. Teachers seem to choose the home, because nearly all children have access to mobile phones at home. They also think that children would be more distracted if they used their mobile phones for learning in the classroom. For children in urban areas, traveling to schools could also be a good setting for learning on their mobile phones, since half of them take 30 minutes or more to travel to school. For children in rural areas, audio-based learning applications would be more suitable, since most go to school by foot.

Results show that there is a high proliferation of mobile phones among school children; and that teachers and students were all able to envision using mobile phones for learning purposes. The survey results indicate that mobile devices have the potential to integrate themselves into existing learning contexts, as well as enable new learning contexts.

Chapter 5

Tool and Applications

While observation and video recording are techniques that support researchers to record user behavior, loggers applications support researchers to track how the user interact with a specific software application. Usually loggers record automatically quantities data (timestamp, frequency of using an application, error log, etc.) while the user is working with the application and save them as a text file. We conducted field studies with children where we wanted to know how they behave when using the mobile phones in class but also to capture how they interact with the applications installed on the mobile phones. We developed as research tool a logger that at the same time takes screenshots of the whole sequence of the screens when a child is interacting with an application. With this textual and visual logger, we have quantitative but also qualitative data on the way children interacted with the mobile phones.

The chapter describes this research tool, as well as two learning application prototypes for mobile phones that were developed along the whole doctorate research. Thereby, here, we present mainly the technical realization of these tools, applications, and prototypes.

5.1 Logging and Screenshot Application

We developed a logger, called *ScreenShotLogger* to support the research realized across this thesis (see Section 6.1). The *ScreenShotLogger* is a powerful tool to monitor and log interaction and usage in the educational context. It takes screenshots of the application in a pre-defined interval.

5.1.1 Motivation

Loggers are widely used for track usage [Doolan *et al.*, 2012], monitor systems' usability and quality [Atterer *et al.*, 2006; Doolan *et al.*, 2012], backup and to track systems' behavior [Ascione *et al.*, 2006]. Loggers installed on the client side [Atterer *et al.*, 2006;] track the usage of the system better than those installed on the server side. Ascione *et al.* [Ascione *et al.*, 2006] implement a logger to get insights into causes of failure on mobile phones.

For our research, we develop and install a logger application on children's mobile phones due to two main reasons. First, we want to better understand how children interact with the mobile phones. While a text log could give us quantitative information about how children use the mobile phones, we are confident that repetitive pictures of the active screen provide us more insights into how children actually use the mobile phones with a focus on how they interact with the mobile phone. For example, how children navigate through a gallery, in which applications or features children have difficulties, or of the children's typing behavior. All these issues are easier to observe using screenshots rather than a simple text logger. Figure 17 shows screenshots created with the logger of one child. The screenshots represent approximately 21 minutes of interaction.

The second reason is to avoid the misuse of the mobile phone. When children are alert of that everything they do is recorded, it minimize the risk that children use improperly the device. It also encourages children to do their best in the learning assignments with the mobile phones created by teachers.

However, it does not mean that children did not explore the mobile phone in ways beyond teachers expected, especially outside classroom, as shown in Chapter 9.

A downside issue with loggers is the privacy [Atterer *et al.*, 2006]. Before we deliver the phones to the participants in our field studies (cf. Section 6.1) we explain the children, teachers, parents, and principal that all the actions done on the phones are tracked. Teachers and directors found the concept helpful to supervise the best use and parents agreed to use the application to monitor the usage of the phones by their children.

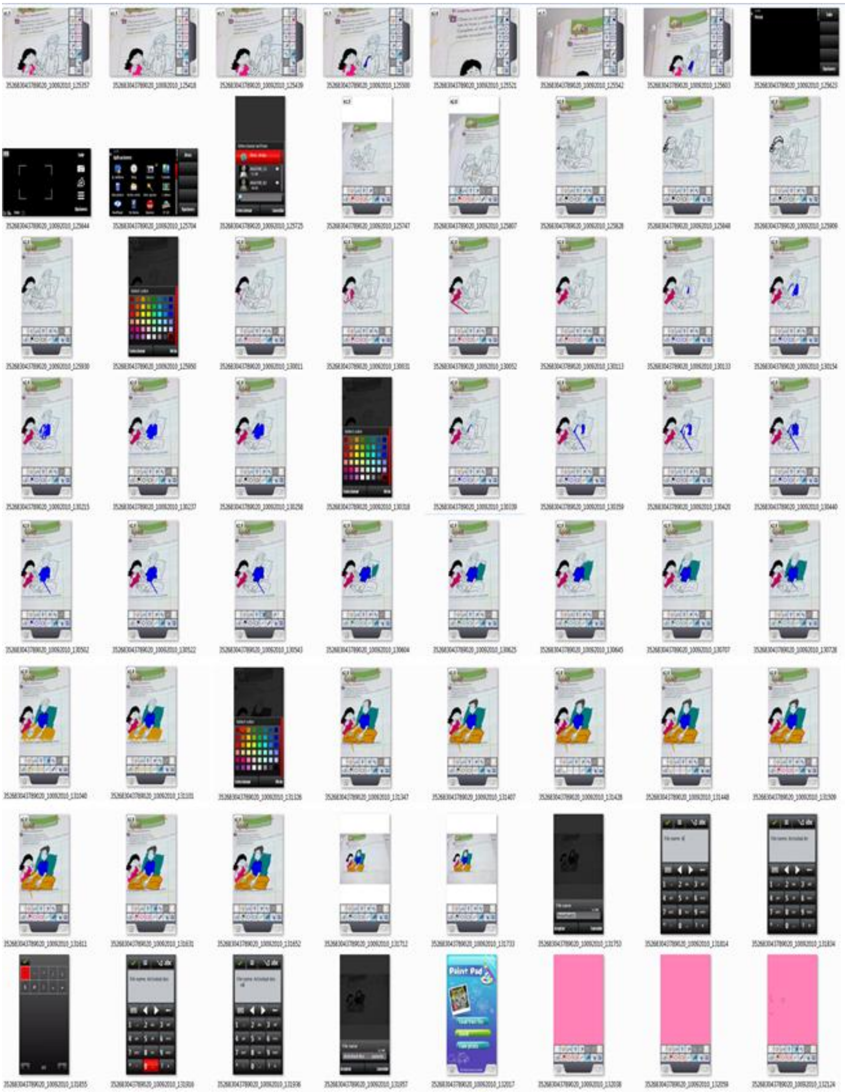

Figure 17. Screenshots corresponding to 21 minutes working with the mobile phone by a student participant in our research. Here we can observe the way child painting using the phone

5.1.2 Implementation

We use Nokia Xpress Music 5530 mobile phones with Symbian OS in our main field studies. Thus, we developed the application in Python (logging and picture taking) and Symbian C++ (access to system APIs). We installed the *ScreenShotLogger* application on all children's mobile phones. The *ScreenShotLogger* runs transparently in the background, it auto starts on a system boot, and is monitored by a second application, called watchdog application.

The *ScreenShotLogger* has two main components: the logger application itself and a watchdog application. As soon the phone is turned on, the logger application starts automatically. The logger application starts the watchdog application immediately and simultaneously the watchdog application checks if the logger application is running and starts it if not. This cross monitoring helps to assure that the logger it is always running. Figure 18 shows the activity diagram of *ScreenShotLogger*.

5.1.2.1 Logger Application

The logger logs every four seconds which application is actively used by the participants at the moment. This data is logged with a timestamp to a text file. Additionally, every 20 seconds the logger takes a screenshot of the active application of the student while the phone is in use (i.e., not in sleep mode). It also starts the watchdog application.

The class `Scheduler` with the method `schedule` manages the interval time of the logging including the timer for the logger itself, the screenshot, and the watchdog. Figure 19 shows the source code of the instantiation of the class `Scheduler` for the three timer functions. The first parameter is the interval time that is the time in seconds between subsequent calls of the callback (function). The function is the second parameter send to schedule and in this case the functions are `logaction`, `startwatchdog`, and `takescreenshot`. The last parameter is the initial delay time to call the function. The `logaction` function is listening for a foreground application change and the `takescreenshot` function takes a screenshot of the active application. Both functions are shown in Figure 19.

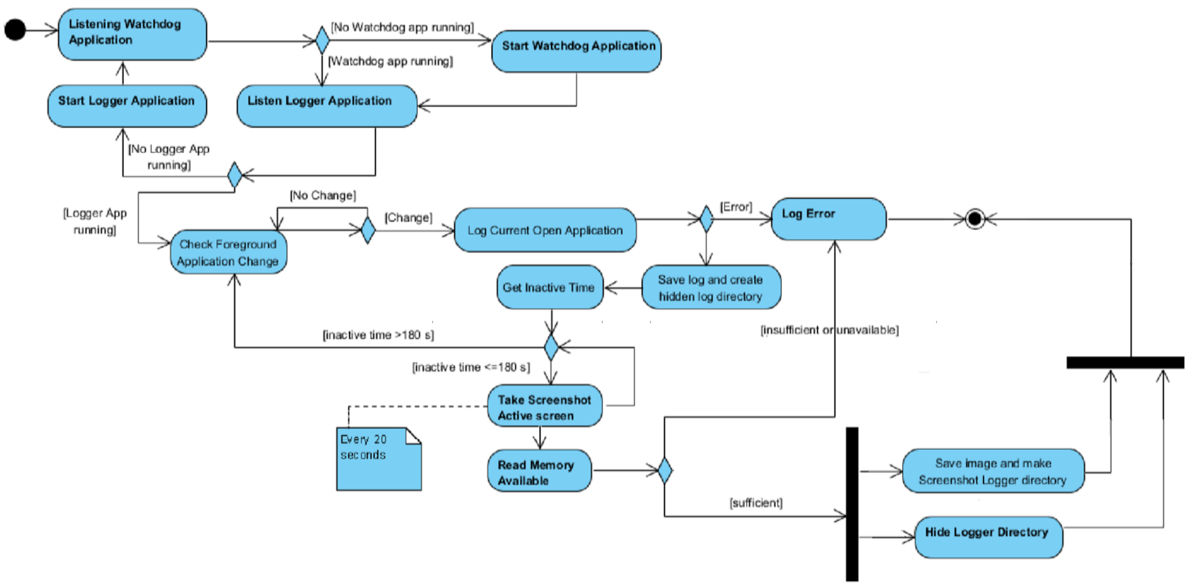

Figure 18. Activity Diagram of the ScreenShotLogger. Once the mobile phone is turned on, the watchdog application immediately initialize the Logging application. It runs in the foreground checking for new applications opened and log it in a file. A screenshot of the active screen is taking every 20 seconds and saved in an external memory. In case user spends more than 180 seconds in the same screen without interacting with the phone. The logger stops the log and takes a screenshot of the inactive screen. The watchdog and the logger application listen each other, and in case one of them is not running, one starts the other and vice versa.

```
...
        actiontimer = Scheduler()
        actiontimer.schedule(4, logaction, 4)
        watchdogtimer = Scheduler()
        watchdogtimer.schedule(5, startwatchdog, 5)
        screenshottimer = Scheduler()
        screenshottimer.schedule(20, takescreenshot,
2)


def logaction():
    global curapp, lastapp
    curapp = amg.application_list(True)[0]
    if curapp != lastapp:
         actionlog.info(curapp)
    lastapp = curapp

def takescreenshot():
    if e32.inactivity() > 180: return
    # prepare directory
    path = os.path.join(screenshotpath,
          imei+time.strftime("_%d%m%Y"))
    if not os.path.exists(path):
        os.makedirs(path)
    # take screenshot
    img = graphics.screenshot()
    # Save the screenshot
    filename os.path.join(path,
      imei+time.strftime("_%d%m%Y_%H%M%S.jpg"))
    img.save(filename)
```

Figure 19. Main methods of the ScreenShotLogger tool

5.1.2.2 Watchdog Application

The watchdog application tests if the logger is running. In case it is not, the watchdog application restarts the logger application. It also includes the same `class Scheduler`. The idea behind the watchdog application is that it restarts the logger application in case of a malfunction, for instance, when the mobile phone freezes and the watchdog needs to restart the logger application. The watchdog application listens for the logger application every five seconds.

5.1.2.3 Log files structure

All the log files including the screenshots are stored in a folder. The name convention of the file is the IMEI number of the mobile phone followed by the date. Therefore, each log file has a unique filename.

The log file is a comma separated value (CSV) file. The CSV convention eases up the later management and analysis of the collected data. It can be easily imported to a spreadsheet or to statistics software like SPSS[16]. Each record consists of four fields: IMEI number, date, time, and name of the application in use. The format of a record looks like:

$$IMEI\_number, date(yyyymmdd), time(dd{:}hh{:}mm{:}ss), application\_name$$

As an example we can have:

`352683043789020, 2010-09-10,10:40:15,Paint Pad.`

The logger stores the screenshots in the screenshots directory. The logger organizes the screenshots of each child of each day in the same subdirectory. The name of the subdirectories is the phone's IMEI number followed by an underscore symbol and the date. The format for naming the subdirectories is: $IMEInumber\_yyyymmdd$. For example, *352683043785770_21102010* is the subdirectory that contains all the screenshot taken on 10/21/2010 with the mobile phone with the IMEI number *352683043785770*.

Then each screenshot is saved as jpg file with a file size of about 37 KB. Each image has a unique name consisting of the IMEI, the date, and the timestamp. For example, a screenshot with the file name *352683043785770_21102010_103240* represents an image taken on October 21st, 2010 at 10:32:40 a.m. As the logger takes an image every 20 seconds, the logger produces up to 180 screenshots per hour.

The logger saves the data including the log files and screenshot files to hidden folders on a 4GB SD card. The data can only be accessed by inserting the SD card directly into a computer. Hidden files and folders prohibited images from appearing in the picture gallery and are more difficult to erase by children.

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[16] *http://www-01.ibm.com/software/analytics/spss/products/statistics/, last accessed on September 30, 2014.*

5.2 mobileMath

As part of our research, we develop mobileMath [Pachula, 2010]. MobileMath is an application that allows teachers to generate arithmetic tasks. Teachers are able to generate the task from both a PC and also from a low-end mobile phone. Figure 20 depicts the concept of mobileMath.

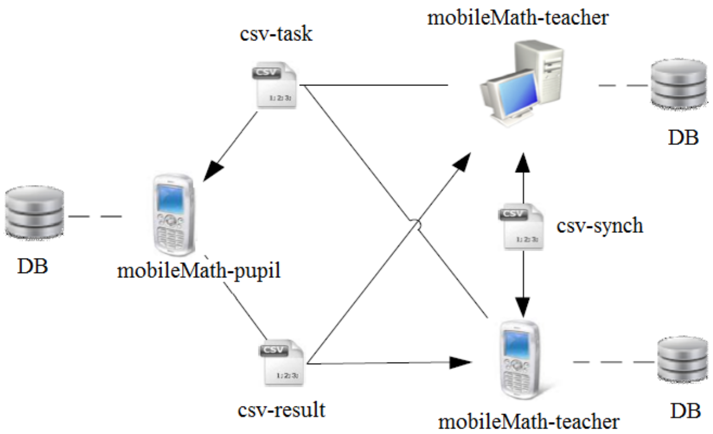


Figure 20. Communication Model of MobileMath [Pachula, 2010]

Once a teacher generates the tasks through mobileMath-teacher, children can access the tasks using their mobile phones (mobileMath-pupil). With mobileMath we *(1) explore the potential of using mobile phones for supporting the learning process of children and (2) offer teachers an easy mechanism to recreate Math exercises for mobile phone users.*

5.2.1 Motivation

Get skills in arithmetic in primary schools is done mainly to the realization of repetitive tasks. Math tasks on books and sheets are a common way for children to practice arithmetic. Sometimes teachers assigned the tasks directly from the books, another time teachers created the exercise sheets that children have to review. Teachers can also give additional tasks to students who she/he observes need more practice than the rest of the group.

Currently, there are several digital arithmetic trainers' games available, online and non-online, that can be accessible from computer and mobile phones. These arithmetic game trainers support students improving their arithmetic skills. However, usually these games do not allow teachers to customize accordingly the tasks children should solve. In addition, considering the high popularity of mobile phones compared to PCs in unprivileged regions, we wanted that teachers are able to generate arithmetic tasks using both PC and mobile phone environments, without the need to be connected to the Internet. On the children side the idea is to run the application only on mobile phones; however the children application (mobileMath-pupil) was not implemented in [Pachula, 2010].

5.2.2 Design and Implementation

The mobileMath application consists of two main components the mobileMath-teacher and the mobileMath-pupil. The mobileMath-teacher runs on both a PC and on a mobile phone as shown in Figure 21. The PC version of mobileMath-teacher was developed using JAVA, while the mobile version of mobileMath was implemented with JavaME. The main components of mobileMath are Task-Generator, Parser and CSV-Engine, which are common on both the teacher side (mobile and PC) and the student side. The data on the PC version is connected directly to JDBC, while the data is managed through record stores in the mobile phone version. Figure 21 presents the component model of mobileMath..

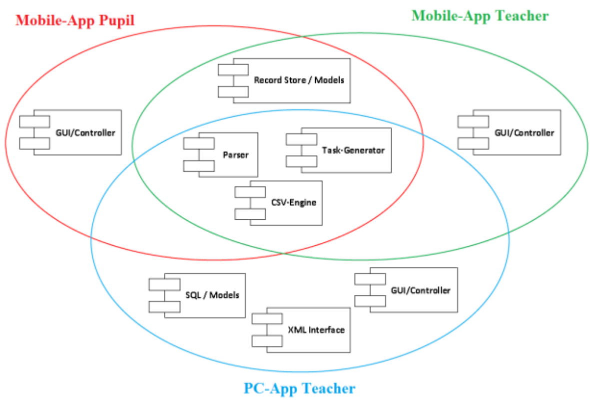


Figure 21. Component Model of Mobile Math [Pachula, 2010]

The configuration and language XML files comprise the XML component. The XML file was conceived to extend the text of the GUI to different languages. SQL-Komponent is the interface that connects to the JDBC DataBase, it also generates the SQL queries. The models represent the data objects inherit form a central abstract model. The values of the models are stored in a table.

5.2.2.1 Parser Component and Task Generator

The parser does the mathematics calculations. The parser has three main functions: (a) to create the arithmetic tasks, (b) to calculate the results of the task, and (c) to manage the tasks. The parser received from the task-generator each term (expression) as a String. Then the parser separates the String in operands, operators and parenthesis. The operator generator selects randomly an operator; and the operand generator generates a random number between the numbers range selected by the teacher. Figure 22 shows the state diagram of the parser component of MobileMath.

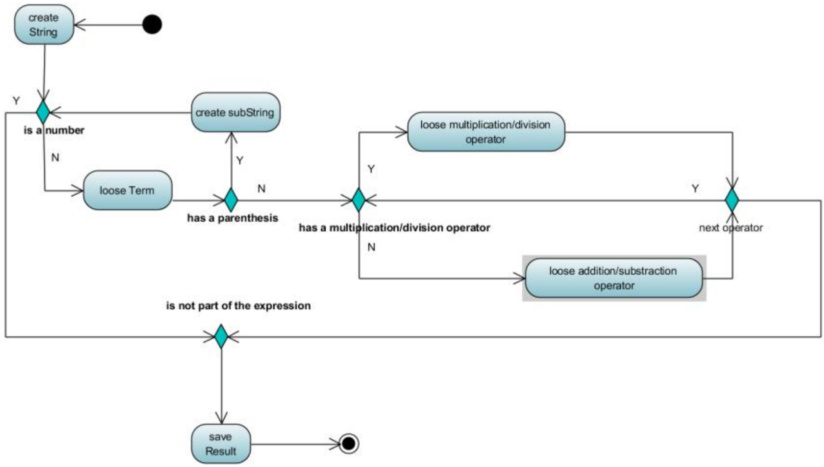


Figure 22. State Diagram of the Parser Component of MobileMath [Pachula, 2010]

5.3 CuentoMovil

During our research, we also developed a prototype for creating written stories called CuentoMovil (story mobile). It is an application that allows students to write short texts with pictures, and later students share them with the teacher and peers.

5.3.1 Motivation

During our initial surveys reported across chapter 4, teachers expressed that Language arts, e.g., Spanish, and English as a Foreign Language, were among the subjects that children present problems, in special with respect to oral and written expressions. Furthermore, as a result of our focus group, teachers depicted an example of an application that allows children to write stories: *“Create [written] small stories support children to improve skill writing and children’s creativity,”* stated one teacher to us during the field study. When children finished their elementary school it is expected that they have develop initial writing skills, which children later perfect when they attend high school.

In addition, during our first field study conducted in 2010, we observed that teacher access to content created by students mainly through direct observation of the children’s mobile phone or children send using Bluetooth connection (cf. section 10.3). The later one raised technical issues like the limitation of simultaneously connection. Mechanisms where, teachers can easily access work done by children on the mobile phones was missing. Also, whereas, teachers want to share content to their students, the distribution of it using Bluetooth is slow when the files are big. Finally, current mobile phones include Wi-Fi connection, which allow the creation of applications that allow the upload of content to the server. In order to try our concept we implemented CuentoMovil as a prototype.

5.3.2 Design and Implementation

The concept of the application is that children create short stories which include pictures taken with the camera phone. The stories are written using the virtual keyboard. After the story is created, children can send the story to a webserver through Wi-Fi access. Then, teachers and also students can access (read only) the stories using a web browser from either a laptop or a mobile phone. Figure 23 describes the architecture overview of CuentoMovil.

CuentoMovil consisted in two main components: (1) the component that creates the stories on the mobile phones; and (2) the web page where the stories are available. For the creation of the stories, we take the approach of native programming, in this specific case, we implemented it using JavaME which permit having control over the camera phone of the Nokia devices that we were using during our field studies. In contrast, the webserver was programmed with Servlet and JSP over a Tomcat server.

We discarded the use of SMS/MMS to send short stories, because on one hand the extra costs of sending messages, and on the other hand that teachers dislike the use of SMS with children as reported during the focus group conducted at the beginning of our research (cf. section 4.3.2).

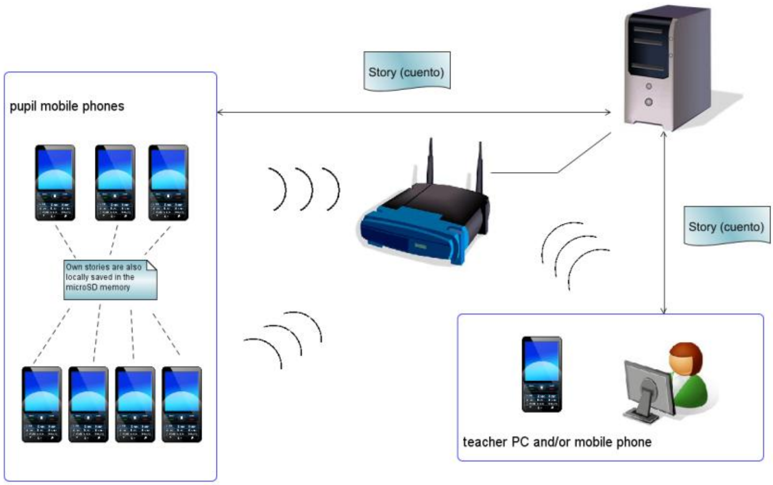


Figure 23. Architecture overview of cuentoMovil

Whereas Bluetooth allows free connection, the interchange is slow and only allows up to seven connections simultaneously. Finally we decided for a web approach, as the phones support WiFi, it is free and allows the access simultaneously to the web page. Because of the difficult to a real Internet connection, the initial implementation was made for a local network.

Although the concept was initially thought for written stories in Spanish or English lectures, however in the field study (cf. section 6.1.3), it was extended to other subjects. Thus children can write short text or stories in other subjects, or free stories. Figure 24 presents a screenshot of the CuentoMovil application on the mobile phone.

Figure 24. Story created by a girl about Aquatic Ecosystem in the Nature Science class

CuentoMovil consists of the following main classes: *Student, Teacher, Story, Slide, Image, Text, and Connection*, as shown in Figure 25. The class Student implements the method getIMEI() that recovers the IMEI the telephone of the phone, which is unique and represents the ID of the child who is using the cell phone. The class *Story* represents the story created by the children, which is composed by the class *Slide*, and aggregates the class *Connection*. The class *Slide* is composed by the class *Text* and the class *Image* that represents the text and picture show in the slide or pages of the story. The class *Connection* is in charge of connecting and parses the story to the webserver.

JavaMe does not include an own local library that connects to a DBMS, although there were some third party limited open source database management APIs for JavaME, they were ambiguous. We decided to create a file system manager for access, save and recover stories locally on the handset. The stories are saved in the external microSD card, they are identified by a unique ID, which is the combination of the subject ID that the story it belongs to and a generated increasing number. For our initial implementation it includes five categories: Spanish, English, Social Sciences, Nature Sciences and free Story. Each subject category is a text file that contents the list of the stories, the date of creation of the story, and the text of each page that composes the story. The images related to the same story are saved under a name that combines the subject, the story ID and the page number. The stories ID are registered using a hash table in a text file called *PrimaryKeys*. In order to open a story created previously, the application looks in the *PrimaryKeys* to recover the story ID and the subject ID, then open the subject file corresponding, and recuperate the story that correspond the ID. With these two IDs the application recovers the images corresponding to a specific story.

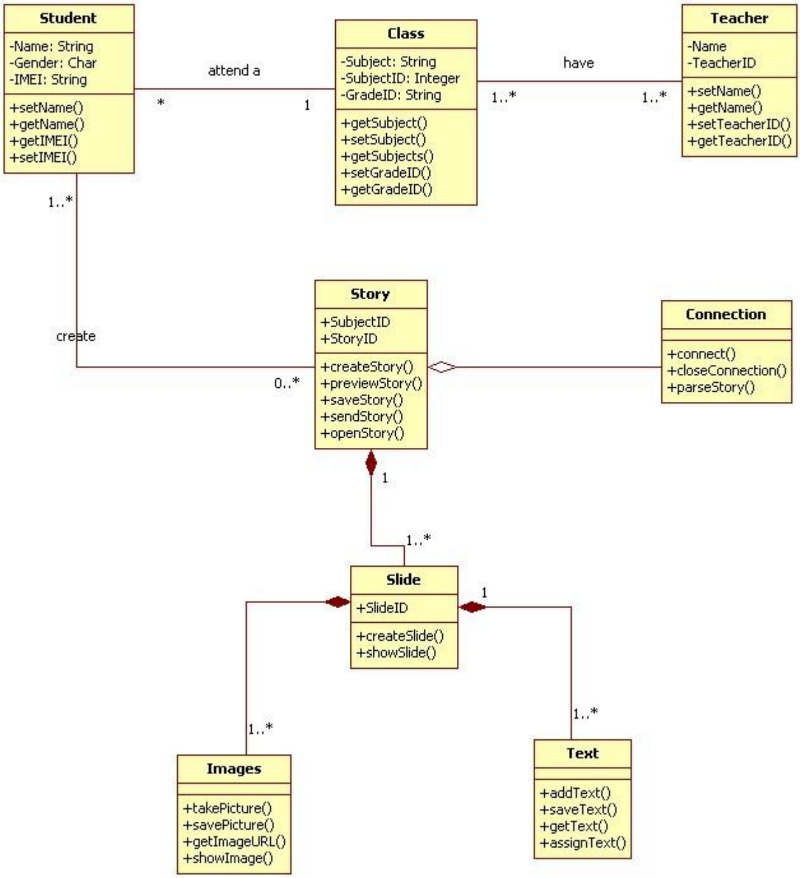


Figure 25. Class Diagram of the CuentoMovil application

The class *Connection* sends a Post request to the server with a string that concatenates IMEI number, with the story information including text and the image as string. The images are transformed to ASCII following the Base64[17] format approach. On the server side, the request is received, processed, and decoding the string. Through the

17 *https://tools.ietf.org/html/rfc4648, last accessed on September 30, 2014.*

IMEI, the story can be saved accordingly in the database to the corresponding students.

The database, called *VirtualClassroom*, is implemented using MySQL. It includes three main entities: *story, slide, student and teacher;* and one associated entity: *subject*. The *Student entity* contents the general information about all the students, like name, grade, a StudentID as primary key, and also their respective IMEI, which is unique. While the *teacher entity* contents the general information about a teacher like name, grade and subject. The *Story entity* contents the information of each story for example, the name, number of pages or slides, the StoryID as primary key, and as foreign key includes the attribute StudentID. In the *slide entity* the data related to each slide or page of the story is recorded. Its attributes are: text of the slide, the URL where the images are saved in the server, the SlideID and the StoryID which the story belongs to. The combination of these two attributes comprises the primary key of the *slide entity*.

The children selected the subject which this story belongs to. Then the child writes the title of the story, states the amount of pages or slides, in our prototype up to 3 pages. After that, the child writes content and takes picture to illustrate each page of the story. Later, the child saves the story in the external memory of their mobile phone. Using CuentoMovil, each student can decide to send the story to the teacher immediately or later. Once the story is received on the webserver, it is saved in the mobislides database. Teachers can search for stories either by subject or by the name of a student accordingly using a computer or the mobile phone. A screenshot of the web application that is accessed by teachers is shown in Figure 26.

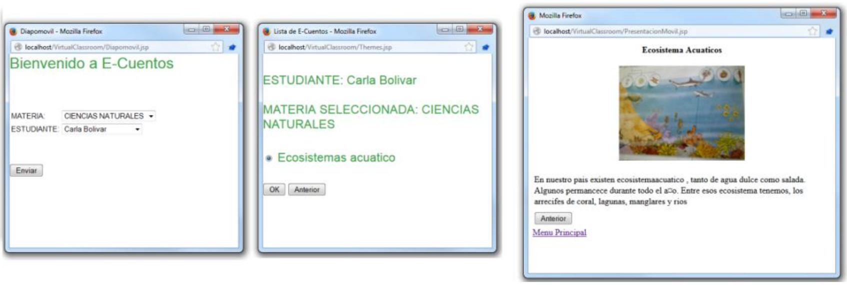


Figure 26. Screenshot of the Web prototype of CuentoMovil. The picture on the left shows the home page where teachers can select the subject and student, in the middle it shows the stories available per student and on the right presents the story

Due the unreliability of the Internet, CuentoMovil was connected to local network using a Linksys WRT54G as wireless access point and a laptop as server. We try once CuentoMovil with the children, after that, during the long field study (cf. section 6.1.3) one teacher used the application three times for creating text and stories (cf. section 8.2.3) In these occasions only the creation of the story was working, because the network setup was dismantled. Although this issue, teacher participants found the tool helpful to support the writing. As it is explained in section 6.2, teachers were free to select what applications and features to use in the classroom.

5.4 Summary

In this chapter three applications developed during our research were described. Our main contribution is the ScreenShootLogger. This is a powerful tool for supporting research, because it gives us both textual and visual insights on how users interact with mobile phones. The tool runs transparent to the user; however it can raise privacy concerns. But during our research, as we worked with the children, parents and teachers like the use of such tools because it also helps to control misuse of the mobile phones. We also presented the prototype CuentoMovil that eases mechanisms to share content among teachers and peers using the web. The writing of stories with text and pictures was utilized as use case for evaluating our concept. Other application presented was MobileMath, that auto generates randomly arithmetic exercises according to the requirements stated by teachers.

Chapter 6

Adoption of Camera Phone and Multimedia Playback for Learning

The use of multimedia in education has been explored widely by researchers and teachers [Collis, 1991; Asthana, 2008; Mishra & Sharma, 2005; Bourgonjon *et al.*, 2010; Kay, 2010; Zhang D., *et al.* 2006]. Multimedia –including computer and other ICTs– can support and enhance the learning [Zhang D., *et al.* 2006; Collis, 1991]. Nonetheless, the role of a teacher is crucial in the impact multimedia can have for the children´s learning [Collis, 1991]: Teachers know the content, the context, and their students. Therefore, they are who better can decide how to integrate technology and multimedia in their teaching.

Therefore, we conducted three field studies in order to know the way teachers integrate multimedia phones in the daily teaching activities. This chapter reports mainly the findings with respect to the playback of multimedia of the mobile phones in classroom by children as a result of learning activities designed by teachers in a set of field studies realized in public schools in Panama.

This chapter is based on the following publication:

[Valderrama Bahamondez, 2011a] Valderrama Bahamondez, E., Winkler, C., & Schmidt, A. (2011). Utilizing Multimedia Capabilities of Mobile Phones to Support Teaching in Schools in Rural Panama. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '11),* 935-944, ACM. DOI: http://dx.doi.org/10.1145/1978942.1979081

6.1 Description of the Field Studies

We conducted two sets of field studies in order to explore the design space of using mobile phones inside the classroom that fit with the local educational curriculum and teachers' needs. In detail we want to answer the following research questions:

- *How can multimedia capable mobile phones be used for learning in real classroom settings?*
- *How do teachers and students embrace the use of mobile phones to support common learning tasks in-situ?*
- *How do teachers integrate mobile phones into their daily teaching plan?*

The first field study was a short field study and it had a duration of two working weeks. During this study children only use the mobile phones at school. It was conducted in two elementary schools: one school was a multigrade school, while the other school was a double-shift school. The second field study was a long field study and it was conducted in the double-shift school. In this study children used mobile phones at school and at home.

6.1.1 Study 1: Short-Term Study in a Multigrade School (School-A)

The user study was realized with students and teachers from 4th, 5th and 6th grade of the school El Retiro. The school is located in the province of Coclé, around 120 kilometers from Panama City. The school El Retiro is classified as a rural multigrade school. The school grades are organized as follows: 1st and 2nd grade are together in one classroom; likewise 4th and 5th grade are together. Kindergarten, third, and sixth grade have their own classroom. This class arrangement is made accordingly the number of students by level and the teachers available. The families there have very low income, and live mainly from subsistence agriculture, and as service staff in hotels. Although located in a rural area, the school is one of the few schools privileged with a computer lab with (very slow) Internet access. There was one TV set and a VHS player. In total 80 students attended the school during 2010. Figure 27 shows a view of the school El Retiro.

Figure 27. View of the School El Retiro.

For a better and easier understanding in the reading, we name this school as school-A, and the short-term study realized there as study-1 during the rest of this thesis.

6.1.1.1 Participants

In total 40 (20 girls, 20 boys) and 3 teachers participated in this user study. The mean age of the students was 10.5 years. The students attended 4^{th} to 6^{th} grade, 13 of them attended 6^{th} grade, 13 students attended 5^{th} grade and in 4^{th} grade there were 14 students. The three teachers who take part of the field study were the class teacher of sixth grade, fourth-fifth grade, and their English teacher. Among the 40 children, only 4 stated to have a computer at home, but 39 children stated that someone in the family had a mobile phone. Already 10% of the children participants owned a personal mobile phone. There were 7 children that had never used a mobile phone before. No child had experiences with touch screens before.

With respect to the teachers, 2 teachers owned a computer but all teachers owned a mobile phone integrated with camera and audio player. The teachers stated to have basic knowledge in using the Internet and the MS Office tools (i.e. Word and Power Point).

The schedule in the school was from 8 a.m. to 1:30 p.m., thus five and a half hours. There were two short breaks of 15 minutes. School-hour in multigrade schools is 60 minutes. On average, children used the mobile phone around three to four hours daily, which represents between 54% and 72% of the daily school time.

6.1.1.2 Procedure

We contacted the schoolmaster of the school by email, who was also the teacher of sixth grade. It is common in the multi-grade school, that a teacher of the school at the same time has the role of the principal. The schoolmaster, after getting the allowance of the parents, agreed and allowed us to do the field study in the school.

She introduced us to all the teachers together and we explained the project. From this meeting with the teachers, we decided to conduct the field study to children from 4^{th} to 6^{th}. Teachers stated their concerns to work with lower class because, according to them, children were too young to work properly with the mobile phones; and still many of them have problems with reading and writing. During this meeting we also introduced all the features of the mobile phones to the teachers.

We decided first to introduce the mobile phones in the highest class (grade 6). We then continued to introduce the phones to the next lower grade and so on. The reason for this was that allowed a step-by-step introduction. We anticipated two effects (1) that the younger children would then be eager to try it out if the older children had it first and (2) that older children could help explaining how the phones work and provide additional support. Both expectations were well met and the introduction went without difficulties.

The mobile phones were only used at school; no child can bring it at home, but the two class teachers took the mobile phone at home. Daily the experimenter distributed the mobile phones to the students at the beginning of the first class and collected them at the end of the last class. However children can only use the mobile phones when teachers wanted that they work with them for the realization of a learning activity.

The short-term study took part the first two weeks of September 2010, but it ran for exactly 9 days, because one day in between there was school free day. The experimenter was present in the classroom, eight from the nine days of the duration of the field studies. In case, a teacher needed to install e.g. audio or short videos, the experimenter installed it on all the phones the night before. The memory SD card was empty every day. During the first week, one phone got lost; therefore we had to change one phone.

6.1.2 Study-2: Short-Term Study in a Double-Shift School (School-B)

A second short-term study was conducted in the school Angelina M. de Tirones, located in the district of Rio Hato, province of Cocle. Rio Hato is an average village in the Panamanian countryside. The inhabitants are mainly working as fishermen or service staff (e.g., in hotels) and have a low income.

Although located in a rather rural area, the primary school Angelina M. de Tirones is still classified as an urban school. It has about 1200 pupils from grade one to six as well as kindergarten classes. In order to accommodate all pupils, classes are offered in two school shifts: The morning shift last from 7:00 am to noon (12:00 pm) while the afternoon shift lasts from 12:30 pm to 5:30 pm. Kindergarten, fourth and sixth grade attend in the morning shift, while pre-kindergarten, second and third grade attend the afternoon shift.

With respect to technology, the school owns a TV set, a DVD player and a computer lab and one video projector. The school has access to the Internet through a portable Internet connection via satellite that is shared via WiFi. However, the signal quality of the satellite link only allows for Internet connectivity when set up near to the computer lab, in the front schoolyard or at the director's office.

For a better and easier understanding in the reading, we name this school as school-B and the short-term study realized there as study-2 during the rest of this thesis.

6.1.2.1 Participants

We conducted the field study with two fifth class groups who attended the afternoon shift. There were 42 children (23 girls, 19 boys). The mean age of the students was 11.05 years. The participating teachers were the two respective grade teachers of these classes as well as the English teacher. All the teachers were female.

Only 11 children stated to have a computer at home, and 40 children said a family member had a mobile phone at home. Already 23 students owned a mobile phone. There were 7 children that had never used a mobile phone before. Similar to the participants of our study-1, no child of the study-2 had experience with touch screens before.

With respect to the teachers, only one teacher owns a computer, but all the three have a mobile phone. They also have mobile phones integrated with camera and audio player.

Figure 28. View of the School Angelina M. de Tirones.

The morning shift of the school was from 7 a.m. to 12 m., and the afternoon shift was from 12:30 p.m. to 5:30 p.m. A lesson at a non-multigrade school lasts 40 minutes. Thus, the students have seven lessons and one pause of 20 minutes every day. On average, children used the mobile phone around two to three hours daily, which represents between 40% and 60% of daily school time.

6.1.2.2 Procedure

Likewise the study-1, we contacted the schoolmaster by email. After getting the authorization of the parents, the principal introduced us to the two teachers, the Friday before the study started. We gave a mobile phone to each teacher in order to explore the phone. We met the English teacher when we started the experiment.

According to the functions children needed to know for the realization of a learning task, they were introduced to student and the teacher at the same time. However, as both groups were in the same class –5th grade–, all children were trained in using the multimedia phone simultaneously. The access to the Internet was not explored neither introduced because there was no wireless Internet connection.

In the case of the short studies (section 6.1.1 and section 6.1.2) the mobile phones were only used by the students in school and were not taken home in order to minimize the risk of theft or mugging. The mobile phones were delivered daily at the beginning and returned at the end of each class when the teacher planned to involve cell phones in the learning activity. Similar to the study-1, in case required by teacher, the experimenter installed any short video or other digital material, the night before students need it.

Like study-1, in order to introduce the use of mobile phones to students, to help when required and to observe the development of the field study, we stayed in the classroom. The study took part the first two weeks of October, 2010, and lasted exactly 10 days.

6.1.3 Study - 3: Double-Shift School - Long Term study

In 2012, we conducted a follow up field study that was designed similarly to the short term field studies, but with two variations: (1) children were allowed to take home the mobile phones; and (2) the study was designed as a long-term study of about seven months compared to the two weeks of the short term study. As children were allowed to take home their mobile phones, we also explored the adoption of the use of the mobile phones outside the school environment.

The field study was conducted at Angelina M. de Tirones School, which is the school-B described previously (cf. section 6.1.2). In order to facilitate reading along the thesis, we name this long-term study as study-3.

6.1.3.1 Participants

Two sixth grade classes (6th A and 6th C) from the School Angelina M. de Tirones (school B) together with their grade teachers participate in the study-3.

The students and teachers who participate in study-3 were different to those who take part in the study-2. In total 53 children participated in the field study (28 boys and 25 girls). The students were between 11 and 15 years and with an average of 11.6 years. 17 children had access to a computer at home with Internet access and 8 without Internet access. Almost all children's households had at least one mobile phone: 52 students reported that their family owns at least one mobile phone, from them 24 touchscreen mobile phones. Moreover, only 9 children had never used a mobile phone before but half of them (26 children) reported to own a mobile phone. One male and one female teacher participated in the study-3.The children attended the morning shift of the school-B, thus is from 7 a.m. to noon.

When we started the study, only the female teacher had a computer, but later the male teacher also bought a laptop[18]. Both teachers had mobile phones, but the male teacher had a simple phone with no camera or audio player integrated.

6.1.3.2 Procedure

During the setup phase of our study, the new schoolmaster of the school-2 had been contacted via e-mail in order to get the permission to conduct the study at his school. Once the permission had been received, the schoolmaster introduced the experimenter to the corresponding class teacher and class. Being in class, the phones were presented to the students. First, the phones were only handed out for in-school use, but only during times when the teacher requested to use the phones. The pupils were allowed to explore every feature of their phone. However, they were warned to properly use the phone. An explanation was given to the children that the logging application allows us to post-hoc see any activity on the phone, and that inadequate behavior and use will thereby be revealed to and prosecuted by teachers and parents. Within the first days of the study, a meeting was held with the schoolmaster and all parents. During this meeting, the purpose and procedure (including the logging application and process) of the project were presented to the parents. An explanatory letter about the project was handed out to the parents, which also contained a consent form that – once signed – allowed the pupils to participate in the project.

Each teacher used different approach of using mobile phones in class. The female teacher of the first class (6^{th} A) distributed the mobile phones only during the times when children should work with them to solve an assignment, and collected them again when the task was over. She only allowed taking the phones home when homework involved using the device. Instead, the other

[18] *The Ministry of Education offers to their teachers computer for an affordable price (200 USD).*

teacher of class 6^{th} C distributed them among the students, and allowed to carry them always with them. At school, the children only used mobile phones when requested to complete a suitable learning activity.

Once the consent form had been signed, the children were allowed and encourage also carrying and using their phones outside of the school during their spare time. During their spare time, the children were allowed to use their phones for any purpose. The features of the mobile phones were introduced to teacher and children simultaneously. Besides the general introduction of the phones, certain features of the phones were explained throughout the course of the study: On the first day, when the phones were initially handed out to the students, the video and photo recording and playback functionalities were shown and discussed. After two weeks, the Paintpad application (which had been installed before) was introduced. The experimenter in class demonstrated another week later how the pupils can connect phones and sharing objects via Bluetooth. Using the Internet was not explicitly explained nor did the phones come with a SIM card. However, it was discovered by children themselves who then show it to their teachers.

Throughout the study, technical issues were solved both via e-mail contact between experimenter and teacher or by the experimenter visiting the school and fixing problems in situ. Initially, the study was only planned from May to July but was extended due to the positive experiences teachers and pupils had during the first two months. The study started in May 2012 and ended 7 months later in November 2012. As the size of the SD cards limited the storage of screenshots, the SD cards and phones had to be collected four times throughout the study. It took about one week each time to empty the SD cards. Also, the Panamanian vacation schedule contains quite a few holidays that resulted in phones being only used at home or on vacation during these times. Holidays were from June 4, 2012 to June 10, 2012 and from September 10, 2012 to September 16, 2012. Additionally, November is traditionally a month with many holidays, extra activities and celebrations outside of the ordinary school life. All together, the phones were used for 20 weeks, including 16 weeks with school days. In November, the experimenter collected all phones. Besides four SD cards (damaged or lost), all phones were returned without a single phone being lost.

6.1.4 Apparatus and Methodology

In order to investigate our research goals, we provided with touchscreen phones (Nokia 5530 Xpress Music1) to all students of the selected class as well as to the teacher. The phones were provided by Nokia for the duration of each of the different studies conducted (study-1, study-2, and study-3). This mobile phone´s model was selected because it includes robust and rich multimedia and communication features. This type of mobile touchscreen phones comprises amongst other (general) phone features an integrated video camera, music player functions, and a voice recorder. In Panama, a modern mobile phone is a status symbol similar to most places around the world, (retail price in the US in 2010 about 150 USD) of these mid-range phones is in this region significant (a phone represents 60% of a typical monthly salary in both communities El Retiro and Rio Hato).

We did not install any customized learning application on the devices. Instead, we added two general applications to complement to the default features and software set of the selected phone model: PaintPad[19] and Sticky Notes Touch[20]. PaintPad application allows drawing and painting from blank as well as painting on saved images. StickyNotes Touch application instead simulates a post-it pinboard where users can pin hand-written messages. However, the StickyNotes Touch application was not used during the study-3. For camera, video, and audio functions only those functions integrated with the mobile phone have been used.

On each handset a logging and screenshot application was installed in order to have a better insight in how the children use the mobile phone. This application includes a screenshot application, which automatically takes a screen shot of the active screen every 20 seconds while the phone is in use. The screenshots are then stored on a SD card. Similar to the screenshots, the logging application also creates log files containing time stamps and the currently active applications in order to continuously log the use of the phone. Each time a new application is started, a new log file entry is generated. Besides allowing a detailed analysis of the phone usage of every pupil, a second goal of the application was to prevent inappropriate use, which could have been revealed by looking at the screenshots. For a further description about the implementation of the logger application see section 5.1 of this thesis.

[19] *http://store.ovi.com/content/2623, last accessed on September 30, 2014.*

[20] *http://www.offscr.com/en/utilities/index.html, http://store.ovi.com/content/14200, last accessed on September 30, 2014.*

Besides the information we extracted from the logger file, we realized two surveys (one before and one after each study), a final group interview, and a daily observation of students' interaction with the mobile phone (study-1 and study-2). In the first survey, we asked children and teachers about their expectations on how to use a multimedia mobile phone for learning. At the end of each study, all participants filled in a post study questionnaire about their feedback and opinion of the study. Additionally, we interviewed all the children to discuss about their learning experience during the study. We also met some parents to get their opinion about the use of mobile phones to support learning. In the case of the study-3, the observation was done not daily but at random days, e.g., once a week or every two weeks.

During the short-term study-1 and study-2 (section 6.1.1 and section 6.1.2), we gave a general overview of the multimedia capabilities of the mobile phones to all teachers of the school on the first day. With respect to phone capabilities, we studied four main multimedia features: *(1) taking a picture and recording a video, (2) watching a video, (3) recording voice and listen to it, and (4) painting and writing with the stylus.*

6.2 Learning Tasks Designed by Teachers

We asked teachers to design tasks that utilize mobile phones as an addition for a traditional task to achieve the learning goals they were supposed to meet during the time the studies were running. Additionally, based on previous findings from our surveys (section 4.2.1), we asked teachers to focus on Mathematics, Spanish, English, and Natural Science. However, teachers were free to add additional subjects where they wanted to use the phones during the study.

Table 13 shows the activities realized with the mobile phones during the field studies. It also presents the frequencies of how often the features of the mobile phone were used. From the table, we can observe that video playback; video recording and working with PaintPad with the photo camera were the three multimedia features involved most in the learning activities designed by teachers, with about 31%, 24% and 16% respectively. The description of the activities realized during the field study including tasks, multimedia features used, and learning content is presented in Appendix C.

Table 13. Applications and Features of the Mobile Phone Used during the Field Studies

Learning activities solved by the children using a mobile phone	*Frequency a feature of the mobile phone was used for learning*				
	Total		***Short Field Study***		***Long Field Study -3***
	n	***%***	***Study -1***	***Study-2***	
Playback learning videos	**21**	**31%**	**8**	**6**	**7**
Record video files	**16**	**24%**	**5**	**2**	**9**
Listen to audio files	**4**	**6%**	**3**	**1**	**0**
Record audio files	**2**	**3%**	**1**	**1**	**0**
Take picture only	**3**	**4%**	**1**	**1**	**1**
Work with PaintPad together with photo camera	**11**	**16%**	**5**	**2**	**4**
Use Sticky Notes Touch	**3**	**4%**	**1**	**2**	**0**
Look up information on the Internet (e.g., Google, Wikipedia)	**5**	**7%**	**1**	**0**	**4**
Only using PaintPad	**2**	**3%**	**1**	**0**	**1**

6.3 Playback Videos in Classroom

The activity of watching learning videos was realized for different subjects: Mathematics, Spanish, and Nature Sciences, as described in Appendix 1. Because of the considerable size of the videos (between 3 and 142 MB) they were mainly installed on the students' phones before class.

In both schools, all teachers used the observation of the video to introduce a new topic, following the same pattern:

- *students observed the video several times;*
- *after that the teachers reinforced the concept with explanations and discussions with the students;*
- *the students saw the video one more time,*
- *at the end, the teacher conducted other activities to extend and reinforce the topic either with or without the mobile phones.*

Teachers and students considered watching educational videos the most useful feature for learning. This thinking is reflected as in 31% of the learning activities, teachers included the playback of an educational video (cf. Table 13).

Children and teachers stated that watching videos helped students in understanding the class. One teacher said "*it (the video) can help the student to learn easier through repetitions"*. Another teacher added "*when the students see the video three or four times, they have almost learned the lesson."* The children also welcomed the use of watching videos, as one student commented to us: *"(videos) explained (the lesson) better."*

6.3.1 Sources Type of the Learning Videos

The learning videos used in the study had a relative short duration. They lasted between 1:10 and 9:38 minutes. These learning videos were either: *online videos, pre-downloaded videos and self-made videos*. Videos recorded by students as part of learning activities are not considered under this classification.

- *Online videos:* children observed a video that was directly streamed from online sources like YouTube. However the Internet connection was so slow that this form of watching video was tried only once in the study-1 and the study-3. In the case of the study-2 this approach was not tried at all.

- *Pre-downloaded videos*: as online videos did not work, later we replaced by the option of download, save and install on children's phones the day before the lesson. The teacher searched for educational videos on YouTube by using a desktop computer. Once videos had been found, they were downloaded and installed on the devices.

- *Self-made videos:* one teacher created his/her own video. Three teachers requested an external Math teacher the creation of educational videos in different topics in the subject of Mathematics like measuring an area using the International System of Units, fractions and integers (cf. Appendix C).

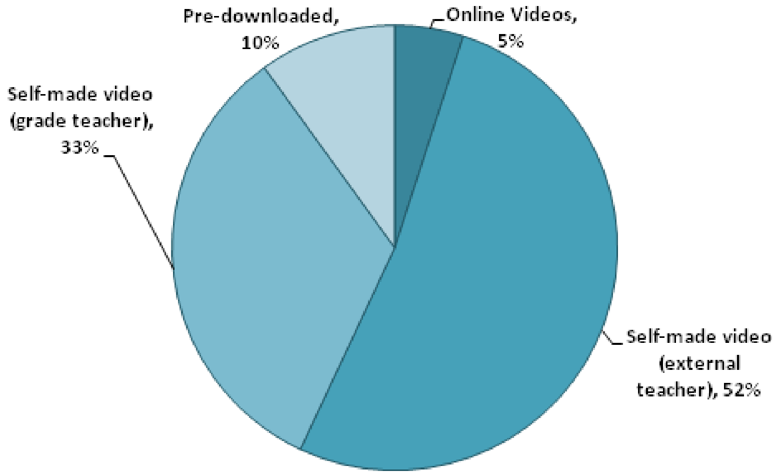


Figure 29. Source of the Educational Videos Watched by Students in the Schools.

In total children watched 21 learning videos. Most of the educational videos watched, as shown in Figure 29, were made by an external teacher (11 videos) on request of the grade teacher. Only one video was self- made by one teacher who participated in the study-2, and 7 videos were pre-downloaded. Lack of time was mentioned as the main reason of no creating their home made learning videos. Approximately one third of the learning videos were downloaded or streamed from YouTube.

6.3.2 Content of the Videos Watched

Most of the videos were played in Mathematics. 14 of 21 videos watched (67%) of the videos played were in the area of Mathematics. Mathematics seems to be complex in Panama, both to teach and to learn. Elementary school teachers in Panama have no specialization in any specific subject of the educational curriculum, but have a general background in all the subjects. This might be a reason why 79% of the videos in Mathematics were produced by an external Math teacher on request of the grade teacher.

During the observation of videos, students were fully concentrated and most of them played the videos longer and more often than required while waiting for peers to finish. On average each learning video was seen 3.5 times.

In standard class situations, children are often distracted and miss part of all of the teachers' explanations and the lesson. Children are often too shy to ask the teacher to clarify on open questions. When watching lessons from video, students can easily repeat those parts of the video that they missed or did not understand.

None of the three English teachers who participated in our field studies included in any activities with video playback. They rather preferred audio playback (cf. section 6.5). However, filming English presentations given by the students was common during the short-term study-1 (cf. section 6.1.1) and the long-term study-3 (cf. section 6.1.3).

6.3.3 Students Preferences in Playback Educational Videos

At the end of the long-term study-3, we asked the 53 children in which device they prefer to observe learning videos, the computer screen or the mobile phones. Figure 30 shows the results of this question.

The small screen size of the mobile phones seems to not be that relevant for most children when watching educational videos. From the 53 students who answered, 38 students stated that they would prefer to see the videos on mobile phones, 11 on computer and 4 showed no real preference. No difference was perceived between male and female.

We also asked children about the reason of their choice for playing videos on the mobile phones. Most students found it easier to play videos on mobile phones than on a computer. *"The videos are easier to find", "on PC I forget where to find the videos", "I can find the videos faster", "on the mobile phone I just press a button",* and *"I found videos easier here [on the mobile phone] than on the PC"* were some of the comments given by the students.

The freedom of replaying a learning video was the second reason given by participants to prefer play videos on mobile phones as is: *"I can see the video as long as I want", "I can replay a video until I understand the subject", "I can watch the video again the other day",* and *"I can see the video without time pressure".*

Mobility was another reason why children preferred to watch videos on the mobile phones rather than on a computer: *"I can see a video at anyplace I am, in* *contrast to PCs [that] are difficult to transport"* and *"It is easier to carry with me"*.

Children consider that they have learnt more by watching videos on mobile phones compared to computers: *"[it] helps me to memorize", "I can concentrate more", "I can learn more"*.

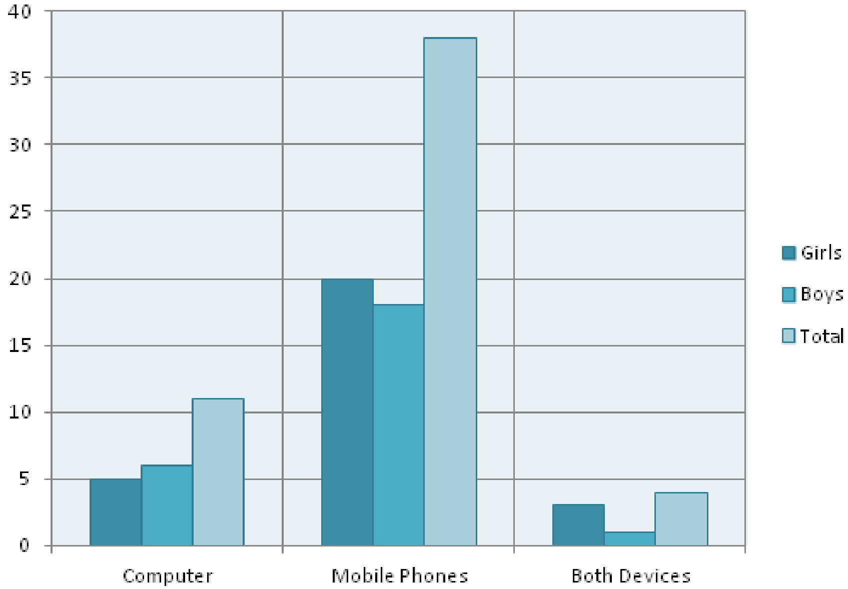


Figure 30. Viewing Preferences for Educational Videos with regard to Playback Locations and by Gender: (1) on Computer, (2) on Mobile Phones, and (3) on Both.

Approximately 64% of those students who preferred to play educational videos on a computer than on the mobile phone have access to a computer at home. A big screen on the PC was indicated as their preference for playback videos on computers: *"I can see the video bigger and clearer"*. Among those who showed no preference clarify that in both medium they can do the task: "*I learn the same"* and *"I am doing the same thing"*.

6.4 Filming Learning Videos by Children

In contrast to watching pre-recorded videos, filming videos was used by teachers to extend, review, and reinforce a topic. Teachers implemented different approaches on how children should record the videos. Debate, dramatization, speech, and dialog were common activities which teachers used to help students to learn the concept. Teachers stated that using the video camera enhances the motivation and involvement of students to do these tasks. As one teacher of 5th grade of the study-2 shared to us "*M. never wanted to act or give a speech in front of the class, but now he is my first volunteer to participate in… He likes to be in front of the camera*". Students were highly motivated with filming as they did not stop before every group member was satisfied with the result. Repeating the film-takes could as well help students to indirectly learn the teaching content.

Filming videos was one of the most preferred activities and students found it simple to use: *"for me it is very easy… I only need to press a button and I start filming"*.

In almost all cases, teachers assigned the same topic to each group or to each child depending on the case. Students filmed individually as well as in small groups. Overall, the children filmed videos for the subjects of Mathematics, English, Spanish, Social Sciences, and Nature Sciences. In total, 16 educational videos were filmed by the students during the field studies. This number only reflects the videos filmed as part of the learning activity as described in Table 13. Multiple takes of the same video were considered as one video.

During the long field study (study-3) children and teachers used the mobile phones for recording *extracurricular activities* realized in the school. One example is a film about the activities realized during the "Values week". In one activity students of the 6th grade worked in groups, created a poster (using cardboard), and explained it to the students of the 1st grade about values. One member of the group filmed the presentation. For the other activity, students used the mobile phone to take pictures during the "Cleanup Day" where children and teachers cleaned the school. The goal was to create a video with the pictures taken to present in a local contest. For the creation of the video, photos and short videos were combined on a PC. This activity could not fully be finished with the mobile phone. The creation of the video was done by pictures taken by students. We do not consider these videos as part of the learning activities videos, therefore they are not included in the 16 videos analyzed in this section.

6.4.1 Film Shooting Approaches by Children

The children used three approaches to film depending if children filmed individual or in group: (1) *individual shooting*, (2) *group recording*, and (3) *collaborative filming*.

- *Individual Shooting* is when children filmed individuals to create their own video. In this kind of videos children describe or report something. The student acts like a cameraperson and in seldom cases appears in the video.

- *Group recording* are videos where all children filmed individually but did so simultaneously and recording the same content. The goal of the children was filming a lively presentation of peers and teacher.
- Figure *31* shows an example of such a group recording.

Figure 31. Example of a Group Shooting. In this example all the class including the teacher filmed the dramatization played by students in front.

- For *Collaborative filming*, children worked in small groups between 2 and 4 students for the creation of a video. Within this category, we could observe two variations. One is when children played a role while another child of the team filmed them. The other one is when children work in pairs, where one acts as cameraperson and the other child is the one who describes the task or topic. This category also includes those videos that were made at home when someone of the family filmed the student describing or explaining a topic.

There were 16 educational videos recorded by children as learning tasks. This number also includes five videos recorded during the holidays that were presented and discussed in class (cf. 6.4.4 section). In general, we did not observe a trend toward a specific shooting approach. Collaborative and group shooting were slightly preferred to individual shooting, as shown in Figure 32. In a further analysis by school, we observe that in study-1 collaborative shooting was preferred (67%); while in the study-2 collaborative and group shooting were equally preferred (50%); whereas in the study-3 group and individual filming were preferred (40%).

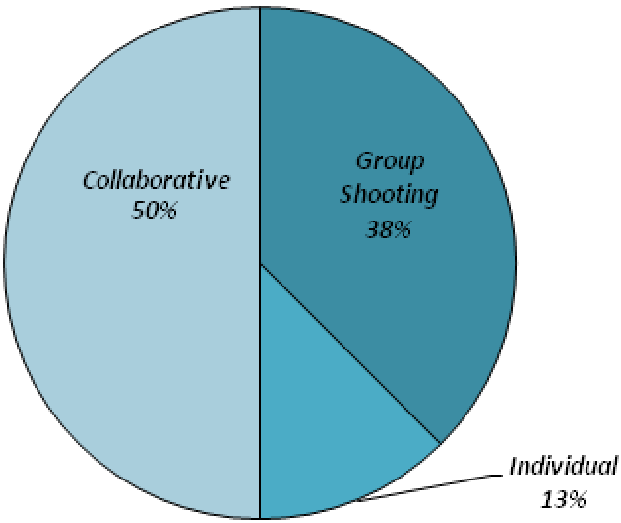


Figure 32. Shooting Approaches Implemented by Teachers in Percentage.

6 4.2. Type of Video Filmed by Students

We grouped the videos content students filmed in the learning activities as *children performing, reporting, lecture, outdoor experience, verbal presentation, and solving* tasks. Figure 33 shows examples of videos recorded by the students.

- We call Performing when the students play a role in front of the camera. Examples of this category are when children played dramatization, debated, played talk shows or recited a poem. The children's performance was recorded immediately or also in case of a collaborative video after more than one trial. This approach was implemented in the courses of Spanish, Social and Nature Sciences (see Appendix C). Figure 33 (a) shows an example of a video where children performed a dramatization.

- Children shared some of their outdoor experience when visiting other places, like a Zoo, Panama City, the beach, or other provinces during their vacations. In section 6.4.4 we deepen this experience. These videos were only recorded during the long field study. A screenshot of a visit to a ZOO by a student is presented in Figure 33 (b).

- We called it verbal presentation when children had given presentations in front of the class using cardboard. This practice was done for English and Nature Science. Children gave their presentation individually or in a group. They usually used a cardboard with an image to support their speech. Figure 33 (c) shows a girl giving a presentation about her family in English.

- We called it lecture when children simply filmed their teacher giving an explanation inside the classroom. Figure 33 (d) presents a child filming his teacher's explanation in the class.

- Solving tasks are tasks that children solve from e.g., book exercises, conceptual maps, or math exercises. They filmed directly from their books or notebooks. Children filmed either individually or in groups of two. Figure 33 (e) shows a screenshot of a video filmed when solving a task from a book.

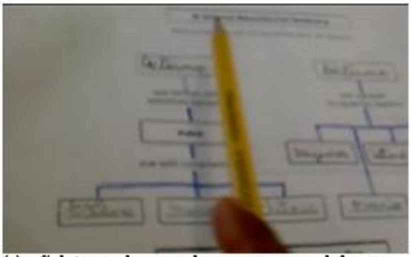
- A *reportage* is a video where children present and explain a topic. It can be filmed inside or outside of the classroom. Figure 33 (f) shows a screenshot of a child explaining the papaya tree.

(a) *Children Performance: children perform a dramatization in Spanish class*

(b) *Outdoor experiences: a child records his visit to the Zoo during his holidays*

(c) *Verbal presentation: a girl gives a speech in English class*

(d) *Lecture: a child films the explanation of the teacher.*



(e) *Solving tasks: a student answers a task from a book in Biology.*

(f) *Documentary: a student explains about the reproduction of the plants in the class of Ecology.*

Figure 33. Screenshots of Videos Recorded by Students during the Field Studies.

Without considering the outdoor visits and the extracurricular videos taken, we did not observe a strong tendency towards one specific type of video. Videos where children acted, presented a documentary, filmed their teachers' explanation and gave a verbal presentation comprised 87% of the total videos created by children as part of a learning activity, the other 13% were the videos filmed when children solved a task from a book or exercise. Table 14 presents the types of video created by school and study.

Table 14. Content of the Video Filmed according to the School and Field Study.

STUDY / SCHOOL	TYPE OF VIDEO					
	Children Acting	Documentary	Verbal Presentation	Teacher Explication	Solving tasks	Outdoor Visit*
Study-1 / School-A	2	2	2	0	0	0
Study-2 / School-B	2	0	0	0	0	0
Study-3 / School-B	0	2	1	3	2	5

**These videos are not considered as a learning task listed in table 13.*

6.4.3 Film Settings

Filming in teams collaboratively and simultaneously was not suitable inside the classroom. There are children that speak louder than others. For instance, dialogs from one shooting team group can be captured by the other shooting group and overlap the own voice of the latter group. This issue influenced the shooting approaches adopted by teachers in the schools.

The infrastructure of the school building played a role in the approach taken by teachers for shooting. In the school-A (study-1), four over the five videos made by the students were filmed outside the classroom. The school had a big yard and two available rooms where children could take of their videos. Instead, in the school-B (study-2 and study-3) no child filmed a video outside of the classroom. This school only had a small yard and no other room was available.

Throughout the long-term study-3, we observed that filming the teachers' explanation was a common approach. In a similar way, group shootings were favored over collaborative filming. This is a variation with respect to both short-term studies, where children acting videos were preferred. However in the multigrade school (school-A) the collaborative shooting was done simultaneously, and in the double-shift school (school-B) was done sequentially. For instance, in one learning task that involved filming a video collaborative (Appendix C.2), in the study-2, it was done by every team sequentially. First one group presents the topic playing a debate in front of the class, and one member of the team filmed the panel. After the first team finished, the next group presented, and one member of their team filmed the debate. Successively, the other teams followed, until the last team had presented. In contrast, in the study-1 (school-A), each group filmed the debate simultaneously.

6.4.4 Impressions from the Holidays

During the long field studies (study 3, section 6.1.3), there was a school break of one week, after four weeks of using the mobile phone. Both teachers from the 6^{th} grade of study-3 allowed 6 children to take the mobile phone with them during their vacation. The rest of the mobile phones were collected in order to empty their memory cards. The task was that they film and/or take photos what they do during this school vacation. In total, 19 videos were filmed and 31 pictures were taken by students. Some children only recorded their daily life routine like, playing with their friends in the playground; others filmed the travel they did and one girl filmed herself singing. The places where children recorded videos were the Panama Canal, the beach, the travel to the province of Chiriqui, the Zoo, and even one girl visited San Jose in Costa Rica.

When back at school, the videos made during the holidays were presented to the rest of the class. With the help of one student, who brought her aunts' laptop, and by using the school's projector, some of the videos and pictures taken during the school break were presented to the rest of the classroom. The teachers together with one student operated the projector, while the student who brought the laptop helped the teacher and her classmates to download the files to the computer.

Sharing holiday memories at school enriched the experience for the students, since many of them had not yet visited Panama City with its Panama Canal, and no child had traveled outside Panama. The videos and photos of the different places visited raised curiosity and questions of the children. For instance, questions about the Panama Canal like "*how many ships pass through the Panama Canal per day?", "why the ship moves so slowly in the Canal?"* or about San Jose, Costa Rica "*what is a national theater?*", *"what is a Central*

Bank?" (Panama does not have one since we use USD) "*Do we have Museums in Cocle?*" were among the questions the students asked.

6.4.5 Students and Verbal Presentation

During the study-3 we asked the children about their preference for verbal presentations in case they can choose between an instant presentation in the classroom and a pre-recorded video presentation that has been recorded at home. In addition, we asked to explain their reason about their choice.

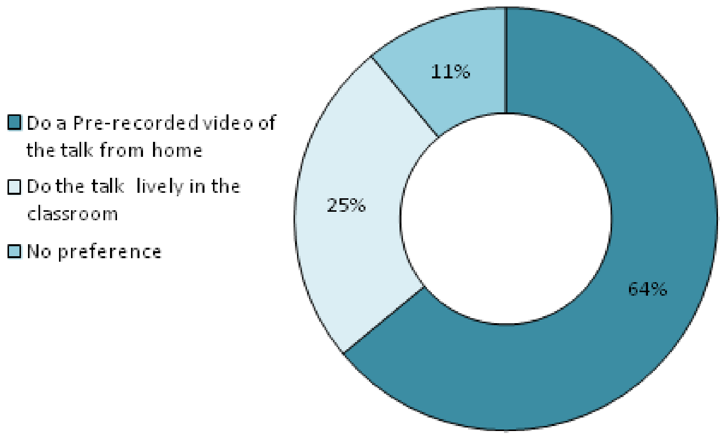


Figure 34. Preferences of the Students when Giving Presentations Pre-Recorded at Home or Lively in the Classroom.

Most of the students, (64%), said that they prefer to bring the presentation pre-recorded from home. About one fourth of students said that they would prefer to do it live at school. 11% had no preference. Figure 34 shows these preferences. There was statistically no significance among boys and girls. Shyness and nervousness to talk in front of classmates, can repeat the presentation, and take advantage of new technologies were the reasons stated by the children to prefer to bring their presentation from home. Among the reasons listed by the students who preferred to present directly in front of their colleagues were to show braveness to the classmates and the teacher can confirm that he/she learns/does the task.

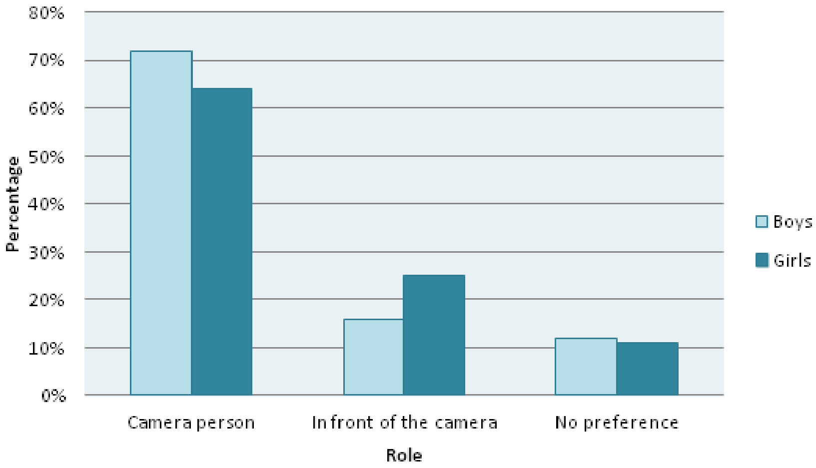


Figure 35. Roles Preferred when Filming by Gender.

With respect to the role students like to take when filming, we found out that most children (68%) preferred to be a cameraperson, 21% preferred to be in front of the camera and 11% showed no preference. In Figure 35 we can observe that boys and girls showed a similar trend. However, comparing among genders, the percentage of boys that like to be a cameraperson is 8% higher than in the case of girls. The percentage of girls who like to be in front of the camera is 9% higher than their male peers.

6.5 Recording and Playing Audio

Teachers used recording and playing audio especially in English (see Figure 36), but also in Mathematics (Appendix C.1). Students found this feature to be very practical for improving the pronunciation in English and welcomed it more than we expected: *"I can hear me and correct pronunciation errors"* a student said. Teachers stated that when children record their own voice when reading and later replayed it, supported: *(1) the self- evaluation and self-critical spirit of the students, both important aspects for the teaching-learning process;* and *(2) the improvement for pronunciation and listening to English.*

Figure 36. Children Recording and Playing Audio Using a Multimedia Phone. A student recording his voice in the English lesson in the yard of the multigrade school (left). Students from the double-shift school during the short field study listening to the voice recorded of their English teacher (right)

In our pre-study questionnaire, half of the 5th grade children (study-1), answered that they imagine mobile phones to be helpful for learning multiplication tables. In contrast, they do not think that with pictures, games or text as we imagined, but with the voice.

Teachers stated that with the cell phone they can record the multiplication table talking or singing, and children can listen repetitively. From our observation and talks with teachers, we think that there are two reasons for this preference:

(1). The usual technique at school for learning the multiplication table is iterative listening and repeating in choir (auditive memory)

(2). Different to lower grades where students who learn the concept of multiplication, fifth grade students already know this concept. The requirement for visualizing when learning the multiplication table is lower.

6.6 Summary and Discussion

Our studies revealed that teachers are able and willing to create tasks that fit to the phones available. We noticed how well mobile phones could be utilized in lessons and how their features truly support teaching. The learning activities designed reflect the individual teaching style of the teachers.

In the field studies, we realized that standard video and audio capabilities of the mobile phones, that are limited on a traditional PC, were considered among the most useful functions for supporting learning because both allow children to create and to replay content. Photo and video camera are better integrated in mobile phones than desktop computers. Therefore using a mobile phone for taking pictures or filming a short video is more appropriate than using a computer. In addition, the mobility of mobile phones offers a further advantage to traditional desktop computers –which are the usual devices and in the computer labs at schools.

Primed by having computer labs in their schools, teachers were concerned about managing the phones and the infrastructure and teaching the children on how to use them. With traditional PCs, this is in many schools the central issue. Here, we see an interesting advantage of mobile phones. In the field study we could observe that children learned very fast using the new device after a short introduction. As the children used the phones as a personal device (each child had one phone) while in school, they felt ownership and also had the opportunity to explore on their own speed. Playback learning videos on a video player in a classroom is a 1:n model (a single screen shared by all the students); and playing it on computers in school in the best case a 1:2 model (a single shared by 2 students). When using mobile phones for play back learning videos, we have a 1:1 relationship (each child has his/her own screen). A child can replay, forward and pause a video on the mobile phone according to his/her own pace until he/she understands the content without disturbing anyone. Instead, playing videos on other media is restricted to the teacher’s decision or peer consensus. If the child is shy, he/she probably will hesitate to request playing a video again, even if she/he did not understand the video when played once. Both children and teachers stated that watching educational videos helps to understand new concepts better and faster.

Although children can take the phone home along the long study, they did not film at home as many videos (as part of a learning activity) as we expected. It seems to be that teachers (as discussed in section 4.3) preferred children to use the mobile phones at school, where they can supervise them. Differently, with respect to playing back videos children watched them both at home and at school.

The home-made videos created by teachers reflected the way they usually teach, especially in Mathematics (see section 6.3.2). The teacher explains the concept on the video in the same way as when they would explain using the blackboard.

This approach was easier to implement because the teachers are familiar with it. However, teachers downloaded learning videos more often than they created their own ones. Despite the fact that teachers expressed that filming was not a complex task, only one video was made by one of the grade teachers. This reflects the difficulties of self-filming when giving a lecture, a task by a default mobile phone is not fully suitable as observed in figure 71. This issue will be discussed further in section 10.2.3.

In addition, teachers mentioned the lack of time as another important factor that discourages them to film their own videos. We were witnesses of that, in both schools, in addition to attend in average 25 children, teachers have to take part of all school extracurricular tasks, they have to attend mandatory seminars within the scholar year, and some teachers even attend the university. Furthermore in the case of the multigrade school one teacher was at the same time the principal of the school. Continuing their own education it is not unusual among Panamanian teachers; two teachers were following postgraduate studies during the course of the study. They attended classes at night and on Saturdays. In addition, most of educational videos viewed were about Mathematics and most of them were made by external Math (high school) teachers on request of all teachers. It reflected how difficult it is for them to teach Mathematics.

Teachers selected the way children should film based on content and learning goals. But they also considered the school infrastructure as well as the amount of students attending. The multigrade school has a wide yard and a low number of students. Children filmed more in teams. In contrast, in the double-shift school, that has high number of students and lack of free spaces children filmed more individually. Filming in groups inside the classroom was not possible because of the high noise. Nevertheless, filming videos was very versatile from simply filming the explication to the teacher until to simulate talk shows. Students were higher motivated when filming. Behavior of the students and adoption of the mobile phones by students will be further discussed in chapter 8.

Chapter 7

Using the Phone to Work with Documents and Organizing Knowledge

This section is the continuation of the findings from the set of field studies we realized during our field research (cf. section 6.1). Working with documents, e.g., exercises sheets, books, draws, etc., are common and important tasks in daily teaching. In addition, after the topic is introduced to the students, they organize the knowledge through summary techniques like conceptual maps. While in chapter 6 we described how teachers used mobile phones for multimedia recording and playback inside the classroom, in this chapter we describe the adoption of mobile phones for working with documents. Additionally we present a case study comparing the use of mobile phone versus the use of the computer lab to execute a common learning task.

In section 7.3 we describe the results of the subjective feedback and evaluation done by teachers and students about the use of mobile phones for the learning tasks described in section 6.2 and appendix C.

The school, teachers and children participants as well as the study setup are the same as those already described in section 6.1 of this thesis. For evaluating the use of the stylus with the touch screen, third-party software was used, namely PaintPad and Sticky Notes Touch (cf. section 6.1.4).

Part of this chapter is based on the following publication:

[Valderrama Bahamondez, 2011a] Valderrama Bahamondez, E., Winkler, C., & Schmidt, A. (2011). Utilizing Multimedia Capabilities of Mobile Phones to Support Teaching in Schools in Rural Panama. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '11),* 935-944, ACM. DOI: http://dx.doi.org/10.1145/1978942.1979081

7.1 Hybrid Interaction: Enhancing Printed Books through Digital Input

Filling in forms and complete exercises from books are common tasks in schools. Books are only lent to children, thus they are not allowed to write into them. So either students handwrite the exercise or pay to receive a copy of the exercise. What happens often is that children take too much time writing the exercise and have too little time to answer the exercise itself.

During the field studies one activity proposed from teachers was to take a picture of a task in the book, then let children fill it in, and finally send it back to the teacher. This approach was realized 11 times as part of learning tasks (cf. Table 13) during the field studies.

This activity was done in classes of Spanish, Biology, Social Sciences and Mathematics (cf. Appendix C). In some cases children themselves take photos of the task from the book or another printed medium, and then fill in the blanks using the drawing application. Sometimes teachers take pictures of the task and send them to their pupils via Bluetooth who then open them in the drawing application. A detailed description of the learning tasks is shown in the Annex C of this thesis.

Figure 37. Different usage of Photo Annotation by Students during the Short Field Study. Left: Filling in a Spanish orthographic task 6th grade; middle: writing the parts of the human sexual reproductive organs 5th grade; right: filling in a math task 6th grade.

Two examples of filling in tasks using the mobile phone in a Spanish class are shown in Figure 37 (left). In this example children take pictures of exercises about orthography from their Spanish book. Figure 37 (middle) presents an example where children had to recognize and name the organs of the human sexual reproductive system in their Biology class. In this case teachers take the picture and send the image to the pupils via Bluetooth. These two tasks were realized during the short field studies (section 6.1.1 and section 6.1.2).

In contrast, Figure 37 (right) that was taken during the long field study presents one example when children take pictures of a Math exercise on the blackboard, and complete the task using the drawing application. One pupil commented "*I feel the phone was helpful for learning about female and male reproductive systems and it was very funny to write on the phone"*, referring to Figure 37 (middle).

We observed that during the short field studies children preferred handwriting the text for filling the blanks. Zoom in/out functions of the drawing application supported students to write into small spaces. In contrast, during the long field study, students preferred to input text through the virtual keyboard, as shown on Figure 38. In this case the drawing application allows through pinch and zoom touch gesture to control the font size of the text. In our interviews, students from the study-3 stated that they would like handwriting as input modality if the writing would be digitized and converted into text.

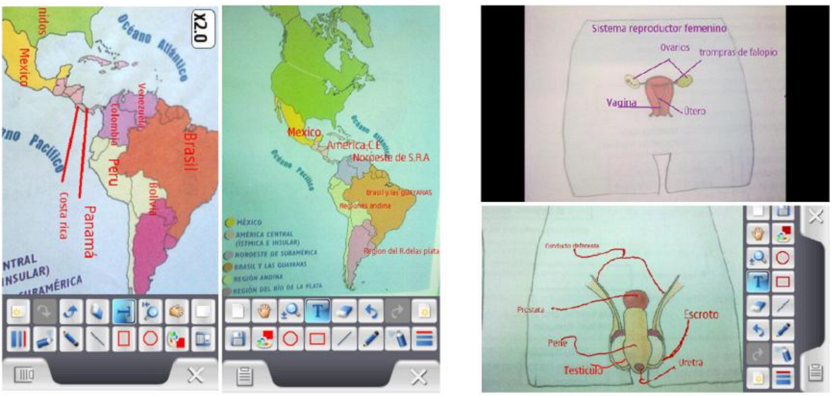


Figure 38. Examples of Completing Tasks Using PaintPad. In this examples children typed text instead of handwriting during the Long Field Study. Names of countries and regions from Latin America in a map (left) and the description of the organs of the female and male reproductive system (right).

Age and experience with mobile phones are the reasons of this different approach. The student participants in the short studies were younger and had no experience with any touchscreen device beforehand (section 6.1.1.1 and section 6.1.2.1), whereas students who participated in the long study (section 6.1.3.1) were older and 46% of the families of the students reported to have a touchscreen phone.

7.2 Painting and Drawing

Painting and drawing still plays a role in upper levels of primary schools and not only in arts. In subjects like Sciences and Religion, painting is among the main activities done in class. In a sixth grade from the long field study, a teacher asked pupils to paint and illustrate readings from the Bible, which can be seen in Figure 39. During the study-1 and study-3 the PaintPad application was also used as a tool for drawing and painting.

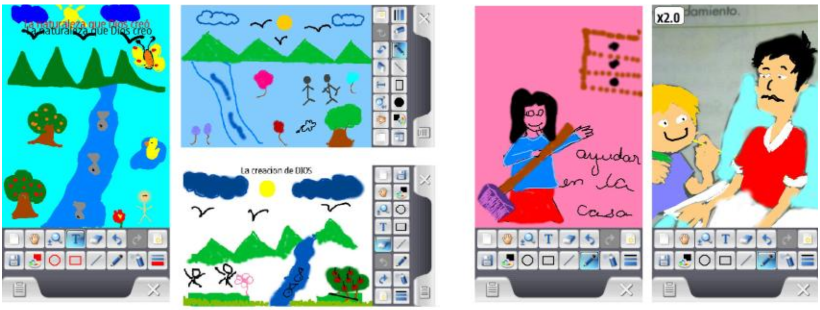


Figure 39. Screenshots of Painted Pictures done by Children in the Religion class. Painting about the Creation (left and middle left) and about the 10 Commands (middle right and right).

Using PaintPad for drawing and painting was welcome by students, as one student said to us: *"I love it... I can erase, change color and repaint again ... in the paper I cannot erase or change colors after I started*". Teachers commented *"children manage the pencil [stylus] just as it [would be] a real one"*.

7.2.1 Case Study: Painting Using a Single Mobile Phone versus a Shared Computer Lab Approach

In a Geography class, one common task for children is to learn the localization of countries, political divisions, main mountains, rivers and lakes. For that goal, children commonly paint and draw in blank maps. Figure 40 shows a painted map of America using the color pencils (left). During the long term field study, one learning task created by one teacher during the long field study was to paint a map of America and localize the countries which produce iron (see Appendix C) using the mobile phones.

We decided to recreate the same task using the computer, and observe how children interact with the computer. The goal in this exercise was to compare the experience on doing such kind of painting tasks on two mediums.

7.2.1.1 Study Setup and Methodology

The participants in our study were 23 children (11 boys, 12 girls) from sixth grade who took part in the long study described on section 6.1.3. The learning task was to locate the iron's manufacturing countries in America on a map.

The proceeding for completing the task on a mobile phone is as follows: Each child takes a picture of a blank map of America (letter size). After that, children open PaintPad®, paint and write the name of the countries on the map which is a producer of iron. We base our findings on the logger and screenshot application as well as on a post interview with the children. Figure 40 shows a map of America painted using the stylus and PaintPad on the mobile phone (middle).

Children recreate the same task in the computer lab. First pupils look for a map online, then save it to the computer and after which they use the software Paint, load the image of the map, paint and write the name of the countries on the map. Figure 40 shows a map of America painted using Paint (right).

The computer lab of the school had 16 computers with access to Internet, from them 2 computers were not working at the time we realized this study. Children have to work in pairs. Windows 98 was the OS installed on all machines. Students from 6th grade usually visit the computer lab once a week for 45 minutes. We did the study during their corresponding visit to the computer lab. We video-recorded the activity; in addition to us and the pupils, the grade teacher as well as the computer teacher were present.

7.2.1.2 Observations and Qualitative Findings

With the mobile phones children take on average about 28.58 minutes for completing the task. The time described above includes also the time spend for taking the picture. Children use the *zoom in* function in special when they have to paint the border of the countries; all children used the input text rather than handwriting to write the names of the countries. We observed that only one child had a problem taking the picture, as at his first shoot the picture was too dark, so he took it again. Girls trend to paint, change color and repaint the map more often than their male peers. Once the map was painted it was not sent via Bluetooth to the teacher, instead it was preferred that children showed the mobile phone screen with the map painted.

Figure 40. Images of Maps Painting by Children with Color Pencils and Paper (left); Using the Mobile Phone (middle) Using the Computer (right).

The same task on a computer worked as follows: We had to postpone the activity for another day as there was a blackout during the planned date. Once the bell rings, children picked up their books and walked from the classroom to the computer lab. They arrived at the computer lab about 5 minutes after the class has started. Twenty two children worked in group of two and one child worked alone. First, as normal proceeding when pupils visit the computer lab, children have to turn on the computer, which takes around 1-2 minutes. Pupils worked in pairs and as usual at that age, girls preferred to sit together with girls and boys with boys.

Then we asked children to go online. On one computer the Internet froze so one team children had to change to another computer. Children on whose computers the web browser was not located on the desktop had problem to find it using the start Windows button. But in general children were familiar with using the web browser. Once all children opened the web browser, Google was the default search engine; we requested pupils to open Google images and to look for blank maps of the American continent. Until this point the activity ran well, as no further problem was reported nor observed. We explained the children how to save the images under the folder *mis_imagenes*. At this point, eight groups required help to save the image properly. Together with the grade teacher and two pupils, who already finished and were more skilled in IT than the rest, helped us. We visited group by group and explained individually how to save the image. At this point the computer lab teacher was not involved in the activity.

The next step was to open Paint, load the image and paint it. Few children knew how to find Paint by their own, but after our explanation most children had no further problem to find the Paint application; only three teams (two groups of girls and one of boys) needed help to find the application as it was not in the start menu. Already, about half of the children team had opened the Paint application and loaded the image. Those children who loaded the image first, helped the other teams which were behind. We observed two approaches that we called *passive and active help*. With *passive help* one child of the team having problems with doing the task, visits a team who is doing the activity properly to see how the other group is doing it, then he/she comes back to his/her partner and tries to do the activity. With *active help* the team with a problem explicitly requests help from their peers, who come and explain the steps to do the tasks while at the same time e.g. he/she loads the image. Boys followed more the passive help and the girls the active help approach. At this point one team of girls had to switch the computer, as the computer did not work. Then this team had to divide, and one girl sat together with another student who was alone whereas the other girl joined the other group. This later team was the only group of three students during the user study. Only two girls reported that they had never used the Paint application before.

We did not observe difficulties to save the map once it got finished. During the development of the whole activity we observed a dominant effect of working in pairs, which is when one partner takes full or most control over the mouse and computer [Moed *et al.*, 2009]. This was especially observed with boys, the girls tended to discuss with each other and work more collaboratively. For example, in reference to load the image in the paint application one girl team said *"I think it is saved under Documents"* and the other said *"No I think it is in the big blue screen [desktop]".* For the whole activity children needed about 45 minutes. Before leaving the computer lab children had to turn off the computer.

Feedback from Students

We also asked children their opinion about the use of the mobile phone and the computer for the development of the task. Most children (88%) considered taking photos of the map with the mobile phone as being easier than looking for a map online with the computer. Similar most children (84%) liked most to paint the map with the mobile phones than with the computer.

Some children commented *“in the computer it was more difficult to paint using the mouse and with the mobile phone I have the small pencil [stylus] which helps me to paint accurately in the borders”,* and *“with the stick [stylus] I can paint better as I have a better hand movement to paint”*. Some children who preferred the computer for painting stated *“I prefer to paint with the computer because I can add further colors, in the mobile phone I cannot”*. Children preferred to type the names on the map with the mobile phone (88%) compared to the computer. When we asked children what medium –mobile phone or computer– they would prefer to paint digital maps, 92% stated that they preferred to use mobile phones, and 8% preferred to use the computer.

7.2.1.3 Discussion

On mobile phones children worked individually. On the computer children worked in pairs, as there were not enough computers to work individually, which is a common scenario in schools of developing countries. When the students work with the computer, we observed the dominant effect of one child controlling the mouse and keyboard [Moed *et al.*, 2009]. Therefore only the dominant child played an active role in the realization of the learning activity. This is a disadvantage as shy children or those with less IT skills tend to play the passive role in the team.

As a touch screen affords the natural way of painting, the results showed that children preferred to paint using the stylus on the mobile phone screen which was expected. It is clear that for painting the mobile phone was more suitable than using a mouse on a traditional desktop computer. Children reported to already have used the Paint application before, mainly in previous school years as part of the class art. This shows an effort from teachers to integrate the use of technology in their teaching, and a valid use case where touchscreen phones and devices would be more useful than using a computer desktop.

The IT teacher reported children having skills in using MS Office. Taking into consideration that both Office and Paint have similar menu bar and file open mechanisms, we expected that children had no problem opening files. However, children showed difficulties to open the file in Paint. Once the application was open children could easily paint. But, it was clear that the steps to navigate and find the application as well as open a file were difficult for them and needed further instructions. Children were familiar with the drawing application of the mobile phone, even though they just had worked with the phones for about three weeks. Whereas students have visited the computer lab since they were in third grade.

Using the computer to complete this task required children to navigate through different applications, i.e. the web browser and the Paint Application. In some computers the applications have a direct access on the desktop, on other computers the applications have no direct access and children have to navigate through the start menu, in order to find the application. The IT teacher stated that the reason is that pupils sometimes change the position of the access to the applications, or even erase the direct access. Children spent time looking where the application was located and in remembering how the application works if they have not used it recently. The Paint application on the mobile phone included all the features pupils needed for painting the map, from taking the picture to even sending the map to the teacher (either via SMS or Bluetooth). While the Paint application allowed to open recorded images files, the Internet was used to get the map. For sending, the Paint application included neither mechanism. In such a case the closes approach would have been to send it by E-mail.

Our findings are not conclusive, and have to be interpreted in relation to the particular context we did the study in. However, they give us insights in to how children use and interact with the computer lab in unprivileged schools in Panama.

7.3 Organizing Knowledge: Conceptual Maps

Conceptual maps are developed by children to summarize the content, usually at the end of the learning phases, typically before written exams. There was not an application specifically targeted to the creation of conceptual map installed on the mobile phone. However, three teachers from the short studies found it useful to utilize the post-it notes application as a means for creating conceptual maps (cf. Table 13). In Figure 41 a conceptual map using the Sticky Notes Touch® application and a conceptual map from a children notebook are depicted. From the experience with the children using Sticky-notes Touch® we found that the hand-writing input, the zoom in/out of each note, the square shape of the notes and the flexibility to move the written notes through different points of the screen were key in the success when creating conceptual maps. These features together with means for automatically saving and improved editing mechanism give the basis for guidelines for the creation of a simple conceptual map tool for touch-screen phones.

During the short studies (see section 6.1.1 and section 6.1.2), in the class of Nature Science, Social Sciences and Spanish children used StickyNotes to create a conceptual map. From our observation and conversation with children they missed tools and not to throw out the whole note away. It is important to note that the creation of conceptual maps is the most common practice in Panamanian schools to summarize what children have learned.

Figure 41. Conceptual Maps Done by Pupils of 6th Grade. Example of a traditional conceptual map done with paper and pen (left); examples of conceptual maps done with the mobile phone application Sticky Notes Touch® (middle and right). In the class of Ecology and Spanish in vertical mode (middle) and in the class of Spanish and Social Science in horizontal mode (right)

Teachers from the long field study did not use the digital post-it notes for creating conceptual maps. Instead, the approach teachers followed was to integrate real drawing to complete the text digitally, as shown on Figure 42. Here children during the Spanish lessons, copied from the blackboard an incomplete conceptual map on a blank paper, then took the photo and filled in the missing text using the drawing application.

Figure 42. Conceptual Maps Created by Pupils during the Long Field Study about Adjectives in the Spanish Lesson. Children copy an exercise from the blackboard on a paper of an incomplete conceptual map. Then Children take a photo of it and use the draw application to fill in the missing text.

7.4 Evaluation of the Learning Tasks Realized with the Mobile Phones

After finishing the short as well as the long term field studies, we asked teachers and students to evaluate the features and applications of the mobile phones for supporting the learning activities described throughout chapter six and seven (see Appendix C). In addition, parents' feedback during the short field studies were also presented, however feedbacks from the long term field study were presented in the next chapter.

7.4.1 Children's Evaluation

In multigrade school (study-1), most of the children, 84%, stated that they felt like learning more using a mobile phone, 54% stated that they participated more actively in the tasks, and around 65% of children stated that classes were more interesting and fun when using a mobile phone. 63% of children stated that with mobile phones they were more collaborative with their peers. Only 3 students stated that class interaction was equal to the ones without cell phones. Similar opinions shared the students of the double-shift school (study-2), 86% of the children felt that they have learned more using the mobile phones, 64% said that they participated more actively in the assignments, and around 84% of the pupils found the classes were more interesting and fun using mobile phones. About 79% of the pupils also considered that with the mobile phones they worked more collaboratively. The interaction in the class with mobile phones was perceived similarly to the one without mobile phones by around 24% of the pupils.

We asked pupils for their opinion about the use of the different application and features used during the field study. Figure 43 shows a summary of pupils' opinions during the first field study. Task-wise, recording video and painting on the phone were the activities that children liked the most.

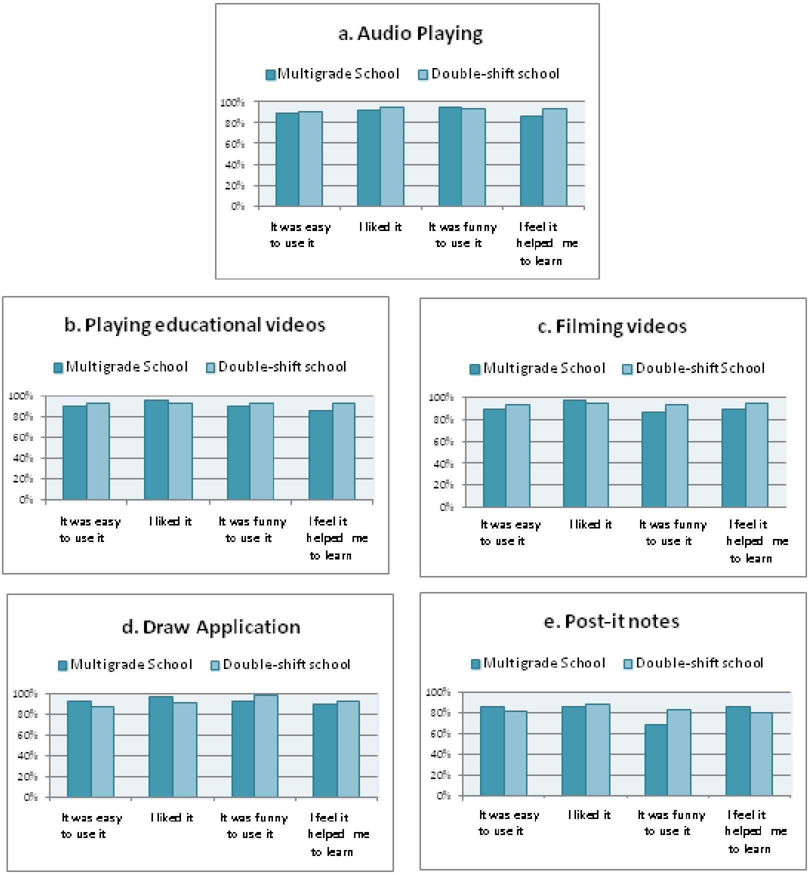


Figure 43. Evaluation of the Use of the Multimedia Functions for Learning by the Students according to the Type of School during the Short Field Study. a) Audio Playing, b) Playing educational videos; c) Filming videos; d) Draw application and e) Using Post-it notes.

We asked the pupils of the long field study, using a Likert scale, if they felt the different applications of the mobile phone used during the study helped them to understand the class better. The results are presented in Figure 44. Most children considered that watching a video was the most useful to understand the lesson, followed by a recording video.

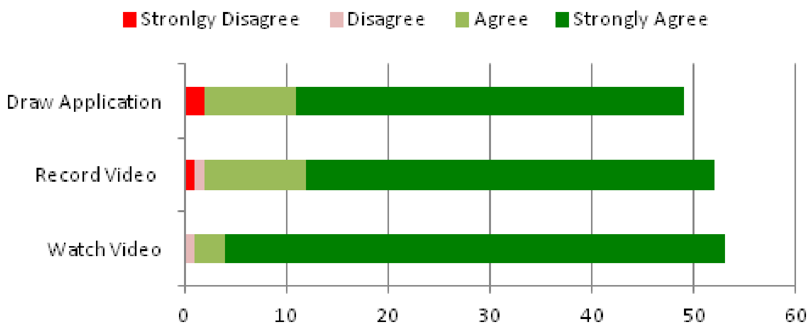


Figure 44. Opinion of the Students from the Long Field Study: about if the use of some multimedia functions has supported them to learn better the lesson. The opinions are given in number of participants.

Similarly, we asked the children to evaluate, using a Likert scale, how easy it was to use some of the common multimedia application during the long field study. Figure 45 shows the results. In general most children rated as “agree” and “strongly agree” that the different functions of the mobile phones that children worked with were easy to use. Most children strongly agreed that watching a video was the easiest function to do.

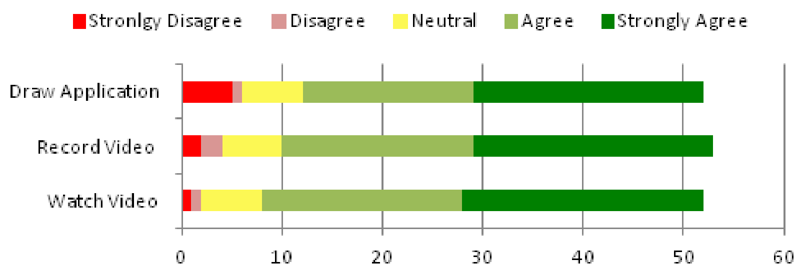


Figure 45. Opinion of the Students from the Long Field Study: about if they consider it easy the use of some multimedia functions. The opinions are given in number of participants.

7.4.1.1 Further Observation

Although children had no experience with such phones, they learned very fast how to use them. After the second use of any phone feature and application, most of the children had no more questions regarding the use of the mobile phone. For example, sending a file via Bluetooth was explored only three times with sixth grade during the study-1 and two students were able to do it alone the second time. In the long study, children explored the use of Bluetooth while interchanging songs before we explained them how to use it. According to our observation children who had not used a mobile phone before, at the end of the study, were similarly skilled as others. The most difficult task was writing with the virtual keyboard, especially for those not familiar with mobile phones.

During the 2nd week of the short field study, there was no question how to use a function of a mobile phone in 6th grade (multigrade school) and 5th grade (double shift school). Fourth and fifth of the multigrade school still had some questions because they started with the study two days later than 6th grade. According to the teachers, pupils were much more involved and participative in the class, and more enthusiastic and concentrated in the realization of the tasks with the cell phones. In the case of the long field study (study-3) children who brought the mobile phone regularly at home learnt to use faster than their peers who only bring it only to do specific tasks (cf. section 6.1.3.2). The experiences with all the children were encouraging; we also observed a higher degree of concentration, involvement, motivation, and participation in the realization of the tasks given when pupils learned with mobile phones.

7.4.2 Teachers' Evaluation

Teachers also reported positive feedback from the features used. We asked teachers to evaluate the usefulness of the multimedia functions used during the study on a 1-5 scale, where 5 meant strong agreement that it was useful. All the functions were considered between useful and highly useful:

- *Play a video 4.5;*
- *Record a video 4.9;*
- *Take a picture plus Paintpad 5.0;*
- *Record voice and play audio 5.0.*

Teachers found that the use of mobile phones would be a great tool for multigrade schools. Most teachers agreed that they would not use the mobile phones daily. Seven out of the eight teachers stated that they will only use the mobile phone for some subject and not for all the subjects. For example, PaintPad was found useful especially for nature science, arts, social science and Spanish, while filming was considered especially useful for Spanish, and Social Sciences; watching video was considered especial useful in Mathematics.

Filming is a hand-on activity where children themselves created content. Children showed a high engagement from the pupils, who did several takes until they liked the final product. In this review process children unconsciously also learn. Filming also supported the collaboration between the peers. Teachers considered the presentation of videos with learning content as the most useful function for the children. The opportunity to repeat the lesson several times helps children to understand the concept better. And different to video or TV set mobile phones, playing videos on mobile phones gives the privacy and feeling of ownership.

According to the teachers during the field studies, filming and being filmed doing dramas, debate or speeches increases the motivation of the children to do an active participation. As one teacher commented to us *"Jose never wanted to take part in the social sciences discussion activities [debates]. But today he has prepared very well and has an outstanding participation. I think he likes being in front of the camera"*.

7.4.3 Parents' Feedback during the Short Study

At the end of the short field study in the multigrade school we met five mothers and three fathers of the participants from 6th grade in order to get to know their opinions about the study. From the eight participants, only one male had never used a mobile phone before, the others owned a mobile phone. We presented some of the works done by children with the mobile phones.

Parents were very astonished when seeing the works done by the children with the mobile phone since they did not expect such outcomes. As one father commented "*at the beginning when my child told (me) about this (study) I was very skeptical of using (mobile) phones in the class…but now I am surprised and really see (it) would be very useful in class*". At last, one mother commented at the same respect "*I did not know all the things that are possible to do with a cellphone."*

Similarly to teachers' concerns in our surveys, the main concern of parents was the bad use of the cell phone, for example playing or accessing/recording inadequate material. Nevertheless, parents saw more benefits than risks using the mobile phone and were conscious of their role as supervisors of their children: "*it is important that (we) control that the children use them correctly*" and "*having the right supervision from us at home and teachers at school, I see no problem of using them (mobile phones) for learning*".

All the parents welcomed the idea of using a mobile phone for learning. They mainly thought that children will be much more motivated and involved in class; as one mother said "*my son was extraordinarily motivated (during) this two weeks to go to the school*"; another mother commented "*for children learning how to use a mobile phone is amusing*".

7.5 Summary and Discussion

We have shown that mobile phones with their rich multimedia features can support and complement the classes in developing regions better than traditional computers, as they are accessible, portable, and have better integrated video and photo cameras. Similarly to a pencil, a mobile phone can be used as a general learning tool. Teachers adopt the use of the mobile phones in the way they were used to teach.

In our study we chose a phone model that is currently at the upper end of mid-range phones and has many features of a simple smart phone. We expect that these capabilities will be also available on the low-end phones over the next years. Many of the functions used rely on a touch screen with a stylus. However, our studies revealed that teachers are able and willing to create tasks that fit to the phones available.

In the surveys and focus groups we asked (cf. chapter 4) children and teachers to speculate about the potential uses of a mobile phone as educational device and got valuable responses on how to create successful learning environments in a developing country context. Though major parts of the field study were inspired by these comments, over the course of the study we got interesting findings that validated, but also contrasted, contradicted, and extended the suggestions made. Hence we argue that the use of surveys and focus groups only is not sufficient to understand the requirements and to design deployments. In the surveys, using phones as educational devices was often seen as using the phone instead of a computer.

The most common step after capturing a photo of a worksheet or a form was to use the installed image manipulation software Paint. Using this app, the pupils were able to digitally fill in missing numbers or words into worksheets and forms. Well-equipped schools have the chance to use (physical) workbooks or to receive actual copies to fill in. If this option was not available, as in the case of the school in Panama we worked with, having the opportunity to capture images and fill out forms digitally was a welcomed alternative. This is especially helpful for math as this increases the number of tasks a student can solve compared to the situation where they have to copy the tasks first.

We observed that some children acquired skills very fast and were able and willing to help their peers. Though, we observed a gender difference in the approach of exploring devices. Teachers learned within days to make use of the phone as a teaching resource and discovered new opportunities for using it in class. Several of the ideas, especially with taking photos and annotating them, were mainly developed and refined by the teachers. Having the simple usage model of a phone and in some cases the paint application enabled a versatile use without requiring a complex learning platform. For teachers it was a great value to tailor the content in an easy way to their current teaching plan. Here the multimedia recording turned out to be a very valuable resource. We learned that providing pre-fabricated digital content might be very difficult, as it would need to fit the teacher's plan and style of teaching. By providing tools where teachers can move their content easily into the digital domain we expect that many teachers can be won over as it eases their effort for preparation.

Before the field study, teachers and especially parents were worried that mobile phones might not be useful and distract the children from learning. Furthermore they did not see a link between a PC and a mobile phone and most of them could not imagine how a mobile phone could be used in a sensible way in school and for teaching. However, after the field study parents saw a clear benefit in using mobile phones in the school context, even though they were initially skeptical. They were surprised of the activities done with the phones and proud of the products their children created with these devices.

Chapter 8

Adoption and Social Impact of the use of Mobile Phones by Children

In the former two chapters, we reported on how teachers integrate the use of camera phones with multimedia capabilities in their daily teaching. They used the mobile phones just like one more tool or resource for teaching their lessons.

In this chapter, we analyze the use of mobile phones by children in the daily life inside and outside the classroom. We described the ways children adopted the phones under the novelty effect –during the short studies (section 6.1.1 and section 6.1.2)– and in a longer term when children are well familiarized with the devices –during the long study (section 6.1.3).

At the end of the chapter we present a deep interview made to teachers and parents of the students who participate in the long study about the social impact of the use of mobile phones during the field study.

This chapter is based on the following publications:

[Valderrama Bahamondez *et al.*, 2011b] Valderrama Bahamondez, E., Kauko, J., Häkkilä, J., & Schmidt, A. (2011). In Class Adoption of Multimedia Mobile Phones by Gender - Results from a Field Study. In *Proceedings of the 13th IFIP TC International Conference on Human-Computer Interaction (INTERACT '11)*, 333-340, Springer-Verlag Berling Heidelberg.
DOI: http://dx.doi.org/10.1007/978-3-642-23771-3_25

[Valderrama Bahamondez *et al.*, 2014] Valderrama Bahamondez, E., Pfleging, B., Henze, N., & Schmidt, A. (2014). A Long-Term Field Study of Introducing Smart Phones to School Children in Panama. In *Proceedings of the 16th International Conference on Human Computer Interaction with Mobile Devices and Services (MobileHCI '14)*, 163-172, ACM.
DOI: http://dx.doi.org/10.1145/2628363.2628403

8.1. In Class Adoption of Multimedia Mobile Phones during the Short Field Study

Using mobile phones for learning in formal classroom settings is still not common and little is known how to do this in a successful way. Most of the approaches found in the literature have focused on the development of dedicated learning games or applications to cover one specific learning subject or content (cf. section 2.3). Understanding children’s practices of learning how to use new technology could support the creation of better learning applications and teaching practices.

The experiment was run in two schools in the countryside; see sections 6.1.1, 6.1.2, Table 13 and Appendix C for a detailed description of the school, participants and settings.

8.1.1 Observation in the Use of Mobile Phones by Gender

At the beginning, boys seemed to be more comfortable and learn faster using the phone than their girl peers. During the first day of the user study in 6th grade, four of the first five children who finished the activity were boys. Consequently we got more questions from girls the first day.

Our recorded screenshots indicate that boys were more curious than girls and explored the phone more eagerly than girls – though this gap decreased a little by the second week. The most explored and used applications by boys were games, filming and taking pictures. Possible explanations for this are *1) that according to teachers the female pupils behaved and are better students than their male peers, and 2) boys at the beginning finished many of the tasks quicker than girls and therefore had more free time while waiting for girls to finish.*

Another interesting aspect was the carefulness. Girls have been more careful in completing the tasks with the mobile phone, especially when painting with PaintPad. E.g., girls painted slowly and if the painting did not satisfy them, they repeatedly started over. In contrast most boys did not, which can also explain why girls took longer to finish.

Children learned by doing, they were not intensively trained in any of the features used. Further, age played a significant role as well. Comparing children of 6th, 5th, and 4th grade, higher grades learned faster to use the functions of the mobile phones. However we think with more training children of 4th grade could compete with their higher peers.

8.1.2 Adoption of the Use of Multimedia Phones during the Learning Activities

One of the goals of this research was to explore gender differences in using multimedia features of the mobile phone in class. From our observations made during the short field studies, apparently, boys seemed to be more distracted than their female peers while working with an assignment on the phone. For example, they explored other applications during an instructed task. Also, our observations suggest that boys are faster to adopt the mobile phones than girls. As initial point, we analyzed two learning tasks: watching a video, and filming a video. The choice of these two tasks was based on the opportunity of analyzing different roles of the children: one as active role (filming video) and the other as passive role (observing a video).

8.1.2.1 Watching Videos

Overall, there were six learning tasks involved watching videos during the study-2, and the videos varied in terms of topic and duration. We restricted our population to two 5th grades groups who observed the same Math video (introduction of the multiplication of fractions), to ensure comparability. The video has a duration of 5.7 minutes and was watched by 21 girls and 18 boys. In our first analysis, see fig. 1 (left), we found a gender difference in how many times the pupils observed the same video. In general, boys watched the video 1.2 times less than their female peers. To confirm this difference statistically, we conducted 2x2 between subjects ANOVA to analyze the net time used for watching the video. The analysis revealed a significant difference between the groups 1 and 2 ($F_{1,35} = 6.65$, $p < 0.05$). However, the difference between genders was only marginally significant ($F_{1,35} = 3.77$, $p = 0.060$). As illustrated by Figure 46 (left), group 2 observed the video fewer times than group 1, while maintaining the trend between girls and boys.

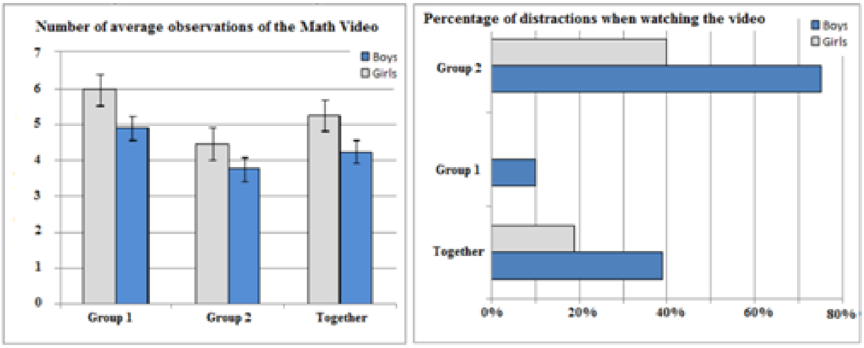


Figure 46. Number of Repeated Observations of the Math Video by Gender and by Class Group (left), and the Percentage of interruptions in the video Watching Task (right). Group 1 and 2 represent the pupils of 5^{th}-A and 5^{th}-B respectively. Together refers to both groups.

Figure 46 (right) shows the number of distractions while watching the Math video by gender. We define distractions as the occasions when the pupils pause/stop playing the video and open another application on the mobile phone instead. Figure 46 (right) illustrates that the number of distractions by boys (39%) is approximately double in comparison to their female peers (19%).This also explains the shorter time used by boys for watching the video. We notice also that in group 1 girls show no distractions, and the number of distractions by boys is considerably lower in group 1.

An explanation of the variation between the two groups showed in both graphs is that in the first group, the teacher used the video to introduce the concept (multiplication of fractions), while in the second group the topic was already introduced and the video was used to reinforce the learning. Another explanation is the learning effect. The group 1 observed the video during the first day of the field study and group 2 during the fourth day. This means that pupils in group 2 were already familiar with the mobile device. For both groups, however, this was the first time they were introduced to playing videos by using the phone.

8.1.2.2 Filming Videos

Although there were around 7 tasks involving filming a video during both short studies, most of them were realized in a team. Only in one learning activity every child had to film a video. We analyzed the children’s behavior during this task. In this activity, pupils had to go out to the school garden to film and describe a part of a flower. Children were free to choose the flower(s). This task was performed by children from the 5th grade of the first school, including 8 girls and 4 boys. The task was conducted during the third day of the trial, but it was the first task involving video recording. In general, we noticed two major gender differences:

(1) All the girls worked in pairs – one filming while another was presenting and vice versa; in contrast all the boys worked alone and filmed their own videos;

(2) boys had no technical problems when filming, while two girls had difficulties with the task.

Figure 47. Screenshot of the Video Recorded by the Children for Nature Science Class.

Boys maintained focused in the flower as the main subject (Figure 47 right), while girls were more concerned about acting in front of the camera (Figure 47 left and center). All the girls cut off the flowers and held it in the hand in front of the camera; in contrast all boys completed the tasks without cutting it. As the boys created their own videos, they did not appear on the film in person. Six girls presented in front of the camera (full view), while two only partially (hand and lower body). The zoom option was neither taught nor explored by the participants.

8.1.3 Adoption during Explorative Use

In addition to instructed learning activities, children were allowed to explore other functions of the mobile phone. Teachers reserved specific time slots (between 10 and 15 minutes) for free exploration, but unscheduled explorative usage also occurred during and between the instructed learning activities. We analyzed the explorative use of the phones mainly from log files containing active application history data. Findings from the quantitative log data were then contrasted by qualitative observations.

8.1.3.1 Log File Analysis

We did not have any a priori hypotheses, as the original focus of the study was in the learning activities. Due to lack of control in the field trial method, the results are affected by unknown random and potentially confounding factors. Therefore, the following results should be interpreted merely as hypotheses for future experiments unless strongly supported by qualitative findings. To avoid bias in selecting metrics and comparisons, the log files were analyzed by a researcher who was not involved in the field trial.

Log files contained a time-stamped history of active applications. We analyzed the usage during the first 4 days, and excluded 3 users who participated less than 4 days.

First, the applications were categorized in system applications (e.g., home screen, application menu), learning applications (e.g., Camera, Paint Pad) and explored applications. A subset of the last category was further classified as game applications. Second, a set of metrics were extracted from the log files. We analyzed the results using mixed models ANOVA with gender and school as between-subjects factors and day as a within-subjects factor.

Time used for learning applications varied between the schools and days, but there were no systematic differences. Overall, the mean time used for learning applications was 60.8% (sd = 21.3%). For explored applications, there were significant main effects for gender ($_{F1,53}$ = 5.98, $p < 0.05$) and school ($F_{1,53}$ = 6.86, $p < 0.05$). In the first school, the mean exploration time by boys was 8.5% (sd = 13.4%) and by girls 3.6% (sd = 3.7%). In the second school, the corresponding results were 14.8 % (sd = 15.1%) for boys and 8.9% (sd = 8.9%) for girls. The remaining time was used in system applications. Idle time was excluded from the analysis using a threshold of 1 hour without an application switch.

By analyzing the explorative usage further, we found a significant gender difference for game applications ($F_{1,53}$ = 5.99, $p < 0.05$). There were also significant school-day and gender-school-day interaction effects.

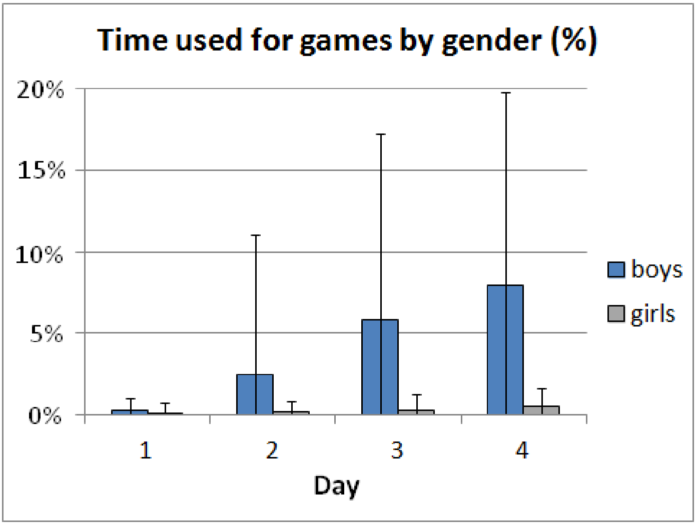


Figure 48. Mean Percentage Time Used for Game Applications.

A posthoc analysis with Bonferroni correction revealed a significant day effect for the second school ($F_{3,132}$ = 10.91, uncorrected p < 0.000005). This reveals that time used for games increased day by day, as illustrated by Figure 48. Overall, the time used for games was more significant for boys (μ = 4.1%, sd = 9.6%) than for girls (μ = 0.3%, sd = 0.9%).

Similarly to these findings, during the field study we observed that girls played games notably less than their male peers. One girl commented to us *"I find this game [car racing] very boring and difficult"*, while a boy stated *"I like this game [car racing] ... is easy but I have to be concentrated"*. The most played game was the Global Race Raging Thunder® where the player drives a car in a racing competition. Most of the boys played alone, but four boys discovered that turning on Bluetooth allowed them to play against each other.

In order to analyze the scope of explored applications, we calculated the amount of new applications discovered daily by each user. System and learning applications were excluded from this analysis. We found significant main effects for gender ($F_{1,53}$ = 12.28, p < 0.001) and day ($F_{3,159}$ = 5.28, p < 0.005). The mean amount of discovered applications was higher for boys (μ = 3.5, sd = 3.0) than for girls (μ = 2.6, sd = 2.2). The discovery rate decreased moderately with time. Cumulative amounts of discovered applications are illustrated in Figure 49 (left).

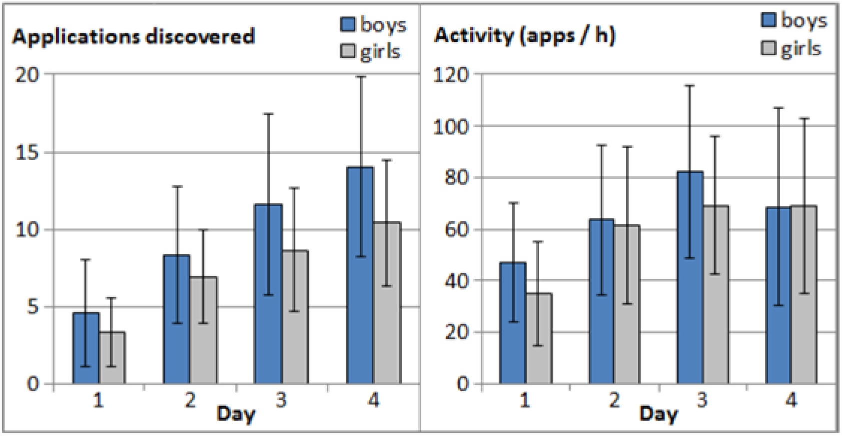


Figure 49. Cumulative Amount of Discovered Applications (left), and Application Switch Frequency (right).

We also analyzed exploration activity by calculating the frequency of switching the active application per hour. This metric includes learning and system applications, such as the application menu. We found a significant main effect on activity by day ($F_{3,159} = 5.28$, $p < 0.005$). Further analysis shows that there is an increasing trend in the activity during the first 3 days. Interestingly, the activity seems to decrease after the third day, as illustrated in Figure 49 (right). Decreasing activity and slightly decreasing discovery rate may indicate that users found the most interesting applications during the first three days.

8.2 Adoption of Mobile Phones by Children during the Long Study

As described in the section 6.1.2., children were allowed to take their mobile phones during the long study. This gave the opportunity to also study the way children adopt and use the mobile phones after the novelty effect, when they were well familiarized with the mobile phones.

8.2.1 Motivation

Can children and teachers get along integrating the mobile phones in the learning activities without our supporting attendance? This was the question raised at the end of the short-term study-1. Thus we decided to conduct a trial with 6th grade where teacher and children worked completely alone without being observed by the researchers. The teacher advised two activities: first, children had to look up information about natural gas (Nature Sciences) on the Internet (in teamwork). Then, they should create a video with the information found. The second task was to take a photo from an exercise in the Spanish book, complete it on the phone, and send it to the teacher via Bluetooth.

According to the film captured, screenshots, and the teacher's opinion, the activity worked very well; she commented to us *"there were no questions on how to do the task, they just knew how to do everything (on the phone)." "They were concentrated…"* The only problem was that the phone memory was full and she could not receive all exercise sheets.

These results motivated us to realize a long-term field study, study-3 (section 6.1.3). In this later study the activities were realized without the presence of our research team.

8.2.2 Methodology and Setup

We conducted a 20 week long study in a school in a small town in rural Panama. We introduced the phones to a natural setup where we could study opportunities and challenges that arise when phones are available as personal tools. The analysis of the screenshots were done with the sixth grade C, with a total of 23 pupils as they were required to bring their phones to school every day, but they could also use them in their spare time and take them home. For further description see section 6.1.3. Due to health problems with the female teacher, their students (sixth grade A) had to stop their participation in the long field study.

Based on the large sets of screenshots that were recorded we are able to analyze how children used the phones over the course of the study. Overall about 1,663,000 screenshots have been taken that documented the phone usage. As screenshots were taken every 20 seconds, longer interaction periods with the same application result in several images that allow seeing which progress in a task or game was made. For applications that were used shorter than 20 seconds it may be the case that no screenshot was recorded. In this case, only an entry in the log file exists. We especially analyzed (manually) about 200,000 screenshots and logs of 10 selected days toward the end of the study period. In our analysis we were interested in:

- Identification of main use cases of the phone at school

- Identification of main use cases at home (educational and recreational)
- Long term changes in the use of the phones
- Comparison between users over the time of the study

The analysis was conducted manually by inspection and interpretation of the screenshots. In our analysis we identified the following major actives that occurred throughout the study: *image capture as replacement for a copying machine*, *information gathering*, *usage of the phone as a tool*, *listening to music*, and *playing games*. We also observed that using the phone for *watching and recording videos* was a major feature used for teaching and learning.

8.2.3 Image Capture – Educational Proposes

As reported in chapter 7 multimedia-enabled phones allow children to use the camera to capture worksheets and fill them out virtually by using a paint application (cf. Table 13). This usage pattern was observed in our study, too. The convenience of this approach seems to be a main driver. The teacher does not need to prepare work sheets; she or he can directly use material from books and children can capture it on their devices. Such an approach is in particular important for differentiation. For instance, if one child has already finished a given task this method allows the teachers to provide, additional material with more challenges to certain students.

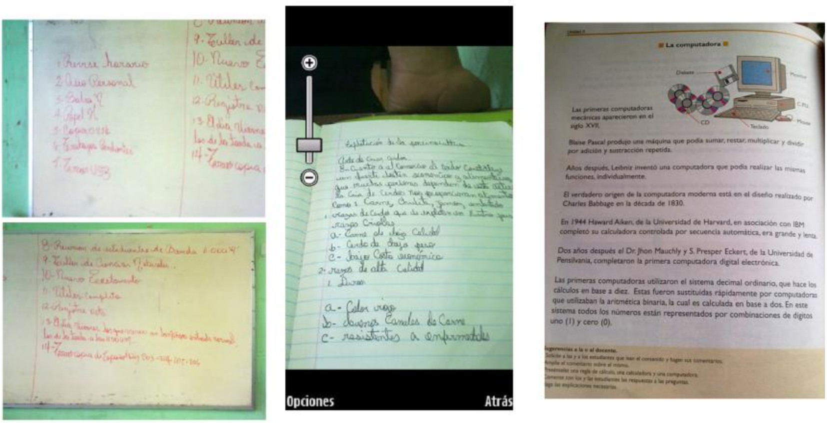


Figure 50. Images Captured with the Phone’s Camera. Left: copying written notes; center: photo of the description of the homework for the next day; right: photo of a book page in order to do the homework.

From the screenshots we collected during the field study, we found that eight pupils used the camera phones to take pictures of books, blackboards and classmate's annotations and notes. When asking the children about the images there were different reasons for capturing content. Photos of the blackboards were taken of children who expected that this information would help them with their homework. When one child was away from class, photos of the blackboard and of certain written notes (e.g., a text written by the classmate, see Figure 50) were taken to allow the child to rework what happened at school.

We also saw that children used the camera of the phone to take photos when they forgot books at home that were required to work with in class. Without the use of the camera, children typically have to copy the written information by hand. In general all these cases show that the phone replaces the function of a copying machine, which is not available.

Figure 51. Children in Class Working with Their Phones.

From the screenshots we saw that the children often use the calculator application (see Figure 51), especially to support them when calculating with negative numbers. Further tools that were used are dictionary and translator applications (Figure 52 left). Our software prototype, CuentoMovil, (cf. section 5.3) was also used by children as shown in Figure 52 right. This application was used three times, once in the class of Spanish, Social Science and Nature Science (cf. Appendix C).

Figure 52. Applications Used by Children during the Unsupervised Long Field Study. Screenshot of a student using the English dictionary (left) and working with CuentoMovil (right).

8.2.4 Information Gathering

How to access the Internet from the handsets was not introduced to teachers neither to pupils. This feature was discovered by children from sixth grade C who show it to their male teacher (see section 6.1.3). Teacher immediately started to use in their class. During the long field study the male teacher set more and more learning activities, in which the children needed the phone to gather information from the Internet. In our conversations during the study, the male teacher stated that he found access to Internet in classroom the most useful function of the mobile phone, which impacted the way he could teach.

Within the classroom there was only limited connectivity, and hence most of the time teacher allowed pupils to go to the yard near to the antenna to connect to the Internet and launch the browser. Even though the bandwidth of the Internet connection at the school was very limited, it provided a tolerable speed when using mobile Internet on the phone.

We provided the phones without SIM cards. As the pupils were allowed to take the phones home, some of their parents bought pre-paid SIM cards to use the phone as well as to have mobile Internet access (cost is about 1U$ for 500MB). About 16% of the children who took part in our study used mobile Internet with a pre-paid card. Once all children understood how to get Internet access with the phone this was widely used across different subjects.

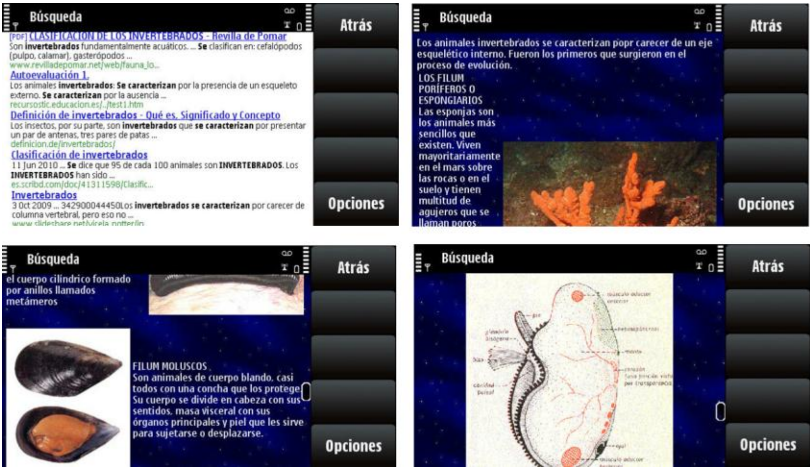


Figure 53. Sequence of Screenshot of a Search on the Internet: about invertebrate animals by one pupil in the class of Nature Science. The search was done via mobile Internet with a pre-paid card.

In Spanish the task was to get information about prepositions, conjugations and accents. In natural science pupils got an open task to learn about invertebrate, as shown in Figure 53. In the context of religion the task included finding a list with the 10 commandments. A further example task was to find details on the history of the Panama Canal as well as images. The information sources used by the pupils were very diverse and contributed – according to the teacher – to the discussion in the classroom.

During the Olympic Games 2012 students used the phones to get news about the events. The teacher took this as an opportunity to discuss the event with the pupils. Further examples of the subjects search are presented in Figure 54.

Figure 54. Further Screenshots of the Use of the Internet in the Classroom. Searching about the 10 commandments in the Religion class (left); two pupils searched about prepositions in Spanish class (middle); and about the use of comma and period in a sentence (right). Pictures showed on the left and middle presents a search done with Wi-Fi while the search on the right was done with mobile access

Overall the phone provides an easy means for individual access to the Internet for pupils. Searching for information on the phone is cumbersome, but sufficient in many situations. Over the course of the study the use of the phone for searching information became more and pupils made use of this function to suit their personal information needs – in the context of education as well as for recreation.

8.2.5 Non Educational Proposes

In this section we explored the use cases by children when using the mobile phones at home as an entertainment tool. Gender differences were observed across the usage of the phones especially for listening to music and playing games.

8.2.5.1 Listening to Music

During the ten days that we analyzed in detail, the children on average listened to music for 12:21 min per day. There was no specific pattern of how long children listened to music. Among all pupils, the average listening time differed between 15:30 min per day and 67 min per day. Figure 55 presents the analysis of the time listening by gender and by day.

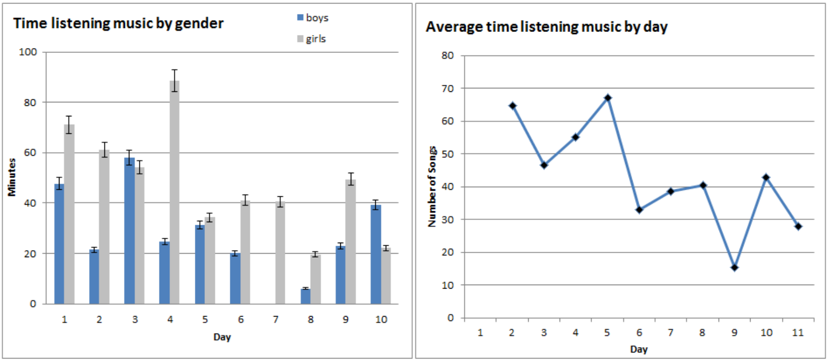


Figure 55. Analysis of the Music Listening by Children: time listening by gender (left) and average time listening by day (right)

In that time children listened to 808 songs, 771 in Spanish, 36 songs in English, and one in Portuguese. Although the number of songs downloaded is quite high, 20 songs were commonly listened to and downloaded by almost all children. The children mainly listened to Latin American music. Furthermore, all children had at least one religious song on their phones; one child only had religious songs.

The pupils shared the music they downloaded from the Internet with their peers using Bluetooth. The transfer of files was usually done at school, either early in the morning before class started or during the morning breaks.

8.2.5.2 Playing Games

Based on our detailed analysis (10 days), children spent on average between 1 and 2 hours per day on playing games. In most cases they played at least 3 different games. Most of these games were downloaded from the Internet. With this regard, we found interesting gender differences: Most girls downloaded the same games. Therefore they were able to interchange information about games they had downloaded. In contrast, most of the boys downloaded different games. Furthermore, girls played different categories of games than boys. While boys preferred to play action games, girls preferred to play adventure games. The most popular game played by girls was WonderZoo[21] where the player has to free locked up animals. To our surprise, during the days we analyzed girls spent more time on playing games than boys. Only four of the children actually played

[21] *http://www.gameloft.com/mobile-games/wonder-zoo/, last accessed on September 30, 2014.*

some kind of educational game (e.g., arithmetic trainer / English trainer) during the analyzed days.

8.2.5.3 Pictures and Images

Taking photos was one of the main activities done by the children. We analyzed the pictures taken by all children that were not part of some learning assignments. During the 10 days that we had analyzed, children took 272 pictures in total. Girls took 190 photos while boys were taking 82 photos, see Figure 56.

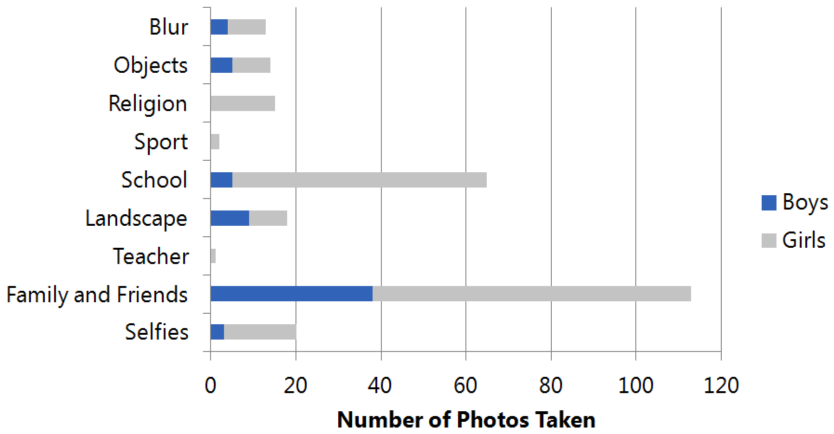


Figure 56. Categorization of the Photos Taken by the Children during the Long Field Study by Gender.

The children took a variety of pictures that we classified by using the following categories:

- *People:* photos of family members or friends, teachers or classmates, and pictures of the children themselves.

- *Nature:* photos of animals in their environment like dogs, chicken, horses but also pictures of the landscape

- *Sport:* pictures related to their favorite football team.

- *Other:* objects photographed like cars, bikes, etc. This also includes pictures of hand-made drawings and paintings.

- *Religion:* images related to Christianity.

- *School-related*: pictures of books, blackboards, events, and contests at school

The main topics photographed by boys and girls were family/friends, either at home or during special events. Self-portrait photos were more common for girls than for boys. Similarly, girls take more photos related to Religion than their male peers. There were 21 photos edited through PaintPad, from those 16 photos were edited by boys.

With respect to images downloaded from the Internet, ten children downloaded 168 images during the 10 days we analyzed. The most frequently category found were friends and love messages (e.g., a teddy bear with hearts), followed by showbiz (e.g., singers), religious images, animals and sports. Photos of singers and cartoons with love message were especially shared by using Bluetooth.

8.2.6 Limitation

In this section we discuss about some of the limitations that we see with our work. As the study was conducted in a natural environment with no researcher present for most of the time we based our findings on the automatically recorded screenshots as well as on interviews conducted in the middle and at the end of the study. While most of the phones worked well we observed that some phones ran out of memory and did not record all screens. The screen capture software did for technical reasons not capture the content of video recordings. Hence, information about video recording was based on the recordings the pupils kept on their phones.

The screen capture software ran in the background and slightly affected the stability of the system software. From time to time, this resulted in some of the phones freezing (every few days). In this case children rebooted the phones, but their task was interrupted.

As phones may be passed between people, we have no information whether or not others used the phone. During school time this was to our knowledge very rare, as all children had their phone available. For use at home we are less certain as parents, siblings, or friends may have used the phones, too.

8.3 Interaction and Behavior of Students in Classroom when Using the Mobile Phones

After the field study we asked teachers if they perceived a change in the interaction and behavior of the pupils in the classroom using a mobile phone. The teachers considered that children adapt easily to the mobile phones, and that the activities done with the mobile phones support the collaboration of working together. Overall four out of the six teachers who participated in the short studies (cf. section 6.1.1 and section 6.1.2) stated that students showed a high concentration in the activities and those children were more involved in the class. All teachers stated that children were more motivated than usual.

Teachers know their students very well. We considered that the teacher can better know if he/she observes a change in the behavior of his pupils. For us, to perceive any change in child behavior is very difficult to evaluate, as we do not know the children. During the study-3 we asked the teachers to fill an evaluation about the behavior of their students two times: end of May and end of July. Therefore we created with the support of two pedagogues an evaluation matrix where teacher have to measure three aspects:

(a) *students' engagement and participation in the learning activities,*
(b) *their socialization toward their peers, and*
(c) *students' discipline.*

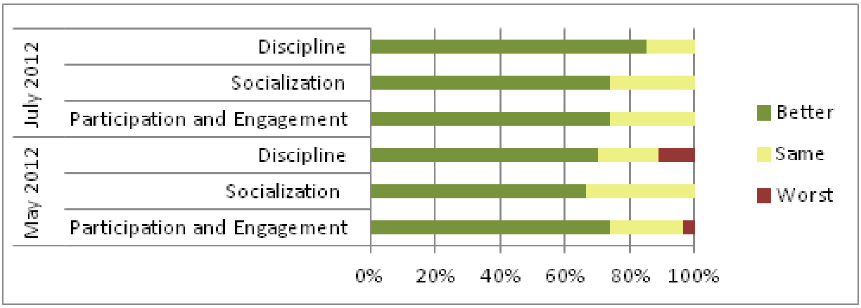


Figure 57. Average Evaluation of the Sixth Grade Pupils' Behavior with the Use of the Mobile Phone by Their Teacher during the Long Field Study.

Teachers grade each pupil individually with a scale from 1 to 3 (1=better, 2= same, 3=worst). The evaluation made by the teacher is shown on Figure 57. In general, both teachers considered that most children showed improvement in their behavior when using the mobile phones.

8.3.1 Interview with Teacher

Three months after starting the study as well as at the end of the study we conducted open interviews (30 minutes each) with the male teacher. In these interviews, we addressed the following topics: impact on teaching and learning, discipline and motivation, effect on interaction between children, opportunities that arise with phones in the classroom, and finally risks and how to deal with them. In the following we report some of the insights that were most interesting to us. We have to point out that the teacher knows his pupils well as he had been teaching them for three years.

8.3.1.1 Motivation to Learn

Just before the field study, three pupils of the selected class (it consisted of 25 pupils before) showed a peculiar behavior. They did not show up regularly at school and showed a bad behavior at school. The teacher reported: "*I have students with really serious problems at home, like parents in jail because of drugs, […] who show a bad behavior and a bad performance in class"* Two of them finally left school permanently. The third student instead changed his behavior with the beginning of the study. According to the teacher, this person showed a radical change in his behavior, attended the classes regularly, and became much more active in class. *"<Name> has made a 180° degree change, at the beginning of the school year he was undisciplined, did not attend classes, nor do assignments, etc. Now he started to be more engaged at school, improved his grades and finally passed the exam to continue to grade seven. And I think that the use of a mobile phone has positively influenced this change."*

The teacher also noted a change in the conduct of his pupils: *"There was a positive change. Students who were not used to participate in class or work on assignments,[…] one [could] see them working and being engaged in the learning tasks… Students who were timid and did not ask questions […] started to put their hands up.*"

8.3.1.2 The Phone as a Tool for Learning and Teaching

When asked about what feature the mobile phone needs to have to be the perfect tool for learning, the teacher answered that *"if it would exist the possibility to have a good Internet connection available, a good big antenna, that allows downloading information and educational videos faster without the need to buy mobile Internet or to move to the front yard. This would be perfect. We used the Internet several times but the Internet was very slow and inconsistent [unreliable]. Mainly those kids who paid [mobile Internet] get better access to* *it… With all these phone companies in Panama, would it not be possible for one of them to install a good Internet antenna at school?* "

Internet for mobile phones was considered as a very useful tool for learning: "*Children can gather Information about the topic we are introducing and discussing… or they can search videos and then download them to their phones and watch them later, it is simply fantastic*."

As a final note, the teacher underlined the increased mobility of the phones:

"[…] if I could give a mobile phone to each child instead of using a computer... it would be easier to transport... The student has direct access to the information in his/her pocket, s/he does not have to move [to the lab] and does not have to install all these tools and it would be more pragmatic. You search for something, save it and he reviews it whenever you want to."

8.3.1.3 Potential of Mobile Phones in Multigrade Schools

In very remote regions of Panama with less population, one can also find a multigrade school, i.e., schools where one teacher is teaching a class consisting of pupils from different grades at the same time. We also wanted to know if it would be possible to use phones in such schools and classes as well. When asked about such schools, the teacher first explained his experience on such a school.

"I was a multigrade teacher for about 10 years. I worked with the tribe [removed for blind review] in the mountains… This is a community that lives in extreme poverty … under inhuman conditions. I had 20 to 25 students from three [different] grades together … I had to be like MacGyver. […] This tool in multigrade schools will be incredible because we can assign a task to each child to develop while the teacher attends the other group. [Mobile] phones can support the teacher to better manage and distribute learning tasks according to age – similar to the approach followed in multigrade schools."

When we asked further about the access to technology and electricity he answered:

"T*o arrive there you need two hours by car with a four-wheel drive and during winter, instead of the car carrying people, people have to carry [push] the car… People there have simple cell phones and there is signal [network coverage]. […] And nowadays I hear there is electricity."*

8.3.1.4 Social Impact

The use of mobile phones caused other positive social effects to the pupils' behavior. Usually only child with the best grades gets awarded or is considered to take part in special or new academic projects. As we distributed a phone to every child, pupils felt that they were equally important and included by the school regardless their academic profile. This also implied that children behaved responsibly with regard to take care of the phone. The teachers underlined this positive effect and commented:

"The pupils feel more motivated and with a higher commitment to work with mobile phones as they feel themselves important. This arouses their responsibility to take care of the phone… No phone got damaged or lost."

Also, the use of mobile phones seems to be also having an influence in the engagement of non-academic activities done at school. As the school has a large number of students, it is often selected to participate in contests or other extracurricular activities. In those cases, not all the children participated in former times. Reasons to not do so, were related to shyness or because the kids simply did not want to.

"*X. is a girl who never participated [in such activities], I mean, she is good academically, but she does not want to participate in external activities… She [only] cares to get good marks ... I have told her mom, education is more: Behavior, performance, and attitude. It is not [the] only [goal] to have the best marks. […] N.N. is the best student [academically] of the whole school, but she is a very timid girl, and she does not participate in extra activities. But the main problem with her is that she is too quiet, and shy… She is afraid to ask [the teacher] – even if she does not understand [the explanation] – or is afraid to talk in front of the class. I organized an activity where students had to give a speech about moral values in groups of four to children of lower grades who attended also classes in the morning. […] I always did these extra activities at school, but now I wanted them to do it. Using the phone to record a video, watching the video, one can see the qualities everyone has […] We have [students with] outstanding voices… I wanted them to go to the other class and see that it is not easy to get other children to pay attention to whom is talking in front ... I accomplished for the very first time that X. participated and N. overcame her shyness."*

Recording videos was a way that the teacher considered as helpful for children to lose their shyness about talking in public. "*Some pupils look nervous when they film and then watch the video showing themselves… [They realize] it is normal* *that everyone needs to get rid of the fear to talk in front of an audience. […] But the engagement has been high...*" In addition he could observe that "*students also have improved a lot [with regard to] their self-confidence".*

However, the teacher will not recommend using phones for teaching every day:

"I would use the mobile phone [only] two days a week […] Part of maintaining the children's motivation for learning is to vary between activities. Therefore I assume that using [it] daily will considerably decrease the motivation and engagement of the children."

8.3.1.5 Discipline

Filming has helped the teacher to witness and control the behavior of problematic students as he explained:

"Although I have no discipline problem with most of my pupils, there are two pupils who are tremendous… When I complain to their parents or guardians on how they sometimes behave at school, their parents do not believe me. They think their kids are godsend […] The other day I used the [mobile phone] camera and filmed one of them while he was fighting against a child of another group before I proceeded to separate them. When I showed the video to his grandmother she was deeply shocked. […] That was the last fight."

The students' learning discipline also improved by using mobile phones as the teacher explained:

"Definitively the discipline is the first thing that improved, when the student is working with the mobile phone s/he is completely concentrated […] doing the assignment, or watching a video."

He also talked about the importance for teachers to know the latest technology:

"*Teachers should adapt to the [new] time […] Sometimes we [docents] say 'I do not like that, but we have to keep up-to-date ourselves […] The pupils already known all these technologies and if not they are fast in adopting them. We teachers have to keep up with the children in the use of technology."*

8.3.1.6 Supervision at Home

With regard to let the pupils use their phones at home, the teacher would recommend usage with caution and clear rules:

"*While I found the use of mobile phones for learning an excellent tool, I think their use at home needs to be controlled. At school, teachers can easily control who is working and who not. However, there are bad addresses [inappropriate web sites] that children should not have access to. Parents should carefully supervise the proper use of the phone as with any other technology. But the main problem is rather that some parents do not supervise what their children do at all.*"

When asked if we provide mechanisms that parents set what children access he answered to us:

"I do not think that any technical mechanism can help parents to manage what children access on the web because simply parents do not know about technologies [...] In fact, also the parents have a low level of education."

8.3.2 Interviews with Children

In order to understand the pupils' opinion on using mobile phones at school and at home, we conducted a group interview with all students. We wanted to know their impressions of using a phone during the study in general and the use of applications in specific. Due to time constraints it was not possible to do individual interviews. In order to minimize any bias due to group influence, we distributed an open questionnaire form to each participant that had to be completed and returned the same day and before the interview.

The children stated that there was no problem with learning how to use the phone. This is consistent to what we observed in the screenshots analysis: *"Although it was the first time I used a cell phone [...] it was easy to work with the phone. [...] No function was difficult for me [...] It was a good experience."*

The children admitted that they mainly used their phones for recreation at home: *"At home I used the phone to get [download] and listen to music I like." "Racing cars was my favorite game, I played almost every day." After having done my homework I watched photos [on the web] and [listened to] songs of Prince Royce [teenager singer]. The best photo I put on the screen [as a wallpaper]."*

Also, the children used the phones as status symbol: "*Now I can show my friends that I also have a music player"* In fact, only 3 participants owned a real mp3 player. Another pupil added: *"When I was bored at home I looked for new games to play on OVI*[22] *[…] Then I showed them to my friend the other day."*

The experience of painting was mainly received well by the pupils: "*Painting with a phone [i.e., the PaintPad application], is similar to painting with pencils only that here I can erase something without holding the paper*" Further the students liked that they "*can change colors while painting"*. However, other children preferred traditional painting due to being more creative or having more freedom: *"I prefer painting with paper and pencil because I can paint [the same color] stronger or softer […] On the phone there is no difference." "I like more paint in paper and pencil because I am more creative."*

The children found it useful to video record own presentations (section 6.4.5), some comments received were: "[*give a live presentation in the classroom] makes me nervous and [I] make mistakes", "in front of others I get nervous and forget everything what I have to say", "[filming my presentation] with the mobile phone I do not get nervous", "it is important to use new technologies"* and *"if I forget something I can record the presentation again"*.

8.3.3 Interviews with Parents and Guardians

At the end of the study, we discussed the concept of using mobile devices with 13 of the children's guardians (all female relatives; either mothers, grandmothers, or aunts). Although we tried to have a lively conversation, they were rather timid. Only six of them engaged a little more with us. We think that the shyness is due to their low schooling, and that they are, in case of older women, technology illiterate. However, only one woman did not own a mobile phone.

Their main concern was the loss of a device: "*My main concern was that the mobile phone gets lost and that I have to pay for it*" or "*it is a costly phone […] so I warned my daughter to really take care of it. […] I was always watching that she took care [of it] properly.*" They were also worried about a proper use of the mobile phone: *"In the news they always show the risk of young children when using such technology improperly. I was worried about a bad use of this device, is there a way to control [access to the] Internet?"* Another guardian stated: *"I find it positive and like that N.N. did assignments with more enthusiasm than before. But I dislike how addicted he became to the device. I have to forbid usage while we eat."*

[22] *http://store.ovi.com/, last accessed on September 30, 2014.*

One guardian also commented the social impact of the use of the phone: "*I observed a new attitude and behavior of my grandson at home and school. He was motivated to attend classes, an engagement that was not there before the [study]*." Later we figured out that she was actually talking about the child who almost had left school forever.

Also, one participant commented how surprised she was about how fast their children adopted the technology and how they learned from them: *"I tried to help my child to film a video at home, my child explained everything in detail although he has never had such a modern phone before. This really impressed me […] how fast kids learn new technologies*". As a response, one mother added: "*My daughter taught me how to use Bluetooth with my phone.*"

The fact that all children were considered for the study was also pointed out by one mother: "*Finally all children and not only the best pupils were considered to take part in the project. They usually only award children with good marks… I think that all children should receive the same treatment.*" Using a projector, we showed some examples of the content created by the class while using the phone. "*I am still surprised that all this can be created with modern phones. It is amazing!*"

8.4 Summary and Discussion

Mobile phones have a great potential as learning tools. In the learning process children need to learn to use the basic functions and a variety of applications of the mobile phone to utilize the tool. Children are fast to adopt these skills, especially if they find the device interesting. Games and media applications can have an important role in maintaining interest and introducing new functions. On the other hand, such applications can distract the actual learning process.

A design challenge for future mobile learning devices is to balance pragmatic learning activities and free exploration. Our results indicate that there is a notable gender difference in how much children weight these activities. As we reported in section 8.1, during the short studies, boys are more active in free exploration and learning new applications, games in particular. Therefore, boys discover the basic functions of the phone faster. Girls are typically more focused on the learning task, but may be accidentally interrupted by problems in operating the device. One possible reason discouraging girls from exploration is that the existing games are more targeted towards boys.

Our initial findings reveal that during the initial phase of use, boys adopt mobile phone usage faster and explore more functionality; while girls take more time to familiarize themselves with the phones. Girls seem to maintain a better focus on the learning activities using the mobile phones across all tasks. When the task implies an active role then boys also showed high concentration. The videos recorded by the children as part of the learning activities showed a remarkable difference in roles between girls and boys. These findings suggest that it is important to consider the different adoption and exploration strategies of girls and boys with new technologies when designing tools for mobile learning.

Whereas in section 8.1 we reported about the novelty effect in the adoption of mobile phones during the short field study, in contrast in sections 8.2 and 8.3 we wanted to understand the impact of using mobile phones as educational tools on teaching and learning beyond the novelty effect. We did neither enforce certain usage patterns nor did we prescribe how the phones should be used. It was deliberately set up so that the teacher could use the phone in ways he considered it useful for his teaching and beneficial for the students. During the study there was almost no interference by the researchers and the data was collected automatically by capturing screenshots every 20 seconds. Over the course of the study more than 1.5 million screenshots were taken and analyzed in parts.

The most prominent use cases found in the long-term study were accessing the Internet as well as using the phone as a camera, as a playback device, or as a replacement for copying machines. Having the phones available at all times allowed the teacher to spontaneously make use of information available on the Internet and enabled him to give different task to students and hence to differentiate on their ability. Using mobile phones as audio player and playing games were the most prominent use cases at home. A common pattern observed was the sharing of songs and the sending of games between students. Through interviews with the teacher, children, and guardians we learned about a strong motivational effect of using phones as educational tool. This effect lasted over the duration of the entire study. According to the interview with the teacher, the use of the mobile phone did not worsen the discipline, participation and behave pattern of the students in the classroom, but maintain them or even improve them.

Concerns about abuse and misuse of the technology were prevalent among the parents. The software for taking screenshots, initially designed as research tool, served a second purpose: supervision. As children knew their actions were monitored, we did not observe inappropriate use. However we did not explore this issue in detail and it remains to further research to investigate how effective and acceptable monitoring can be realized, without violating the need for private spaces in the use of mobile technologies.

Chapter 9

Children's Handwriting on Touchscreen Phones

Currently touchscreen phones are designed mainly for finger interaction, rather than stylus interaction. These phones build up on capacitive technology and are sold usually without an included stylus. However, pupils usually write (on paper) using pen/pencil and not with their finger. As touch screens support handwriting (even if they do not support handwriting recognition) they have the potential to become a ubiquitous learning platform.

Drawing and writing on paper is important in almost all subjects in elementary school. While paper is generally cheap, providing tasks to pupils on paper can be a major challenge. Teachers in developing countries often have no access to a photocopying machine. Further, children do not own their books and therefore cannot write or draw in them.

The use of computers plays a minimal role in daily teaching. Keyboards, the traditional input modality in most schools' computer labs, are not suitable for writing with children in primary school [Berninger, et al, 2009; Read et al., 2005]. In addition, for primary schools in developing countries computers are too costly and require too much infrastructure. In contrast, mobile phones currently become more popular (cf. section 3.5), robust and recent devices with touchscreens support natural handwriting using a stylus and fingers.

In chapter 7 we showed that camera phones with touchscreens offer exciting opportunities. Instead of distributing paper copies to pupils, teachers take photos of tasks from text books and distributed the images to the kids via Bluetooth. The children write the tasks directly on their touchscreen. Touchscreen phones offer apparent advantages compared to paper. However,children's writing and drawing performance on touchscreens phones compared to writing on paper has not been investigated. Different touchscreen technologies exist but it is not clear which technology results in the best performance and legibility.

Part of this chapter is based on the following publication:

[Valderrama Bahamondez *et al.*, 2013] Valderrama Bahamondez, E., Kubitza, T., Henze, N., & Schmidt, A. (2013). Analysis of Children's Handwriting on Touchscreen Phones. In *Proceedings of the 15th International Conference on Human Computer Interaction with Mobile Devices and Services* (MobileHCI '13), 171-174, ACM. DOI: http://dx.doi.org/10.1145/2493190.2493222

9.1 Text Input on Touchscreen Phones

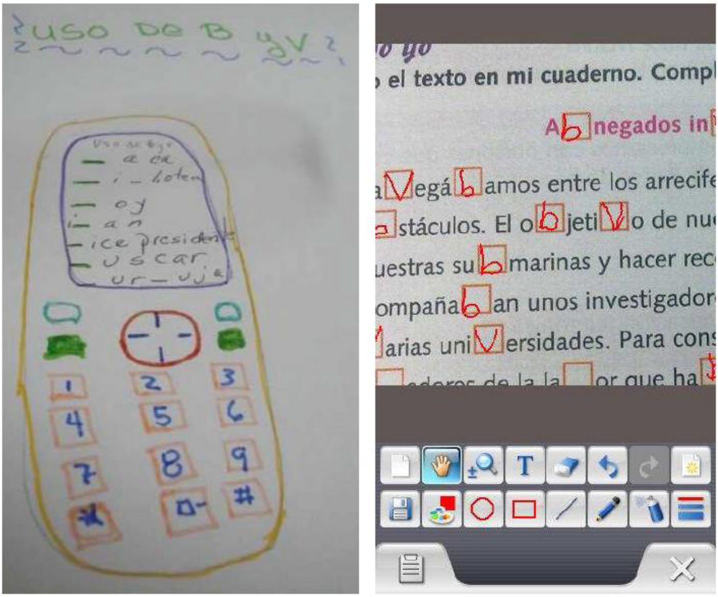


Figure 58. Filling the Blanks with b or v in Spanish Lessons using the Mobile Phone. Learning task designed by teachers during an interview (left) and during the field study.

Undoubtedly handwriting and painting play a crucial role in the teaching process in elementary schools. Many activities during the reinforcement and synthesis phases, as well as in the evaluation phase include writing activities. For instance filling blanks in exercises, creates conceptual maps (see section 7.3), or quizzes require writing. Despite, the limited screen size of mobile phone, teachers designed examples of learning activities that could require simple text input independently of the input text mechanisms of the device (see Figure 58). However, teachers considered other text input applications such as text messaging (SMS) negative for learning (see section 4.3.2). They considered that the current writing practices during text messaging have a negative impact on the language capabilities of pupils. For teachers in elementary schools, good practices on writing correctly the language are crucial, as younger children are just learning the grammar and syntax rules of the written language.

9.1.1 Handwriting vs. Writing with Virtual Keyboard

From our field study we observed that all the children worked well with the tasks involved with the stylus and the painting application. As the stylus supported the handwriting of the children well and was easily understood, this seemed to be a good choice. One teacher commented about the handwriting on the phone: *"they use it like a pencil"*. However when children had to input the names to the files they created, we observed some problems. All the children had initially problems to input their names using the virtual keypad. Two main inconveniences were raised: first the keypad mechanism itself: each key represents three letters which confuses the children how to use this. This problem was observed along the whole field study. Figure 59 shows an example of text input when a child had to hit several times the key before getting the desired letter or number using the virtual keyboard. From left to right: In the first image the child typed letter *u* instead of letter *t*; in the following image another pupil wanted to type the letter *v* but wrote the number *8*; in the third image the correct letter was *u* but *ü came up;* in the last image the child typed *r* instead of *s*.

It was especially hard for those who were not familiar to writing with this type of system (42% of them for the short studies and 38% of the participants in the long study). We even observed this with some of the children who reported to have experience in writing SMS with keypad phones. This typing-problem was also observed when using the virtual qwerty-keyword. Further analyses should be done, i.e., with a real keypad. Our initial findings indicated that handwritten text input is the more appropriate input method for these target users.

Figure 59. Examples of Typical Typing Errors Observed by Children in the Study.

Although children can (hand)write content very well on the mobile phones, we observed that the tasks involving filling in blanks in the drawing application is difficult to understand by teachers for younger pupils (see Figure 60). The inclusion of character recognition in drawing application in the tasks involved could help teacher to understand better the writing of their younger pupils.

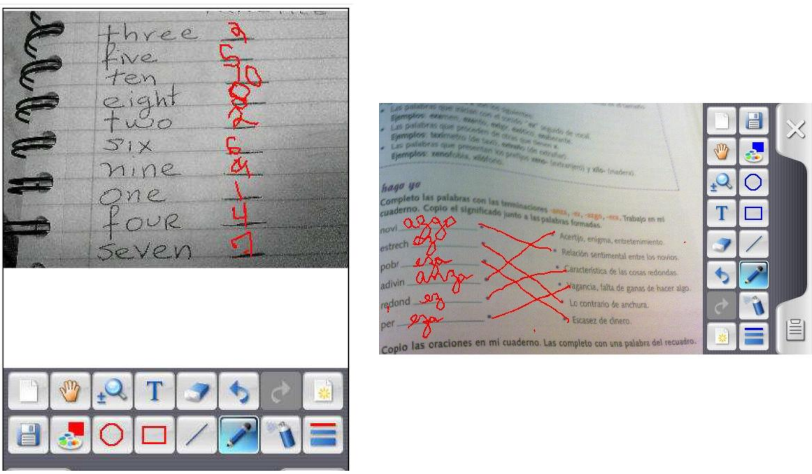


Figure 60 . Examples of Character Input by a Child of Fourth Grade (left) and a Child from Sixth Grade (right).

9.2 Short Overview of Touch Screen Technology

The Oxford Online dictionary defines touchscreen as "*a display device which allows the user to interact with a computer by touching areas on the screen*" [Touchscreen, 2014]. A concept of a touchscreen computer was described by E.A. Johnson between 1965 and 1967 [Johnson, 1965; Johnson, 1967]:

> "*A novel input/output device for computer systems has wires, sensitive to the touch of a finger, on the face of a cathode-ray tube on which information can be written by the computer. This device, the `touch display', provides a very efficient coupling between man and machine*." [Johnson, 1965]

In general the main touchscreen's technologies are infrared grid, resistive, capacitive, and surface acoustical wave [Bhalla & Bhalla, 2010]. Essentially, all touchscreen technology interprets the point of interaction into an X-Y coordinate, only differs in the medium how to capture the position of the touch. In the following, we will briefly explain the resistive and capacitive touchscreen technologies which are the common approaches implemented on mobile phones.

9.2.1 Resistive Touchscreen Technology

Resistive screens are pressure sensitive. They use two active layers: a flexible plastic layer on top of a rigid plastic or glass layer, with insulated spacers in between. The layers are coated with indium tin oxide, and different voltages are applied across the coatings, typically alternating between the layers. When touched, the front layer picks up the voltage from the back, and the back layer picks up the voltage from the front, enabling the controller to determine the X-Y location. Resistive touchscreens are sensitive to the touch of any object that presses the screen.

9.2.2 Capacitive Touchscreen Technology

The capacitive method uses a single metallic-coated glass panel, which is more diaphanous than the resistive method. Voltage is applied to the corners of the screen, and when a finger touches the screen, it draws a tiny amount of charge. The controller computes the X-Y location from the change in capacitance at the touch point. Capacitive touchscreens are sensitive to the touch of conductive objects such as human fingers; currently there are also capacitive styluses available.

9.3 Case Study 1: Analysis of Children's Handwriting on Touchscreen Phones in Panama

So far handwriting is practiced mainly on paper and blackboards. Providing tasks on paper can be challenging in developing countries. With the potential availability of mobile phones in classrooms, there is a new medium that may be used for this purpose. We determined the effect of different touch technologies on children's handwriting in a study with 38 children (Figure 61 shows a participant in the study). Children drew and wrote using different input techniques. We measured their performance and asked teachers to assess the legibility. The findings suggest that in general writing on touchscreens is significantly less readable and slower than on paper. Further, the comparison of touchscreen technologies indicates that capacitive screens operated with a stylus yield the highest readability and are faster to be used for writing than resistive screens. In contrast to these quantitative findings younger pupils indicated that they prefer resistive screens with a thin stylus compared to using capacitive screens with a stylus or the fingers.

Figure 61. Study Participant in a Public Primary School in Panama

In this section we compare writing on capacitive and resistive screens using stylus and finger with writing on paper. We measure writing speed, number of strokes per character, collect qualitative feedback and ask experts to assess the legibility. While the use of smartphones has apparent advantages, our results indicate that touchscreens are slower to use than paper and that the legibility of writing on paper is not achieved. Comparing the phones, capacitive screens used with a stylus are the best option, regarding speed and legibility. However, subjective feedback suggests that younger children prefer resistive screens used with a thin stylus.

9.3.1 Related Work

Read et al. compared writing on a Wacom® tablet, speech, mouse & virtual keyboard and real keyboard with children [Read *et al.*, 2001]. They conclude that performance with tablet and keyboard is similar but the small sample size precludes general statements about their usability. Read et al. further compared pen & paper, handwriting on a Wacom® tablet, and keyboard with children [Read *et al.*, 2005] and conclude that writing with the tablet is as efficient as writing using pen & paper. In [Berninger *et al.*, 2009] the authors study the creation of written text between children with and without writing learning disabilities using the QWERTY keyboard, and paper and pen. They conclude that handwriting with pen and pencil has better performance for writing text than keyboard, for both children those with and without writing learning disabilities.

Only few studies compared finger and stylus interaction. Holzinger et al. showed that the performance and accuracy of stylus interaction on a tablet PC for a medical application is superior to the use of a finger [Holzinger *et al.*, 2008]. Tu et al. [Tu *et al.*, 2012] compared single stroke gestures using stylus or finger. They programmatically analyzed the strokes drawn by adult participants and show that using fingers and styli results in similar performance but using the fingers is generally faster. McKnight and Cassidy explored the behavior and attitude of children using different touchscreen devices, including interaction with finger and stylus for general interaction [McKnight & Cassidy, 2010]. Here children showed a preference towards using a stylus.

While Read et al. showed that using large graphic tablets is comparable to using pen & paper [Read *et al.*, 2004] we are interested in much smaller touchscreen phones. In contrast to [Holzinger *et al.*, 2008; Tu *et al.*, 2012] we study writing and specifically address children that might have completely different requirements. Therefore we compare the performance of children writing and drawing on touchscreens using stylus and finger with a special focus on the legibility of their handwriting. As speed and legibility of handwriting are the main features assessed by teachers and pedagogies [Pollock, et al., 2009] [Koziatek & Powell, 2002] when monitoring progress of children we consider time, speed, the number of strokes, and legibility as the main performance measures.

9.3.2 Methodology and Study Setup

We conducted a repeated measures experiment to assess the effect of the input modality on children's writing and drawing performance. The study was conducted in two primary schools in Panama. We compared four conditions. Children used a Nokia Xpress Music 5530 with a resistive touchscreen and the standard stylus. In addition, they used a Samsung Galaxy Nexus with their fingers and an Amazon Basic stylus. We used pen & paper as control condition.

Children had to complete six tasks. We designed the tasks with the children's teachers to make them appropriate for children's age. In the first four tasks the children had to draw two lines, a square, a circle, and a tree. In the fifth task the children wrote numbers from 0 to 9 and in the last task they wrote a sentence with five words. Figure 62 shows this sentence for each condition written by the same child.

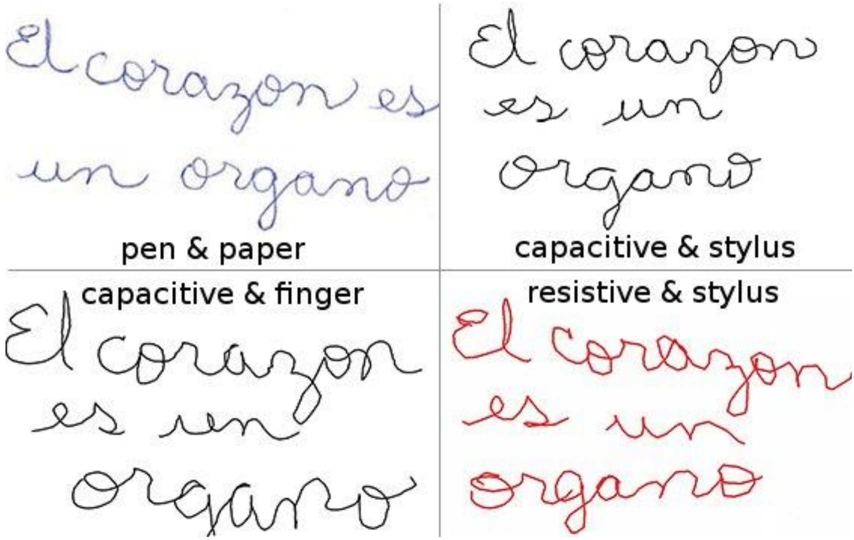


Figure 62 Phrases from One Child from Third Grade Using the Four Alternatives

We assessed children's writing performance using three measures. We determine the task completion time for all tasks. According to teachers, pupils should write a word continuous without leaving the pen from the paper before ending the word. Therefore, we counted the number of strokes to complete the given sentence. All sessions were recorded on video. Screenshots or photos of all results were taken. After the study each child answered a guided feedback questionnaire. We assessed the legibility afterwards by asking 13 school teachers to rate each of the 138 series of written numbers in an online survey.

In total 38 pupils participated in the study (18 female, one left handed). On average children were 10.2 years and attended the third or the sixth grade. 37 were between 8 and 13 years old. One child with learning disabilities was 15 years old. Only 7.9% never used a mobile phone before and 23.7% of them had already experience with a touchscreen device (e.g. Nintendo DS, touchscreen tablet or phone).

Each child repeated the six tasks using the four conditions resulting in 24 tasks in total. We used Latin square to counterbalance the order of the conditions. In total, the duration of the study was about 40 to 50 minutes per child. Beforehand, each child was given the same time to familiarize with both mobile phones and the use of finger and stylus.

9.3.3 Results

In the following we analyze the children's speed, the handwriting readability assessed by teachers, and children's preferences. Furthermore we describe the observations made during the study. We used an Analysis of Variance (ANOVA) to analyze the means and used t-tests to compare the conditions. We used a Holm–Bonferroni correction to prevent inflation of Type I errors for post-hoc analysis.

9.3.3.1 Handwriting Performance

We analyzed the handwriting performance using the four conditions by comparing the task completion time and number of strokes the children did when writing.

Task completion time

The average time to complete each of the six tasks is shown in Table 15. On average, children were slightly slower using pen & paper to draw lines, squares, and circles compared to the touchscreen devices. An ANOVA showed that the input modality had a significant effect on the time to draw a line ($p<.05$). Follow up post-hoc tests did not reveal a significant difference between the conditions. We also did not found an effect of the input modality on the time to draw a circle (p=.51) or a square (p=.51). On average children draw the tree the fastest by using capacitive screen and stylus but the effect is not significant (p=.06).

The numbers were written the fastest using pen and paper, followed by the capacitive phone with the stylus and the capacitive phone with finger. Using the stylus with resistive screen required the longest time. An ANOVA showed that the input modality had a significant effect on the time to write the numbers ($F_{3,111}$=8.13, p<.001). Post-hoc tests revealed significant differences between the conditions. Only the difference between resistive screen with stylus and capacitive screen with fingers is not significant (p=.83).

The phrases were written the fastest using pen and paper, followed by using the capacitive screen with a stylus. The input modality had a significant effect on the time to write a phrase ($F_{3,111}$=5.29, p<.001). Participants were significantly faster using pen and paper than using the capacitive screen with their fingers (p<.01) or using the resistive screen with a stylus (p<.01). All other differences are not significant.

Table 15. Average Task Completion Time for the Six Tasks (in Seconds) and the Standard Deviation (σ).

Item	pen and paper	capacitive and stylus	capacitive and finger	resistive and stylus
Lines	1.9, σ=1.3	1.4, σ=0.9	1.5, σ=0.8	1.5, σ=1.0
Square	4.5, σ=3.5	4.1, σ=2.9	3.5, σ=1.8	4.2, σ=3.5
Circle	2.2, σ=1.4	2.0, σ=1.3	2.2, σ=1.4	2.1, σ=1.2
Tree	13.0, σ=16.1	9.4, σ=7.3	12.9, σ=10.5	13.3, σ=11.4
Numbers	22.1, σ=13.7	26.9, σ=9.6	33.8, σ=14.1	36.4, σ=13.9
Phrases	18.3, σ=11.2	23.7, σ=8.5	27.8, σ=12.9	28.5, σ=10.5

Number of strokes to complete the phrase

The analyzed sentence had 5 words, so there is a minimum of 5 strokes needed to write it. On average, participants needed 7.2 strokes (SD=3.7) using pen and paper, 7.5 strokes (SD=4.3) using the capacitive screen with a stylus, 8.6 strokes (SD=5.2) using the capacitive screen with their finger and 8.5 strokes (SD=8.6) using the resistive screen with a stylus. A Friedman test, however, did not reveal a significant difference X_{23}=1.82, p=.61).

9.3.3.2 Children's Subjective Feedback

Participants were asked to rate the touchscreen alternatives after completing all tasks. In general, they stated that drawing was easiest using the capacitive touchscreen with a stylus (37.7%) or the finger (40.5%). 21.8% preferred the resistive screen. For the writing tasks, 50.0% preferred to use the capacitive phone and the stylus followed by the resistive screen (39.0%) and the capacitive phone with the finger (11.0%).

However, the preferences changed among grades. Participants from the 6th grade preferred the capacitive screen with finger for drawing (50.0%), and the capacitive screen with stylus for writing (55.0%). Participants from the 3rd grade preferred the resistive screen for writing (50.0%), and both phones with the stylus were equally preferred for drawing (36.8%). Overall, young participants found it easier to grasp the resistive stylus than the capacitive stylus. One participant, for example, commented *"I can better control the* small *pen than the bigger pen"*. Figure 63 presented the children's preferences in writing and drawing.

9.3.3.3 Further Observation and Qualitative Findings

We observe two approaches in the way participants grasp the phone: participants who did not hold the device while writing, like the girl shown in Figure 63, and participants who secured the device on the table with their non-dominant hand. Only one participant held the phone with their non-dominant hand in the air, while attempting to write with the other hand. We observed in many cases that participants who initially followed the first approach experienced movement of the device. They also had to start using their non-dominant hand to hold the device on the table.

Some participants had problems while writing on the phones. In particular, unintentional lines were drawn when the border of the touchscreen was touched by the participants' hands. The following numbers of unintended lines were drawn: 20 on the capacitive screen with stylus, 29 on the capacitive screen with fingers, and 18 with the resistive screen. Participants unintentionally exited the application on the capacitive phone. Some participants attempted to write very close to the bezel of the screen. This was observed on both phones, in particular with the stylus. Further problems were, for example, using too much force when pressing the stylus against the capacitive touchscreen, holding the pen at an extreme angle or touching the screen at multiple points, which all resulted in failed writing attempts.

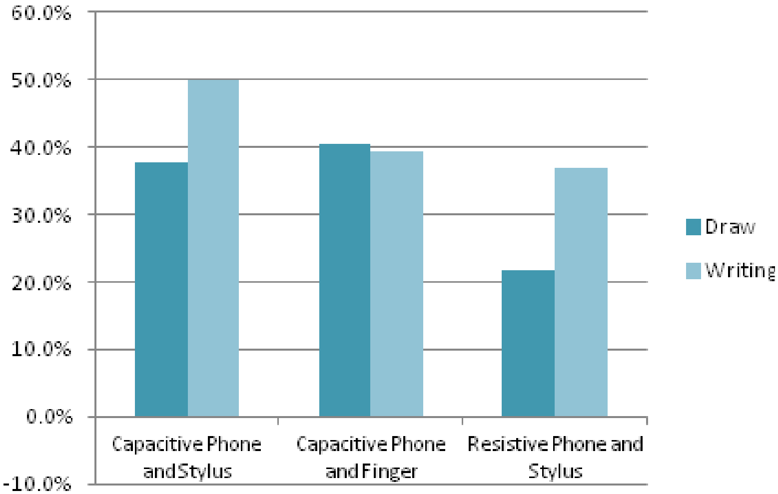


Figure 63. Children's Preferences in Writing and Drawing

9.3.3.4 Legibility

Teachers commonly assess handwriting legibility by looking at the slant, letter formation, spacing, alignment and size [Pollock, et al., 2009]. Experts concur that legibility should consider the words as whole rather than singles strokes [Pollock, et al., 2009; Koziatek & Powell, 2002].

We created an online survey were each page included four phone screenshots showing handwritten numbers. Each screenshot showed a sample from one of the four conditions. The images were taken from the set of numbers written by 38 children. 13 teachers classified the writing samples from most readable (best) to least readable. They also compared the similarity of the phone based writing with the ones created with paper and pencil. Because of the large number of samples gathered during the user study (about 912), we only used the set of numbers (N) for the comparison. Numbers were well known by all the participants and could also be easily verified by teachers. In total 10 female and 3 male primary school teachers took part in the survey. The average age of the teachers was 41.7 years.

Teachers considered by far (91%) the most legible set of number, those written by using paper & pen. Numbers written on the capacitive touchscreen phone were considered the second most legible (45%). At the same time a similar percentage of teachers (44%) considered the numbers written using the finger on the same phone as least readable. Regarding the resistive touchscreen phone with stylus, the opinion of the teachers was mixed, with no clear trend. Table 16 shows the teachers' perception of the legibility of the set of numbers.

With respect to the similarity of the phone based writing to the ones created with paper and pencil half of the teachers considered the numbers written using the capacitive touchscreen phone and stylus the most similar to those written with paper and pencil.

Table 16. Legibility of the Handwriting Assessed by Teachers.

Item	most legible	2^{nd} most legible	3^{rd} most legible	least legible
pen & paper	91.9%	4.3%	0.8%	3.0%
capacitive & stylus	4.6%	46.3%	31.2%	17.9%
capacitive & finger	2.4%	26.0%	31.4%	40.1%
resistive & stylus	1.1%	23.3%	36.6%	39.0%

9.4 Case Study 2: Handwriting Analysis in Younger Children

We tried to conduct the same study described on section 9.3 with children from first grade in Panama, but after conducted the study with four children we realized that all the draws and letters were not legible. Therefore we conducted a second study in Germany in order to analyze the handwriting in younger children who just learn how to write. In this study participated 15 children: 11 girls and 4 boys. Only one child owned a mobile phone, but 11 have used a mobile phone before. Ten children stated to have experience with touchscreen devices before (e.g. Nintendo, touchscreen phones). All children attended a public primary school in a small village in Baden Württemberg in Germany. The children knew how to read and write; their writing was in blocks and they were between 6 and 8 years old, with an average age of 6.86. We conducted this study by July shortly before they end the academic year.

9.4.1 Methodology and Study Setup

We used the same methodology described in section 9.3.2. With the help of the first grade teacher we selected a subset of the tasks realized during the former case study (9.3.2). Children had to write the word "Hose" (pants), the numbers (0 to 9), draw a tree and square under the same four conditions (Pen & paper, Capacitive & Stylus, Capacitive & Finger and Resistive & Stylus) described in section 9.3.2.

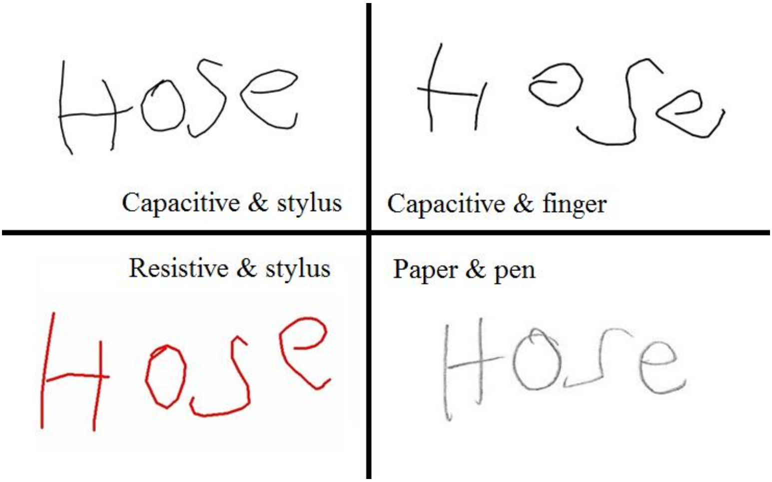


Figure 64. Word Written from One Child From First Grade using the Four Alternatives.

Each child repeated the four tasks using the four conditions resulting in 16 tasks in total. We used Latin square to counterbalance the order of the conditions. The sessions were also video recorded. In total, the duration of the study was about 40 minutes per child. Beforehand, each child was given the same time to familiarize with both mobile phones and the use of fingers and stylus. Figure 64 shows this sentence for each condition written by the same child.

9.4.2 Handwriting Performance

The average time to complete each of the six tasks is shown in Table 17. The shortest average time for drawing a square was achieved using a finger on a capacitive phone and it took longest with a stylus on resistive phone. Table 17 shows the average time needed to complete all the 16 tasks. The tree drawing has the best time using the resistive phone and the stylus, and the longest time when using paper and pencil. However, the ANOVA-test applied on the data has shown no statistical significance.

Table 17. Average Task Completion time for the Four Tasks.

Item	pen & paper	capacitive & stylus	capacitive & finger	resistive & stylus
square	5.8s	5.5s	5.4s	6.6s
tree	15.3s	13.4s	13.4s	10.6s
numbers	19.1s	30.2s	26.1s	26.7s
word	6.9s	10.6s	10.2s	10.0s

The numbers were written the fastest using paper and pencil, followed by the capacitive phone and the stylus; the capacitive phone with finger required the longest time. These results are of statistical significance (p=0.00016). The use of paper and pencil showed clearly the best average time for writing the word (W). The time required on the other devices was significantly slower than on paper (ANOVA-test showed a statistical significance p=0.03536), but there was little difference between the devices ($\bar{x}_{Rs} = 10.0s$, $\bar{x}_{CF} = 10.2$ ms, $\bar{x}_{CS} = 10.6$ ms).

9.4.3 Children's Subjective Feedback

After the completion of the tasks, we asked the children about their opinion on the different technologies presented. Most children preferred to draw with the capacitive phone and the stylus. However for writing they preferred to use the resistive phone and the stylus. The use of capacitive phone and finger was the least preferred for both drawing and writing. Figure 65 shows the children's preferences for writing and drawing.

Comparing with the feedback reported by our earlier study (section 9.2.3.2) we observe a similar trend among the younger children. Pupils from 1st and 3rd grade preferred writing with the resistive and stylus while the older ones (6th) preferred the capacitive phone and stylus. The use of capacitive phones with the finger for writing was the least preferred option among all children. Figure 65 showed a comparison of the children's preferences among the three grades.

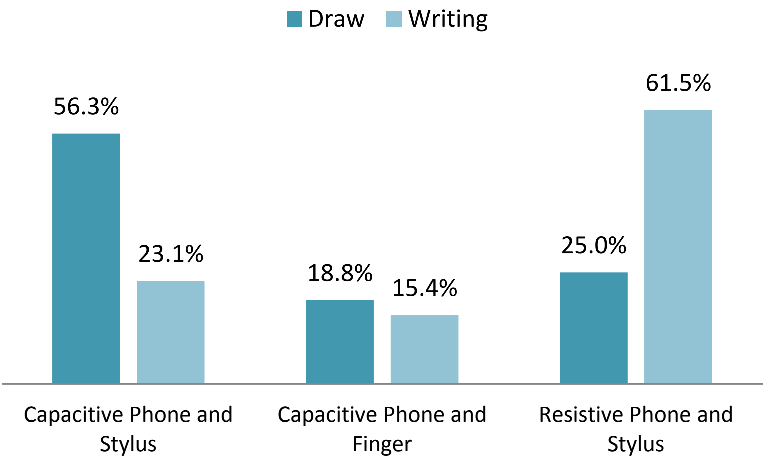


Figure 65. First Grade Children's Preferences in Writing and Drawing.

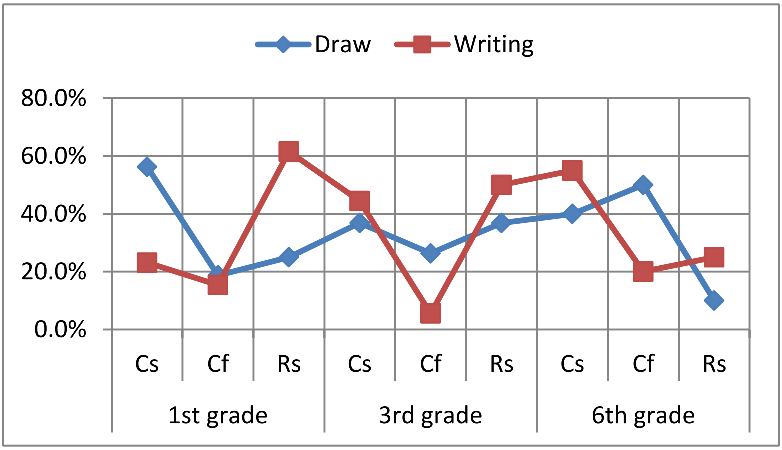


Figure 66. Comparison of the Children's Preferences among all the Students.

9.4.4 Legibility

We follow the same procedure on evaluating legibility as described in 9.2.3.4.Teachers evaluate the 60 samples of sets of number written by children from 1st grade under the four conditions. Figure 67 presents a single example that teachers had to evaluate.

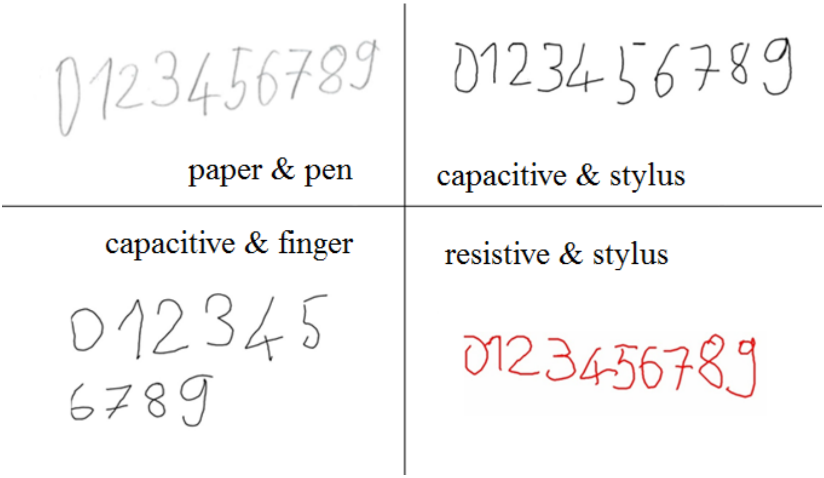


Figure 67. Legibility Sample: set of number written by a first grade pupil under the four conditions.

Most teachers also considered the numbers written with pen and pencil by the younger children the most legible (89.7%), and the number written using the capacitive phone with the stylus as legible (41.4%). The numbers written using the finger and the capacitive phone were considered the least legible by teachers. Teachers did not show a clear trend with respect to the set of numbers written using the resistive phone. All the findings were similar to those reported on section 9.3.3.4. Figure 68 shows the results.

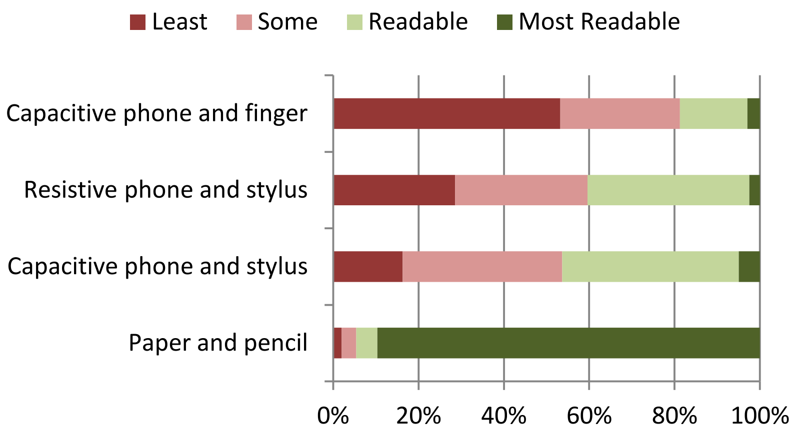


Figure 68. Teachers' Perception of the Legibility of the Set of Numbers Written by the Children from First Grade under the Four Conditions (P_P, C_S, R_S and C_F)

9.4.5 Further Observation and Qualitative Findings

We also observe with younger children similar problems as those reported in section 9.3.3.3. The number of accidentally drawn lines was 8 for Capacitive & Stylus, 4 for Capacitive & Finger and 2 for Resistive Screen & Stylus, most of them were observed when writing numbers. Failed writing attempts describe in section 9.3.3.3 were mainly observed in the case of 1st grade children when they used a capacitive phone and stylus.

9.5 Summary and Discussion

Existing touchscreen phones offer an opportunity to improve education in developing countries. In contrast to PCs they require little infrastructure and offer the opportunity to support handwriting using fingers or styli. Mobile touchscreen devices enable to easily recreate common learning tasks like entering short texts, filling blanks, or arithmetic operations [Ng & Nicholas, 2009; Valderrama Bahamondez *et al.*, 2011a]. In contrast to larger tablets, that might be more suitable, phones are simply much cheaper and portable. Previous work only investigated writing on much larger graphic tablets and analyzed gestures on touchscreens. In contrast, we conducted an experiment to compare different touchscreen technologies and input modalities to assess their effect on children's handwriting. We show that children (3^{rd} and 6^{th} grade) write phrases 28.5% faster with pen & paper than with any tested touchscreen technology. In addition, using pen & paper to write numbers is clearly considered more legible by experts. The results from the touchscreen comparison suggest that writing using a capacitive screen & stylus is considered faster and more legible than using the finger on the same device or using a different device's resistive screen. For younger children writing on the resistive phone with the stylus was faster than the other touchscreen technologies.

Handwriting by using a finger was not well liked by children. A potential reason is that writings with a stylus looked nicer. However, for drawing the finger was preferred by older children. Younger children preferred handwriting with the resistive phone. The thickness of the stylus seems to be a key factor for handwriting in the case of children. Our observations and feedback suggest that small children can control the thin resistive stylus better than the thicker capacitive one. In addition small children tend to press the stylus stronger against the surface than older kids.

In the experiment we used very simple tasks that we designed with children's teachers. While this simplicity limits the results, those tasks resemble typical assignments teachers give to their pupils. Not all participants would have been able to complete more complex or longer tasks. Comparing different phone models while aiming to determine the difference between resistive and capacitive screens we also had to vary the used stylus and screen size. Thus, we cannot ultimately be sure what causes the difference between the touchscreen technologies based on the quantitative results alone. By using standard devices that are ready to be used in the schools we provided valuable insights to them and can assess their effect compared to pen & paper and the difference between finger and stylus for capacitive screens.

We observed that preventing the movement of a paper sheet on the table is easier than doing this for a phone. A simple frame that stabilizes the phone's position on the table could therefore enhance the interaction. Such a frame could provide handles that also allow grasping the phone more easily. Similar to [McKnight & Cassidy, 2010], we observed unwanted contact with the screen, in particular when children held the stylus in their fist. The problem is that the wrist or part of the hand simultaneously touches the screen while attempting to write. An interesting approach to overcome this issue is implemented in iPad app studio pen[23]. After calibration, the software ignores touch contacts by the wrist.

[23] *Studio Pen. http://by-zero.com, last accessed on September 30, 2014.*

Chapter 10

Recommendations and UI Design Guidelines

Across the last chapters we have assessed the potential of the use of mobile phones for learning in developing countries like Panama. However, not all features of mobile phones seem to be suitable for the whole teaching flow, as we discuss in section 10.1. From the data collected previously and a new survey, we assess when and how the different features of the mobile phones can support better the current teaching flow of the Panamanian teachers.

Whereas multimedia mobile phones can be integrated for education without the installation of additional learning software, we observed some technical issues when children and teacher work with the mobile phones. A set of recommendations and UI design guidelines are presented in order that mobile phones support better learning experiences, and also to take in consideration the creation of educational applications for mobile phones in developing countries.

The chapter concludes with the presentation of a mobile tool that can empower local users in developing countries to create their own applications easily by using mobile phones.

This chapter is based on the following publications:

[Valderrama Bahamondez *et al.*, 2012] Valderrama Bahamondez, E., Häkkilä, J., & Schmidt, A. (2012). Towards Better UIs for Mobile Learning: Experiences in Using Mobile Phones as Multimedia Tools at Schools in Rural Panama. *Proceedings of the 11th International Conference on Mobile and Ubiquitous Multimedia (MUM '12),* 39: 1-4, ACM, DOI: http://dx.doi.org/10.1145/2406367.2406415

[Pfleging *et al.*, 2010] Pfleging, B., Valderrama Bahamondez, E., Schmidt, A., Hermes, M., & Nolte, J. MobiDev: A Mobile Development Kit for Combined Paper-Based and In-Situ Programming on the Mobile Phone. In *Extended Abstracts on SIGCHI Conference on Human Factors in Computing Systems (CHI 'EA 2010),* 3733-3738, ACM.
DOI: http://doi.acm.org/10.1145/1753846.1754047

10.1 Teaching Flow and Mobile Phones

We conducted a large set of interviews with more than one percent of the teachers working at elementary schools in Panama. For a complete description see chapter 4. Additionally we conducted a field study within a real classroom environment see chapter 6 and chapter 7. Combining all data collected, we got an impression of how teachers think of using mobile phones in class, and we found realistic use cases where mobile phones can be utilized inside a classroom.

In addition we conducted a survey with 38 teachers (9 male) to better understand the current teaching practices in Panama, and to know how they perceive the different multimedia features of the mobile phones and how they can fit in their teaching style. To avoid any bias teachers who participate in this survey have not been part before of any of our previous interviews or studies.

10.1.1 Understanding the Teaching Flow

One of the main goals of our studies was to identify the teaching flow at schools in Panama and how mobile phones can be integrated into the classroom and support the teaching flow. For our research, teaching flow refers to the different learning steps when an individual learns a new concept. From our interviews, observations and surveys we identified the following teaching pattern when it comes to teaching/learning a new concept at school:

❖ *Phase 1: Introduction of a new topic.* Brainstorming, environmental examples, a teacher's explanation and a variety of other techniques are used to introduce a new topic to pupils.

❖ *Phase 2: Reinforcement of the topic.* Solving tasks from books, completing questionnaires, using images, drawing, and painting are examples of activities that help pupils to understand the concept.

❖ *Phase 3: Creation of content and synthesis of the lesson learnt.* Once the concept is understood, speeches, debates, and posters are used to apply the knowledge; conceptual maps intend to summarize the concept learnt.

❖ *Phase 4: Evaluation*. An evaluation is mainly done as a summative assessment through written exams at the end of the process.

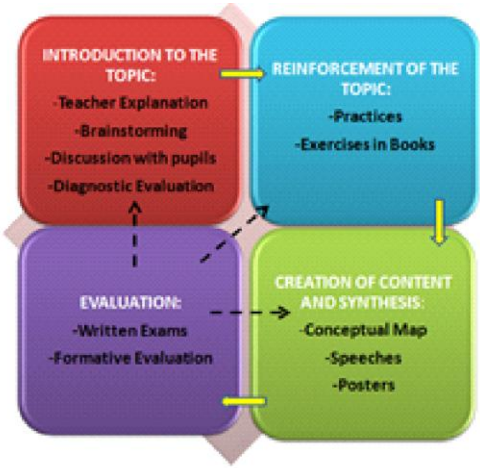


Figure 69. The Identified Teaching Flow Pattern for Teaching in Panama.

In general, the four phases of the teaching flow are sequential. Besides a concluding evaluation at the end of the teaching flow, other types of evaluation can be found during the whole process: During the introduction to a topic, some teachers also use diagnostic evaluation. Formative evaluation can be a part of the reinforcement of the topic and activities related to the creation of content and synthesis are also evaluated summative by the teachers. Figure 69 illustrates the teaching pattern used by the teachers in Panama. Teachers in Panama focus mainly on the evaluation of the classical learning progress of their pupils. Currently, the ability of the children to self-evaluate their work and to do critical (self-) assessments is rather neglected. The teaching flow adopted by teachers in Panama, is based in a subset of the Bloom Taxonomy [Huitt, 2004].

The analysis of the survey revealed that teachers use varying ways to introduce a topic, depending on the topic and the teacher's style. For example, 19% of the 21 teachers who explained how they present the human digestion process lesson to their pupils said that they use environmental examples (pupils bring some food to school, eat in class and have to explain what is happening). 75% of them start through a discussion. Next, all teachers explain the topic using an image. When referring to a multiplication table, teachers prefer to start the lesson directly with an explanation with examples, a video or a song.

10.1.2 Matching Mobile Phones to Support The Teaching Flow

The breakdown of the learning task realized during the short field studies (section 6.1.1 and 6.1.2) reveals that teachers worked on different learning goals across several subjects (Mathematics, English, Spanish, Social Science, Nature Science, and Religion). The teachers designed 67 learning activities; most of them included the use of more than one multimedia application or function of the mobile phone. Further details of the learning tasks are described in Appendix C.

During our field studies (cf. chapter 6) we observed that the applications and functions used on the mobile phone are dependent on the current phase of the teaching flow. For instance, the teachers used the following applications and functions of the mobile phone:

- Playing back and observing a video as an introduction of a new topic (phase 1).
- Taking photos of exercises that are printed in a book, filling them in on the screen, drawing pictures, and looking at information from the Internet to reinforce a topic (phase 2).
- Creating videos (by pupils) in the form of debates, talk shows, or individual videos or creating conceptual maps in Sticky Notes Touch as a synthesis of what they have learnt (phase 3).

❖ A critical self-assessment (phase 4) was observed when children listened to their own voice recordings and when they analyzed their English pronunciation. Some of the activities realized in phase 3 were also evaluated summative by teachers to assess the progress of their class.

Table 15. Classification of learning activities depending on the phase of the teaching flow

Learning activities realized by the children with the mobile phone	Total	Phase			
		1	2	3	4
Watching instructional videos	21	19	2	0	0
Record video files	16	4	9	3	0
Listen to audio files	4	0	4	0	0
Record audio files	2	0	2	1	0
Take only photos	3	0	0	1	0
Take a picture and editing it with PaintPad	11	0	9	0	2
Use Sticky Notes Touch	3	0	0	3	0
Only work with PaintPad	2	0	2	0	0
Look up information on the Internet (e.g., Google, Wikipedia)	5	0	5	0	0

In Table 15 we describe the different learning activities executed depending on the phase of the teaching flow. Both teachers and pupils used Bluetooth to transfer files between the teacher's phone and the pupils' phones. We do not look at this activity in detail during the analysis because it was used only as a communication channel in phase 1 and phase 4.

As the field study was only conducted with six teachers, we conducted an additional survey with 37 teachers to explore how they might use mobile phones during their teaching flow. While analyzing the findings from this survey, we realized that the teachers indicate similar trends regarding a potential use of multimedia and other applications in particular phases of the teaching flow as observed from the children (Figure 70).

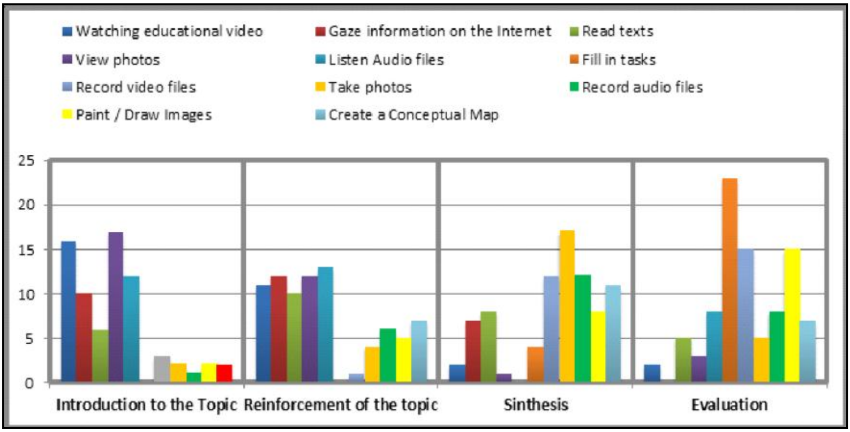


Figure 70. Possible Use of Technology during the Teaching and Learning Process according to the Identified Teaching Flow: (1) introduction to a new topic, (2) reinforcement of the topic, (3) synthesis and summary of the topic and (4) evaluation.

Teachers considered the following activities as useful when introducing a new topic: *view image/photos, watch instructional videos, listen to audio files, look up information on the Internet and read text documents*.

To reinforce knowledge in class, the teachers rated the following activities as useful: *listen to audio files, view images/photos and look up information on the Internet, watch instructional videos read text documents and create conceptual maps*.

Teachers also suggested that *taking photos, creating conceptual maps, recording audio/video files, creating presentations, painting/drawing images, and reading text documents* were the most suitable activities for the 3rd phase of the teaching flow (creation of content and synthesis of the lesson learnt).

Finally, *filling in tasks as an exam, solving quizzes; creating presentations, painting/drawing images, recording video/audio files, and creating conceptual maps* were considered the most useful activities to evaluate the progress of the pupils.

There is potential to improve the UI of phones to make them more suitable for use in teaching and in particular in schools. In the next section 10.2 we give some guidelines on how applications can be optimized to better support the teachers and children in their teaching and learning tasks.

10.2 General Application Design

To investigate the possibilities and obstacles in integrating mobile phones for children's education, we conducted a set of field studies. The methodology, participants and setup is explained in chapter 6, specifically section 6.1. During the field studies, teachers designed learning activities where they integrate the mobile phones to their daily teaching, which are explain in section 6.2 of the thesis. For the complete list of the learning activities done during the field studies please refers to the Appendix C of this thesis. Chapter 6, and chapter 7 presents several visual examples of the main outcomes of the learning activities done by the teacher during the field studies.

The major applications used during the field study were Camera (take photos / record videos), Recorder (record / play voice/audio files), Gallery (watch photos / videos), Messages (open files that were sent via Bluetooth – sending files mostly happened in the application where the content was created), PaintPad, and Sticky Notes Touch, which were installed to the phone prior to the study (cf. section 6.1.4).

In this section we present the findings of the interaction between the participants (children and teachers) and the mobile phones during the learning tasks. Based on these findings, we present some recommendations for the mobile phone UIs in order to better support the teaching process in class. The results show that there is potential for a tighter integration of applications to improve the learning experience.

10.2.1 Issues on a Navigational Level

The tasks designed by the participating teachers reflected a holistic approach in teaching the topic, and often involved the use of several phone applications during a lesson. Whereas the task flow made perfectly sense in the context of teaching and learning, it is evident that the phones did not support those flows as such. During the lesson, the children had to navigate through several applications and they often returned to other applications for several times**.** The navigation became especially problematic when the instructions and exercises could not be opened in the same application and in the same window. Additionally, the navigation from one application to another easily lead to a situation in which the children got distracted. The field study exposed the following issues:

(1) When children had to work with Paint Pad (which directly integrates the invocation of the camera), none of the children opened an application between taking a picture, storing it, and loading it in Paint Pad. The application itself

includes all these mechanism, so that the children do not need to navigate to different applications.

(2) In contrast to this, when the workflow required a navigation between applications, we found that some children were distracted. In a workflow from watching a video and then using Paint Pad in a classroom with 23 pupils (study-2), we observed that six of the pupils opened other applications. While navigating from Paint Pad to the File Manager to send the files via Bluetooth, we found out that five pupils opened other applications during the navigation. On the Nokia MusicXpress phone model used in our field study, for example, the drawing application was installed in the application menu, the option for playing videos was located under Gallery. First, the children had to navigate from the Gallery menu to the main menu, and then they selected the Applications menu, scrolled down and opened the Paint Pad application. Although these findings were realized in a specific model, we believe they can be extended to other models, too.

10.2.2 Issues Regarding a Holistic Design

Our research suggests that the use of different media could enrich and support the teaching flow as well. Simultaneously combining media, for example audio and video clips or audio clips and images can be useful for students and teachers. Simultaneously combining media, for example audio and video clips or audio clips and images can be useful for students and teachers. Figure 71 shows a learning task designed during one of the interview session (section 4.3.2) that suggests integrating audio and images.

During the study teachers use a variety of multimedia functions and features for explaining a lesson. Supporting teachers during the creation of teaching material is essential. Image, audio and especially video files were the main materials that teachers used for creating learning content for mobile phones. We consider that supporting the consumption and creation of 'media packages' is very helpful. The idea is to facilitate the development of tasks for the children, where all material required is included in one package. Thus, students receive the whole material they need to work at once.

Figure 71. Example of a combination of audio and image suggested by a teacher during the focus group (section 4.3.2), where students record their own voice to describe images

With respect to the reproduction of tasks from schoolbooks, the approach was to take a picture of the exercise in the book and then the children could fill it in using the paint application. This seems to be a practical and yet simple solution to integrate book exercises with phones, as book exercises continues to be one of the most used tools to teach.

10.2.2.1 Opening the Work Realized by Children

Children sent the files with their work to the teacher via Bluetooth, which arrives in the teachers' phone like a SMS. When teachers received these files, they intuitively tried to open and corrected immediately using the stylus. As these files are read-only when opened from the Inbox, correcting the files was not possible immediately. Instead, the teachers initially had to save the file, open the draw application, load the file, and were finally able to correct the file. Here, too, an integration of the different steps would be desirable.

Considering these findings, we believe that integrating key features into one application rather than having a set of separate ones can support the teaching flow better. It is expected that this decreases the effort for navigating between different applications. At the same time, we assume that this supports that children concentrate on a certain task by minimizing distraction.

10.2.3 UI Issues on the Application Level

On the phones we used general applications not being especially designed for teaching purposes. It was evident that they were not optimized for teaching and learning tasks. Some issues that we observe due to this missing optimization were:

Auto-save needed

While pupils did the tasks using the draw application, some children accidently closed the application without saving. When they return to the application, they had to start again from the beginning. For example in one of the lessons about 19% of the children lost their painting and had to start again.

Need of Autofocus in photos with text

There were in total 170 photos, related to learning activities taken by students from the study-2 (cf. section 6.1.2). Around 44% of them were out of focus. Furthermore, from the 112 photos content text, 46% were out of focus. In several occasions children needed more than three times to take pictures with legible text. Provide to the mobile phone camera with autofocus could support pupils better to take photos with text.

Larger indicator when video recording is ON/OFF

We observed during video recording tasks by children, that children faced problems to realize if they were filming or not. In total we analyzed 66 videos created by children in the multigrade school (section 6.1.1). Furthermore, 7% of the videos created by the children were not filmed correctly due to this confusion.

Audio quality indicator needed

62% of the videos filmed by the children in the multigrade school (section 6.1.1) had a very low audio volume. On the one hand, a classroom and school environment is usually very loud, which makes it difficult to capture the sound of the speaker correctly. On the other hand, some children speak with very low voices. During filming only little feedback on the audio quality is provided. Children realized that the audio recorded with the video was poor only after filming and hence they had to redo the filming. The video capture application on the mobile phone should provide feedback about volume level and quality when filming.

Applications should support Undo, Erase and Save

When children made mistakes while writing in a single note in the post-it notes application and wanted to correct it, they realized that this is not possible. All children complained about the fact that they had to erase the whole note and start to write the note again. There was not an option to undo or erase part of the writing inside the note instead they had to delete the whole note. In addition there was no way to save their work. A general design rule should be to make fine grain editing possible.

Creation of video combining still images and audio files

During the study-2 (section 6.1.2) one teacher recorded a video herself without any help. She had problems in focusing, and tremor (see figure 72). We also can see in Figure 72, that she followed a similar pattern by using a pencil in this video compared to explaining the topic on the blackboard. In the case of the 66 videos created by the children, 21 videos had problems with tremor and 10 with focusing. Providing a mechanism to still add images and audio in such a situation would be preferable.

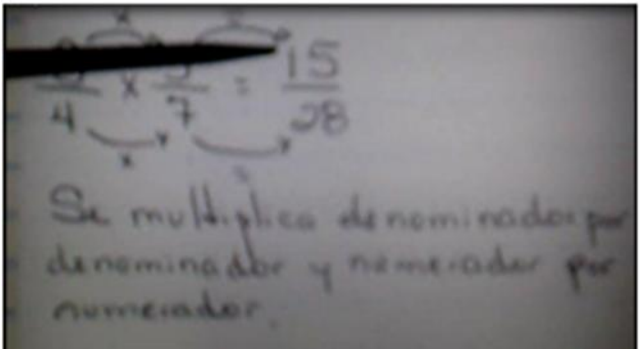


Figure 72. Screenshot of the Video about Multiplication of Fractions Created by a Teacher. The teacher creates the video similar to how she presented the content in class before. As one can see, a focus problem occurred while she was filming.

Need of a school mode in the phone

Although most teachers find a potential in the use of mobile phones in the classroom, all the teachers we interviewed raised their concern on the possible distractions and inappropriate use of mobile phones in classroom. Especially the Internet access to inappropriate pages was the biggest concern of the teachers. Actually, in Panama, as in many other countries too, the use of mobile phones at school is prohibited. In principle, similar attention and order control techniques practiced by teachers in a classroom can also be applied when using mobile phones as a learning tool. For example, collecting a phone after a child has finished a task. However, in large groups it is difficult to properly control the use of the phones by students during a lesson. One suggestion that could decrease the distraction and misuse of the phones in class is the implementation of a school mode in the mobile phone. Through location context awareness the school mode is activated once the child arrives to school. During this school mode only the applications and websites allowed by the school are active for the children. This way, games and inappropriate websites could be blocked.

10.3 Share and Presentation of the Multimedia Files Created

Although teachers were introduced in the use of Bluetooth, and children were skilled using it after few trials, teachers used Bluetooth to interchange images, but seldom to send/receive multimedia files, i.e. audio and video files.

The size of multimedia files as well as the number of pupils was the main reason that discourages teachers to use Bluetooth. For example, one of a teacher in our short study took circa 40 minutes to send the learning video (26,3 MB) using Bluetooth for all the 30 mobile phones of her pupils, even though those pupils who first received the file helped to spread the file. This geometric progression spread is only possible when sending the same file to n recipients (1:n), however this approach does not work when each child sends a file to the teacher (n:1).

Because of the time consuming, most of the educational videos were installed in the children's mobile phones by us. The teacher gave us the files previously and we installed them either using the USB cable or Bluetooth outside the school time.

The settings mechanism of Nokia XpressMusic 5530 model allowed receiving the Bluetooth files only in the phone memory. This limited the amount of files to receive, as the internal memory was only 70 MB compared with the 4 GB external micro SD memory included in the phones.

The most common way adopted by teachers to review the multimedia created by their pupils were to see the videos directly from the mobile phone of the respective pupil. Although there were two beamers in the school, teachers almost did not use them. The beamer was used by the teachers with extreme care and even scare. Teachers confessed of having received instructions how to use them, but they still do not feel comfortable to deal with a “costly” and delicate device. In our last interview with teachers, they informed us that one beamer was broken, since this situation happened teachers of the long study did not use the beamer anymore during the rest of the school year.

10.4 Empowering – Towards Enabling Developers

Currently, the creation of applications for mobile phones is done on personal computers (PCs). However, worldwide, and in particular in developing countries, mobile phones are the major computer platform [ITU, 2014]. Our surveys (see section 4.1) also show that teachers and children have higher access to mobile phones than traditional computers.

This means that in developing countries citizens currently are unable to create custom applications for their mobile phones, as they do not have access to a PC. In addition to this, researchers [Kam *et al.*, 2009a; Jones & Marsden, 2006] agree that for the development of software applications in developing regions it is very important to consider the local cultural and social practices. Easy development tools running directly on mobile phones could empower those people to build successful applications based on the cultural and social context that they know very well.

On the other hand, existing prototyping techniques do not allow adding full functionality of mobile applications. In paper prototyping, real interactions are very limited and higher fidelity prototypes such as those made in Power Point or Flash allow a nicer presentation but still do not permit a real interaction. Some programmers then prefer to create prototypes directly using standard programming languages.

We propose a development framework, MobiDev, which enables users to rapidly develop prototypes and real applications directly on the mobile phones. Programming mobile applications on mobile phones can power local –and potential future– developers that do not have access to computers but who understand better the unique requirements of their communities to develop applications. It also can be the first introduction to pupils to the programming world in high schools where there are not computers.

10.4.1 Related Work

In the literature, some incipient research about prototyping in-situ for mobile environments can be found. The most prominent one is [De Sá & Carriço, 2009], where a framework is presented that support the creation of low to high fidelity prototypes. In this approach, the application allows the combination of scanned hand drawings with digital images to create a high fidelity prototype. The sketches as well as the application flow are created on a PC and the resulting prototype runs on a mobile device. Additionally, the framework allows users to edit the properties of the graphical user interface (GUI) elements both on the PC and directly on the mobile device. The users can follow the transitions of the prototype created by the framework on the mobile device, interact with the prototype, and finally fill out a feedback questionnaire about their experiences.

iStuff Mobile [Ballagas *et al.*, 2007] is another example of an in-situ prototyping framework which in contrast to the former focuses on creating low-fidelity prototypes of new sensor-enhanced interfaces for mobile phones. It uses wireless sensors which are externally attached to existing, unmodified mobile phones in order to augment their features. The framework employs software components across a network to handle phone input events and sensor events and to forward the intended output events to any (even built-in) application on the mobile phone. As the mapping between the before mentioned events is done on a PC using a visual programming environment and as external sensors are attached to the phone, the intended target groups for this framework are mainly interaction designers and researchers.

Some Programming Environments include a visual development tool to support a rapid GUI creation for desktop and mobile applications. Visual Basic[24] users can drag and drop GUI elements, change properties, and define behavior accordingly to events raised. Netbeans[25] for Java ME includes a Visual Mobile Designer tool, which allows the creation of GUIs and the definition of the flow between different screens. In Scratch [Malan & Leitner, 2007] users can create small applications by assembling visual programming blocks. These blocks define the behavior of the application. The MIT App Inventor [MIT, 2014] uses this approach to create mobile application from a desktop.

10.4.2 Challenges of Development on Phones for Phones

Developing applications on phones lead to a number of inconveniences especially if the development method should be similar to desktop development. Main shortcomings are caused by hardware constraints like device/screen size and interaction modalities. The first problem is the limited sizes of most phone displays, which complicate the possibility, e.g., to overview longer parts of code,

[24] *http://msdn.microsoft.com/vbasic/, last accessed on September 30, 2014.*
[25] *http://netbeans.org/features/java-on-client/java-me.html, last accessed on September 30, 2014.*

which is a common task at least while developing on a PC. Upcoming technologies like mobile phone projectors might help to overcome this problem.

Additionally most mobile phones lack of an efficient typing method. This inconvenience might be solved if a full QUERTY-keyboard (perhaps foldable) can be connected to the phone, which in return limits portability. Thus, reducing the typing effort instead might be a better solution. Another feasible solution which is used in our underlying concept is to utilize visual input using the camera, which is integrated into almost every current phone. By drawing objects or writing text and then processing captured images, input can be generated to develop mobile applications.

10.4.3 Concept of MobiDev

In order to allow the development of mobile applications without a PC, we aim to reduce the technological requirements for the development process. The only device is an ordinary mobile phone integrated with a camera. We create an initial prototype in order to get initial feedback about the concept of MobiDev [Pfleging *et al.*, 2010]. A second improved prototype of MobiDev was developed by [Seifert *et al.*, 2011]. The first prototype was implemented in Java ME using a Nokia Xpress Music 5530 phone; the second prototype of MobiDev was developed with Android 2.1, where users can create apps based on HTML and JavaScript.

The key facts of our concept can be summarized as follows:

- ❖ Mobile applications are generated using just a mobile camera phone itself without the need of a personal computer for the developer.

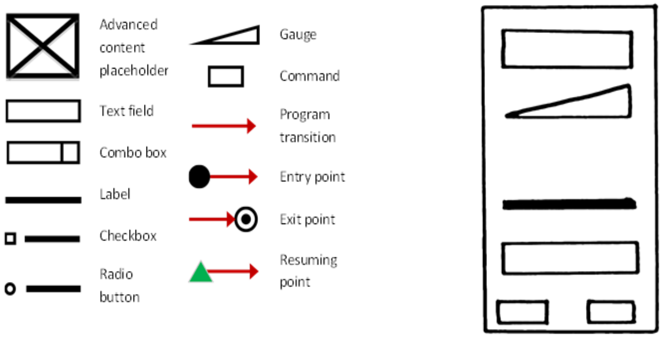
- ❖ Mobile user interfaces can be generated by first drawing paper-based sketches of the required UI screens and then capturing images of the sketches.

- ❖ The general application logic of such a mobile application can be defined by visually connecting the drawn GUI sketches with arrows.

- ❖ Code entry can be reduced to the processing of the different user inputs and to refinements of the application logic.

❖ Mobile code entry can be facilitated by offering code completion, graphical programming, and optical character recognition (OCR).

As a core idea, our concept intends to minimize the efforts of developing applications for mobile phones by providing a software development kit which only requires a mobile, a pen, and a sheet of paper as a development environment. The necessity of entering big amounts of code on the phone is minimized by using the input of an integrated camera to generate the GUI. Thus, mobile application development on the phone becomes as easy as it is when using desktop development tools like the Netbeans Visual Mobile Designer.



a) b)

Figure 73. Example and use of the Symbols for UI Paper Prototype in MobiDev. a) Original symbols to draw a paper-based UI sketch on MobiDev; b) A sample UI sketch consisting of one form which contains the proposed symbols representing the different UI elements.

According to our proposition, a mobile application can be developed by executing the following tasks:

(1). All screens that might be visible when executing the application have to be drawn on a sheet of paper. In order to simplify the image processing methods, every screen is abstracted by using the symbols, which are explained in Figure 73.a. The available symbols correspond to the different objects which can be integrated into a typical form. A sample screen using those symbols is shown in Figure 73.b. In the second MobiDev's prototype the symbols of the text field and label were merged as after the recognition process, the user can establish the function as label or text field. For facilitating image processing the lines next to checkbox and radio button were eliminated; the representation of the check box button was changed to an X instead of a square.

(2). The second step is to define the general application logic, i.e., to specify the different transitions like, e.g., switching between or refreshing screens. The transitions are drawn as arrows on the same sheet of paper. Every arrow connects the triggering object with the screen that is shown next. Special symbols are used to visualize constructs like, e.g., loops (in future versions), entry and exit points for starting, resuming, or terminating an application. Figure 74 shows the sketches for an example application containing all screens of the application as well as the main transitions.

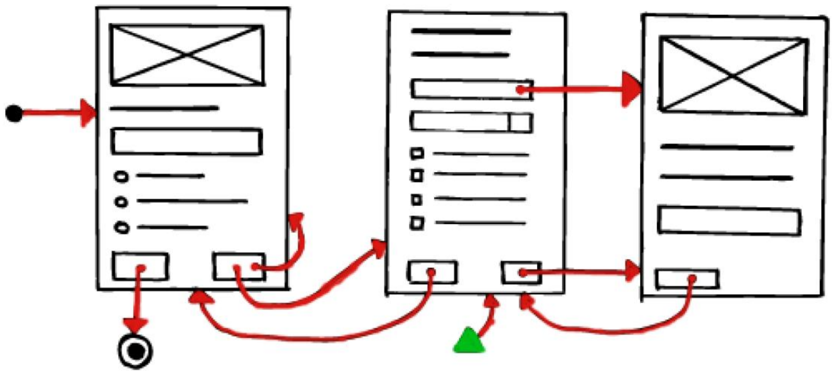


Figure 74. An Example of the Complete Visual Input for Developing a Mobile Application. The sketch includes all screens and the main application flow.

(3). Once all screens and the main transitions are drawn on paper, the software development kit will be used for the final steps until the new application has been deployed. First, the application captures an image of the complete sketch prepared in the previous steps. The image is then processed to detect all visible elements and to generate the desired objects and transitions. In a first processing step, the different screens and the global logic are recognized and the different elements of every screen are parsed. The results for each screen are displayed on the phone one after another. Figure 75 shows the full process in the detection of the UI drawn on paper. Corrections to each screen can be done by modifying or removing the displayed UI elements or by adding new elements. Additionally, the properties of each item can be adjusted like, e.g., setting a meaningful name for an item in order to allow easier access during the coding phase.

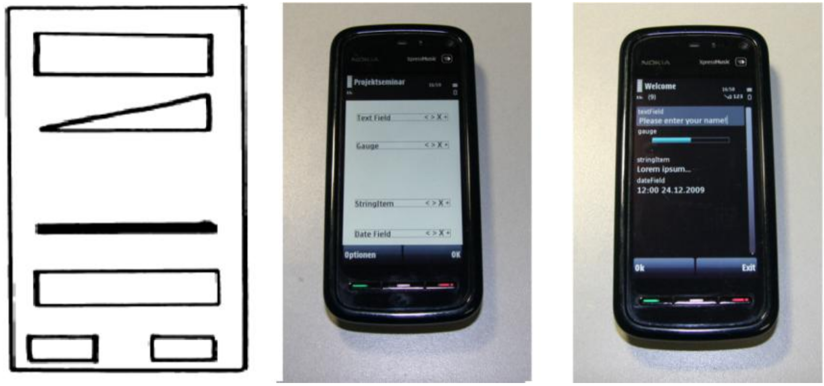


Figure 75. Example of transforming from UI Paper Prototype to UI Software Prototype. An UI Sketch Drawn on Paper (left); after taking the photo of the sketch, this image is analyzed to extract all UI elements and possible transition, resulting on a basic UI (center) where user can edit the UI design and add code. Final view of the UI and the software prototype (right).

Whenever an appraisal of a screen is finished the transitions beginning at the current screen are examined and stored. If a transition starts at a command, it will be initiated when the command is executed. If the transition starts at a specific item on a form, the developer can select the event related to this item which should trigger the transition.

As a last step, the developer has the possibility to add specific code to each transition and thus to give life to the application itself. To reduce code entry even in this step, different supporting techniques are possible. One possibility is of course to provide code completion mechanisms while entering code. If longer pieces of code have to be entered, the user could also write the corresponding code onto a piece of paper and capture an image of the text which will then be processed by an optical character recognition web service to integrate the code into the application. If a projector phone is used, this technique could be extended to allow instant changes within the projection by using a pen.

As soon as all mentioned steps are completed, the mobile application can be started, debugged, and even distributed as a full program to other phones. The second prototype of MobiDev [Seifert et al., 2011] includes a graphical editor that allows the user to create UIs directly on the mobile phone.

10.4.4 Initial Feedback and Evaluation of MobiDev

In order to get feedback about our concept, we conducted a focus group with users who had experiences in mobile programming. The participants were six males with an average age of 23.5 years. All of them were senior students in computer science at our university with experience in mobile and desktop programming.

The idea of programming directly on the mobile devices was well received by the focus group. The participants stated that they could imagine developing on mobile phones instead of on the desktop when they are on the way or have no access to a PC: "*When I have an idea to implement something and I do not have the laptop with me (...) I can just open my (mobile) phone and make the improvements."* In addition the participants found that for some applications debugging and testing in-situ is much more suitable than on emulators as one participant stated: "*Hardware specifics of phones are difficult to test in the emulator, for example: how do I debug a multi-touch mobile application on a PC?"* Another participant complained about the permanent need to switch between the PC and the mobile phone while coding and testing. The small screen and especially the limited text input mechanisms were the main concerns raised by each participant for coding on mobile phones. The members of the focus group considered the use of paper-based sketches as the base for the implementation of GUI elements and interactions as very useful – especially for a rapid development of applications. All participants stated that they would use a tool like the proposed development kit. Without much effort and without any previous explanation the participants understood the symbols and transitions of the presented paper-based sketching method.

Further evaluation was conducted by Seifert et al. in the second version of the MobiDev prototype [Seifert *et al.*, 2011]. Similar to our early feedback of our first MobiDev prototype participants found that learning to use MobiDev is simple and the concept is easy to understand. One participant suggested, *"MobiDev would be great for teaching beginners how to write programs"*.

10.5 Summary and Discussion

In this chapter we presented how the mobile phones can support the teaching flow based on the findings of our field studies and further interviews. We observed the own teaching style of the teacher when choosing the mobile phone application or function. But at the same, we can see a slight trend in the applications used at different stages of teaching. For instance applications that reproduce media –like playback and watching educational videos, audio or see images – are functions/activities preferred by the teacher for introducing a topic. Functions or applications that support the hand-on activities – like creation of audio/video/text and conceptual maps – are preferred as synthesis of the topic, and in some cases are used also as an evaluation of the learning advances of the children.

Whereas the teaching flow made perfectly sense in the context of education, it is evident that the phones did not support those flows as such. We proposed some guidelines in how to improve the UI of phones and the mobile applications of phones to better support the teachers and children in their teaching and learning tasks. Here one key guideline is to minimize the need for transferring between applications and to provide integrated applications that then support the entire teaching task.

Not the complexity of using Bluetooth but time consumption and the file size discourages the interchange of video files using Bluetooth. This represented a problem when children wanted to present their videos to the teacher and classmates, but also when teachers wanted to send the videos to their pupils. In the first case teachers saw the videos directly on the pupil's mobile phone screen and in the latter case videos were installed previously.

The multimedia features of current smartphones have been easily integrated in the daily learning tasks designed by teachers. However, we observe a gasp in how (1) teachers create/access videos and (2) the share of videos created by pupils to the rest of the class and the teacher. One approach we suggest is a database system where teachers have learning videos available, like the Khan Academy project [Khan, 2006]. Subject specialist teachers upload short home-made educational videos, and grade teachers can search for the educational video they need. Similarly, children can upload there their videos and be available to all of them. Another approach can be the integration of print and digital content like those explored on [Seisto *et al.*, 2009; Vihavainen *et al.*, 2010] with the use of mobile phones, which offer an interesting and enhance alternative to playback the multimedia files. A further approach is the use of mobile projectors that will allow students to share their digital work, like videos, easily and faster to the teacher and classmate. Phone projectors have been already explored in classroom settings [Jain et al., 2011] in developing regions. Alternative mobile phones with Audio/Video output can be connected to TV screens.

Finally, we believe that enabling local developers who are part of the communities and better understand the local social and cultural context is the best way to create IT solutions targeted for those communities. Understanding local practices leads to creating local success applications; in this sense we proposed MobiDev, a development kit that combines paper-based sketches with in-situ mobile phone programming. Users can develop mobile phones applications directly on the phones. Citizens from developing countries could directly benefit from such a system. As many of those people only have access to a mobile phone our system would offer them an easy means to develop plain applications for the first time. For example teachers could build learning applications for their pupils, or students could learn how to program, which so far has been impossible to do properly without a traditional computer.

Chapter 11

Conclusions

In this doctoral thesis the adoption of mobile phones by teachers and students and their potential as learning tools in rural primary schools in Panama is described. Our research followed a participatory design approach that is supported by techniques from HCI and ethnography including surveys, focus groups, observations, interviews, and field studies. Our observations were assisted by automated device logs and screenshots. The findings suggest that smartphones, even low-cost multimedia phones are more suitable than computers for supporting teaching and learning in rural settings in Panama.

Previous research on mobile learning applications in developing countries has mainly focused on single applications and narrow use cases that have been designed by researchers. In contrast, our research takes a holistic approach and looks at which kind of mobile phone-based application meets the educational needs in schools without interrupting the common way educators teach and work with their students.

This dissertation contributes to the design of mobile phone-based learning tools and provides practical, hands-on background knowledge for developers and designers of mobile learning applications. In the following sections the main contributions and results are summarized, future work is discussed, and concluding remarks are presented.

11.1 Contributions and Results

The main contributions of this dissertation can be grouped in four areas. First, using participatory design, field studies and other HCI research practices, several use cases were designed that verify the potential of mobile phones to support teaching in rural settings in Panama. Second, with the large amount of data collected we gained valuable insights in the way children adopt mobile phones in their daily life. Third, we designed and implemented software prototypes and tools that either support researcher or as examples of novel learning applications for mobile phones. Finally, we provide a set of recommendation and GUI guidelines to improve learning experiences with mobile phones.

11.1.1 Mobile Phones are a Useful Platform for Learning and Teaching in Primary Schools in Panama

This dissertation evidences that standard multimedia mobile phones can support educators to teach and students to learn in a more natural way than computers. Especially the following issues of computer usage in schools were found.

In chapter 4, surveys with teacher and children, paper prototypes, interviews and focus groups with teachers are used to identify the design space of mobile phone-based learning tools for schools. We developed scenarios according to use cases. Teachers drew scenarios *(1) where mobile phones can support the way they are used to teach; (2) where they integrate multimedia; (3) that allows the creation of content for a variety of subjects, rather than one specific topic.* However, teachers did not found all the features of mobile phones useful for learning. Whereas teachers consider multimedia as a way to enhance the presentation of content and facilitate the learning of the students; the use of SMS was not considered useful by all the teachers as they assumed that writing SMS could worsen good writing practices.

During the field studies, presented in chapter 6, concrete educational use cases were developed using the multimedia recording and playback capabilities of mobile phones. It is shown that the way children recorded videos, as individuals or in teams, depends on the number of student but also on the location and the infrastructure of the school. Individual shooting should be preferred for large classes while collaborative filming should be preferred for multigrade schools, as discussed in section 6.4.1. Teachers created the videos in the same way they are used to teach, but preferred to employ external videos. Teachers and students consider video playback as the most useful technology for learning, because students can replay the content individually until they have understood it. Audio recording and playback support self-evaluation when learning English pronunciation.

Mobile phones demonstrate to be a versatile tool for working with documents as shown in chapter 7. Teachers can use the camera phones to create interesting use cases as reported in section 7.1 where they take pictures of books' exercises that children can solve using a standard draw application. The main driver of this approach was the lack of access to copy machines and the prohibition to write on school books. In addition, students designed further uses for camera phones to support their learning indirectly, e.g. as diary or agenda, as presented in section

8.2.3. Providing mobile Internet access in classrooms proved to be a useful tool to complement and enhance discussions between teachers and students inside the classroom about a lesson or a contemporary topic, as discussed in section 8.2.4.

The quality of children's handwriting using touchscreen mobile phones is assessed in chapter 9. While the performance and legibility is inferior compared to using pen and pencil, writing with a capacitive stylus results in an acceptable outcome. In particular, compared to writing with the finger on capacitive touchscreen phones or writing with a stylus on resistive touchscreen phones. Even though the screen size is limited, children had no difficulty to write with a stylus on touchscreen phones. Children's preferences for writing and drawing with a capacitive stylus, a resistive stylus or the finger with capacitive phones varied across age. We found that children hold and use both styli in almost the same way as using a pen and writing on paper. However, we also observed some grab patterns and hand positions that lead to errors on touchscreen phones.

11.1.2 Understanding the Way Children in Rural Setting Adopt Mobile Phones in Their Daily Life

Although teachers' were concerned that mobile phones have a disruptive effect inside the classroom, we found that mobile phones positively influence the students' behavior, as depicted in section 7.3.2 and 8.3. Timid students overcome their shyness to participate in role plays or speeches thanks to mobile phones' video recording feature. Students' behavior was similar than before using the mobile phones; but concentration and engagement was higher in most cases. Problematic students became motivated to attend school more regularly and engage in the learning activities.

At home and in their leisure time, students mainly used the handset for listening to music and playing games. Probably because of a novelty effect, male students played games more frequently than their female peers, as shown in section 8.1. At the end of the study, however, girls and boys played for the same amount of time but different types of games, as shown in section 8.2.5. The games played reflected the standard gender convention, whereas girls played preferred adventure games, boys preferred action games. Furthermore, girls shared much more content with others compared to their male peers; with exception of music that were equally shared by all children. Both genders mainly took photos of the family and friends.

11.1.3 Development of a Research Tool, and Design of Mobile Learning Prototypes

One tool and three software prototypes were designed and implemented for this dissertation. We designed and developed ScreenShotLogger (section 5.1) as a research tool that supports field studies. In addition to the text log, ScreenShotLogger takes a screenshot of the used mobile phone application every twenty seconds. The screenshots provide researchers a full visual sequence of the way a user interacts with the mobile phone. It provides much better insight compared to the data provided by a log file. In addition, this screenshot logger works unobtrusively for the user. Other techniques such as direct observations or video recordings of the users might change the way a user interacts with the mobile phone. In addition, the screenshot logger was helpful to avoid the misuse of the phones by the students.

In section 10.4 we present the concept of mobiDev, a tool that enables to develop mobile applications directly on a mobile phone. Users draw the UI on paper, take a picture of it. Then, mobiDev processes the image, and creates the UI of the mobile application. With code completion and graphical programming users can add behavior to the UI controls. This tool benefit users in developing countries in two ways *(1) it can empower user in local communities to create their own applications that matches their culture, social context and needs;* and *(2) users without access to desktop computers can use this tool to learn programming.*

Examples of learning application that enables teacher to create content are described in section 5.2. With mobileMath teachers can create and deliver arithmetic tasks according to the knowledge level of their students, targeting all their students or even only students that need more practice. It runs on low-end mobile phones. In section 5.3 we propose cuentoMovil as an example that allows teachers and students to create written stories that can easily be shared via WiFi on the local intranet or on the Internet for schools with Internet access. Compared to using Bluetooth, exchanging content via Wi-Fi has the advantage that a large amount of content can be distributed, which usually is the case when working with students.

11.1.4 Recommendations and UI Guidelines towards Better Mobile Learning Experiences

In the field study (see chapters 6 and 7) we observed how eagerly teachers plan and create cases and how well mobile phones can be integrated in the schoolwork. Our observations strongly support the idea that teachers should be provided means for doing that, and we urge that this approach is taken into account when developing mobile applications for educational purposes.

Not all the mobile phones' features and applications were used for every lesson. Teachers adapted to their usual teaching flow. When introducing a lesson, teachers preferred to use some applications at specific steps within this teaching flow, e.g. watching videos at the beginning, but recording videos by students at the middle, as reported in section 10.1. Mobile phone-based learning applications should be easy to use but general enough to be applicable for a variety of school subjects and grades. In sections 10.2, we provide design guidelines for mobile learning applications. In particular, it is beneficial to develop applications that can be used in a variety of situations. Example applications are a drawing application with character recognition and a simple editor for combining audio files and pictures to create a presentation without the requirement to record a stable video with a shaking hand.

The misuse of mobile phones by children in classroom such as accessing inadequate content on the Web, or playing games are the main concerns of teachers when students use them in class. Implementing context awareness on the phones, i.e. location, can assist teachers to ensure appropriate use of the devices in schools. When students are in the school building the mobile phones can automatically turn on a school mode, which allows children to only access appropriate websites, and block access to games.

11.2 Future Work

There is always room for improvement and every finding leads to new research. In the following section we present new challenges that were identified while conducting the research presented in this thesis.

11.2.1 Augmented Books through the use of Mobile Phones

The role of conventional learning material like books remains strong, partly because they are less error-prone than technical alternatives. However, integrating the use of traditional material with mobile phone usage offers interesting possibilities: (1) the use of camera phones together with a draw application as annotation tool [Valderrama Bahamondez *et al.*, 2011a] and (2) the use of the camera phone to access online content on a server [Vihavainen *et al.*, 2010].

A further direction that should be explored in future work is the augmentation of books by integrating QR codes. Students use their mobile phone to scan this code to gain access to further content, like watching educational videos related to the lesson or even download exercises to their handsets. The access can be online or on local servers; depending of the Internet availability in the school and at home.

In unprivileged rural areas where people have no access to camera phones, the integration of voice applications could provide an alternative way to augment the content of books similarly to mobiLED [Ford & Leinonen, 2009; Leinonen *et al.*, 2006]. Students can request material, for instance by sending a page number, and the application returns an explanation of the topic. This kind of voice application would be especially useful for learning foreign languages. As discussed in section 2.2.1, applications that augment books with multimedia material can be very useful in indigenous areas similar to radio and video that already complements distance learning in areas without any regular high school.

In addition all augmentation tools should include mechanisms that allow teachers and specialized docents (e.g. Math teachers and English teachers) to make material like video, text, audio, images, etc. available for other teachers and students.

11.2.2 Design and Implementation of a School Mode Phone

In this thesis, we proposed the implementation of a school mode for mobile phones using location awareness. However, this school mode concept has not been implemented; further research has to be conducted to implement and evaluate the impact on privacy, distraction and learning. It is, for example, unclear which applications and phone features should be blocked. Further investigation is also required to determine the best approach to activate the school mode.

11.2.3 Extent the Screenshot Logger Application

Although the screenshot logger application provides rich insights into the way students interact with their phones, the process of collecting and extract the data (screenshots) from the SD cards and phone memory was slow. One improvement could be, in case mobile Internet is available, to log data and screenshots directly on an online server instead of saving them on the phone.

An additional enhancement to consider the next version of the screenshot logger is the integration of an image processing algorithm that filters consecutive images that are exactly the same.

11.2.4 Evaluation of the Learning Prototypes

With mobileMath and CuentoMovil we proposed two novel learning applications. While both applications were designed and implemented as software prototypes there is a need to evaluate their impact on learning in situ. A further work with respect to mobileMath (cf. section 5.2) is the implementation of the student component, and the full evaluation of the tool by teachers and students in schools. Although the CuentoMovil prototype (cf. section 5.3) was appreciated and used by teachers and students during the long study we conducted (cf. section 8.2.3), a refined implementation and a formal user evaluation is still needed.

11.2.5 Evaluation of MobiDev in situ

We designed MobiDev as a tool to support easy and agile mobile prototype programming in-situ. As the initial evaluations have been conducted in Germany, it is imperative to conduct an evaluation with teachers and students in rural communities of developing countries.

11.2.6 Exploration of natural user interface for mobile learning

Speech recognition showed to have great potential for learning languages [Kumar *et al.*, 2012]. Whereas Kumar *et al*. explored mobile games, we propose customized learning applications. English teachers should be enabled to record their own content, e.g. words, and create sets of words that children have to speak. Students should not only be able to listen to the recorded words but also to record their own voice. Further research should investigate the automatic evaluation of students' pronunciations to enable self-directed learning.

As children had no problem to write on touchscreen phones, further learning applications that use handwriting should be explored. For example, applications that use handwriting and image processing should be developed to support younger children in learning how to write. The integrating of text recognition would be also useful for annotation tools.

11.2.7 Extend the Analysis of Screenshots

Millions of pictures were taken during the studies conducted in our research. We only analyzed a subset of them, in particular those related to learning; however the screenshots can also provide deep insight in how children use and adopt mobile phones in their daily life. A further analysis of the screenshots can give to the practitioners valuable information that help in the developing of mobile applications that better support and fit according the children´s local context and culture.

11.3 Concluding Remarks

Mobile phones are pervasive devices; and they are widely adopted by pupils and teachers in Panama. Multimedia features, communication networks and the current trend to touchscreens make them a powerful learning and teaching tool for schools. This dissertation assessed the potential of mobile phones for supporting learning in primary schools in Panama.

However, this research does not suggest that mobile phones are the panacea to solve all problems of education in developing countries. In fact, our position is similar to Leung *et al.* that the *"traditional classroom should not and cannot be replaced by the incorporation of any technology"* [Leung & Chan, 2003]. Technology can complement and enhance the learning and teaching process, it can open new learning spaces but it cannot replace the teacher. Furthermore, when new learning technologies are imposed and teachers were not included in the design process of those tools any attempt to incorporate them in the teaching process will fail. It is important to acknowledge that:

> *Teachers have a good understanding of the local circumstances and teaching curriculum and know well how to create material that fits to the students' context. Involving the teachers in creating the material for lessons is the best way to ensure that the content matches the needs of every class.*

HCI practitioners should design learning technologies and tools that enable teachers with easy mechanisms *(1) to create and share content and (2) support the teaching flow and style in the way teachers are used to.* The findings and conclusions of this doctoral thesis are based on scenarios and use cases we designed with Panamanian school teachers. They provide the HCI community with insights that support the design and improvement of learning experiences.

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Appendix A: Surveys

A.1 First Survey to Children, year 2009

MEDUCA-Universidad Duisburg-Essen (Alemania)
ENCUESTA SOBRE EL USO DE LA TECNOLOGIA POR LOS ESTUDIANTES

¡Hola querido amiguito y amiguita de nuestro gran Panamá!

Deseamos que nos ayudes con el progreso en la educación de nuestro país. Para tal fin te presentamos el siguiente cuestionario que te solicitamos contestes sinceramente. Muchas gracias por tu valiosa colaboración, y te deseamos éxito en este nuevo año escolar 2009.

Instrucciones. Las preguntas son principalmente de llenar espacio y de seleccionar la respuesta de acuerdo a la situación que más se acerque a la realidad en que vives. En el caso que así lo requiera, por favor contesta con una ✖ dentro de la casilla en blanco (☐) como por ejemplo (☒). Si alguna pregunta no estás seguro o segura de qué responder, solicita apoyo a tu maestro o maestra.

I. ***Información General***

1. Género: Soy ☐ niño  o Soy ☐ niña 
2. Edad: ¿Cuántos años tienes? Tengo_____años.
3. ¿En qué grado estás? Estoy en ______ grado.
4. ¿En qué colegio o escuela estudias? ____
5. ¿Cuántas personas viven en tu casa?____
6. ¿Tienes hermanos o hermanas? ☐ Si ☐ No

7. ¿Cuántos hermanos tienes y qué edad tienen?
   Tengo _____ hermano(s) y/o tengo _______ hermana(s)
   Edades de mi(s) hermanos(as):_______________________________________

II. Tiempo de transporte desde/hacia la escuela

8. Vas al colegio/escuela por la: ☐ mañana (o por) ☐ la tarde

9. Medio de transporte:
   a) De la casa al colegio/escuela.
   Por lo general, viajo de la casa para la escuela/colegio en:
   - ☐ Bus escolar ☐ Bus público ☐ Automóvil
   - ☐ Caminando ☐ Otro: ___________________________________

   b) Del colegio/escuela a la casa.
   Por lo general, viajo del colegio/escuela a la casa en:
   - ☐ Bus escolar ☐ Bus público ☐ Automóvil
   - ☐ Caminando ☐ Otro: ___________________________________

10. Duración del viaje:
    a) De la casa al colegio/escuela
    Normalmente me demoro viajando de mi casa al colegio:
    - ☐ 30 minutos o menos ☐ de 31 minutos a 59 minutos
    - ☐ de 1 hora a 1 hora y media ☐ de 1 hora y media a 2 horas
    - ☐ más de 2 horas

    b) Del colegio/escuela a la casa
    Normalmente me demoro viajando del colegio a mi casa:
    - ☐ 30 minutos o menos ☐ de 31 minutos a 59 minutos
    - ☐ de 1 hora a 1 hora y media ☐ de 1 hora y media a 2 horas
    - ☐ más de 2 horas

11. Actividades a realizar durante el viaje:
    a) De la casa al colegio/escuela
    Durante mi viaje a la escuela/colegio, hago lo siguiente
    - ☐ Repaso para un examen ☐ Realizo tareas
    - ☐ Leo un libro ☐ Hablo con amigos/familia
    - ☐ Juego con amigos/compañeros ☐ Juego de video
    - ☐ Juego en mi celular ☐ Realizo llamadas con mi celular
    - ☐ Chateo ☐ Duermo
    - ☐ Otro: ____

    b) Del colegio/escuela a la casa
    De regreso de la escuela/colegio a la casa en me dedico a lo siguiente (puedes escoger más de una respuesta):
    - ☐ Repaso para un examen ☐ Realizo tareas
    - ☐ Leo un libro ☐ Hablo con amigos/familia
    - ☐ Juego con amigos/compañeros ☐ Juego de video
    - ☐ Juego en mi celular ☐ Realizo llamadas con mi celular
    - ☐ Chateo ☐ Duermo
    - ☐ Otro: ____

III. Tecnología

12. ¿Para qué utilizas el celular?(puedes seleccionar más de una respuesta si aplica en tu

caso)

- ☐ Llamar por teléfono
- ☐ Enviar mensajes de texto
- ☐ Tomar fotografías
- ☐ Escuhar música
- ☐ Alarma
- ☐ Agenda
- ☐ Jugar
- ☐ Navegar en Internet
- ☐ Otros usos: ____
- ☐ No tengo celular

13. ¿Cuántos celualres hay en tu casa?
   ☐ Ninguno (pasa a la pregunta 17) ☐ 1 ☐ 2 ☐ 3 o más

14. ¿Para qué usan el celular en tu casa? (puedes seleccionar más de una respuesta)
   - ☐ Llamar por teléfono
   - ☐ Enviar mensajes de texto
   - ☐ Tomar fotografías
   - ☐ Escuhar música
   - ☐ Alarma
   - ☐ Agenda
   - ☐ Jugar
   - ☐ Navegar en Internet
   - ☐ Otros usos: ____
   - ☐ No tengo celular

15. En el caso que solo tengan **un** (1) celular en tu casa, ¿Cuántas personas usan ese único celular? ____________________________

16. ¿Quiénes en tu familia usan más el celular?
   - ☐ Mamá
   - ☐ Papá
   - ☐ Abuelos
   - ☐ Hermanos
   - ☐ Yo
   - ☐ Otros familiares: ____

17. ¿Qué marca de celular tienes tú o tu familia? (puedes seleccionar más de una respuesta si aplica el caso)
   - ☐ Nokia
   - ☐ Sony Ericsson
   - ☐ LG
   - ☐ Samsung
   - ☐ Blackberry
   - ☐ Motorola
   - ☐ Otro:_____________________________________
   - ☐ No sé

18. ¿Cuál de las siguientes categorías a continuación clasificarías tu celular y/o los celulares que hay en tu casa? (puedes seleccionar más de una respuesta si se aplica el caso)
    - ☐ **Primera generación.** Mi celular (1) solo hace y recibe llamadas, (2) tiene pantalla blanco y negro
    - ☐ **Segunda generación.** Mi celular (1) hace y recibe llamadas, (2) tiene pantalla blanco y negro o de colores, (3) envía y recibe mensajes de texto, (4) incluye juegos
    - ☐ **2.5 generación.** Mi celular (1) hace y recibe llamadas, (2) tiene pantalla de colores, (3) envía y recibe mensajes de texto, (3) incluye juegos, (4) envía y recibe mensajes de texto que incluyen fotos (5) acceso a Internet, pero muy lento (6) incluye cámara fotográfica
    - ☐ **Tercera generación.** Mi celular (1) hace y recibe llamadas, (2) tiene pantalla de colores, (3) envía y recibe mensajes de texto, (3) incluye juegos, (4) envía y recibe mensajes de texto que incluyen fotos/audio/video (5) acceso a Internet a velocidad aceptable (6) incluye cámara fotográfica y de video (7) permite realizar video-llamada, (7) incluye reproductor MP3 y (8) permite aumentar la capacidad de memoria

19. ¿Tienes acceso a computadora con Internet en el colegio/escuela?
    - ☐ Sí, tengo acceso a computadora con conexión a Internet en el laboratorio de cómputo
    - ☐ Sí, tengo acceso a computadora en el laboratorio de cómputo, pero sin Internet
    - ☐ Sí, tengo acceso a computadora con conexión a Internet en el salón de clases
    - ☐ Sí, tengo acceso a computadora pero sin conexión a Internet en el salón de clases
    - ☐ No tengo acceso a computadora en el colegio
    - ☐ No hay computadoras en el colegio (pasa a la pregunta 23)

20. Por lo general, ¿con qué frecuencia usas la computadora en la escuela/colegio?
    - ☐ Todos los días
    - ☐ Tres veces a la semana
    - ☐ Una vez a la semana
    - ☐ Cada 15 días
    - ☐ Una vez al mes
    - ☐ Otra: ____________________________

21. ¿Para qué materias usas la computadora en la escuela/colegio?
    - ☐ Sólo para Informática
    - ☐ Matemáticas
    - ☐ Español
    - ☐ Ciencias Naturales
    - ☐ Inglés
    - ☐ Ciencias Sociales
    - ☐ Otra: ____

22. ¿Para qué usas Wikipedia? ____
    ____

    - ☐ No uso Wikipedia
    - ☐ No conozco Wikipedia

23. ¿Tienen computadora en tu casa?
    - ☐ Sí, tengo computadora con conexión a Internet
    - ☐ Sí, tengo computadora pero sin conexión a Internet
    - ☐ No, tengo computadora

24. ¿A dónde investigas las tareas que te asignan en clases? (puedes seleccionar más de una respuesta si aplica el caso)

☐ Uso la biblioteca de la escuela/colegio
☐Uso una biblioteca pública
☐ Uso una enciclopedia o diccionario en casa
☐ Internet
☐ Software-Enciclopedia
☐ Wikipedia

25. ¿En qué asignatura(s) te gustaría recibir más ayuda o apoyo para que te sean más fácil entenderlas y mejorar tus notas?

____
____

¿Por qué?

____
____
____

26. ¿Tienes televisor en casa?
    - ☐ Sí, con pantalla a colores
    - ☐ Sí, con pantalla a blanco y negro
    - ☐ Sí, con pantalla a blanco y negro
    - ☐ No, tengo televisor en casa

MUCHAS GRACIAS POR TU COLABORACIÓN

A.2 Second Survey to Children, year 2012

Universidad de Stuttgart-Alemania
Encuesta sobre el Uso y Acceso a la Tecnología

¡Hola querido amiguito y amiguita!

Te presentamos el siguiente cuestionario que te solicitamos contestes sinceramente. Muchas gracias por tu valiosa colaboración. Las respuestas serán confidenciales.

Instrucciones. Las preguntas son principalmente de llenar espacio y de seleccionar la respuesta de acuerdo a la situación que más se acerque a la realidad en que vives. En el caso que así lo requiera, por favor contesta con una ✓dentro de la casilla en blanco (☐) como por ejemplo (☑). Si alguna pregunta no estás seguro o segura de qué responder, solicita apoyo a tu maestro o maestra.

1. Yo soy ☐ niña ☐ niño

2. Tengo ______ años

3. Estoy en: ☐ 4^to grado ☐ 5^to grado ☐ 6^to grado

4. En tu casa hay una computadora: ☐ Sí con acceso a Internet
   ☐ Sí sin acceso a Internet ☐ No hay computadoras

5. ¿Tienes acceso a Internet en casa?
   ☐ Sí con contrato (usando cables) ☐ Sí con Internet Móvil (USB)
   ☐ Usando el celular acceso el Internet ☐ No tengo Internet

6. ¿Cuántos celulares hay en tu casa?
   ☐ No hay celulares ☐ Sí, ¿Cuántos? _________

7. ¿Cuántos celulares hay en tu casa con pantalla táctil (Touchscreen)? _________

8. ¿Tienes tú un celular? ☐ Sí ☐ No

9. ¿Para qué usas tú el celular? (puedes seleccionar más de una respuesta)
   - ☐ No uso celular
   - ☐ Llamar por teléfono ☐ Enviar mensajes de texto ☐ Tomar fotos
   - ☐ Escuchar música ☐ Navegar en Internet ☐ Agenda
   - ☐ Jugar ☐ Alarma ☐ Facebook
   - ☐ Twitter ☐ Ver vídeos ☐ Juegos
   - ☐ Otros usos:____
   ____

10. ¿Cómo son los celulares que tú o tus familiares que viven en tu hogar tienen?
    - ☐ **<u>1era Generación</u>.** El celular permite (a) hacer/recibir llamadas por teléfono, (b) enviar/recibir mensajes de texto SMS y (c) Pantalla blanco y negro
    - ☐ **<u>2da Generación</u>.** El celular permite (a) hacer/recibir llamadas por teléfono, (b) enviar/recibir mensajes de texto SMS, (c) Pantalla de colores, (d) tiene cámara fotográfica y (e) juegos
    - ☐ **<u>2,5 Generación</u>.** El celular (a) hace/recibe llamadas por teléfono, (b) enviar/recibir mensajes de texto SMS, (c) Pantalla de colores, (d)cámara fotográfica, (e) acceso a Internet (extremadamente lento) y f) juegos
    - ☐ **<u>3era Generación</u>.** El celular permite (a) hacer/recibir llamadas por teléfono, (b) enviar/recibir mensajes de texto SMS, (c) Pantalla de colores, (d) tiene cámara fotográfica y de vídeo (e) acceso a Internet (lento), (f) juegos y (g) reproductor de audio mp3.
    - ☐ **<u>3,5 Generación</u>.** El celular permite (a) hacer/recibir llamadas por teléfono, (b) enviar/recibir mensajes de texto SMS, (c) Pantalla de colores, (d) tiene cámara fotográfica y de vídeo, (e) acceso a Internet Wi-Fi/GRPS (velocidad aceptable) (f) reproductor de audio mp3, (g) reproductor de vídeo, (h) permite agregar y usar una memoria externa en el celular.

11. ¿Cómo buscas información para realizar las tareas que te asignan en clases? (puedes seleccionar más de una respuesta si aplica el caso)
    - ☐ Uso la biblioteca de la escuela/colegio ☐ Uso una biblioteca pública
    - ☐ Internet en la computadora ☐ Internet desde el celular
    - ☐ Wikipedia ☐ Software-Enciclopedia
    - ☐ Uso una enciclopedia o diccionario en casa

¡MUCHAS GRACIAS POR TU VALIOSA COLABORACIÓN!

A.3 Survey to Teachers, year 2009

MEDUCA-Universidad Duisburg-Essen (Alemania)
ENCUESTA SOBRE EL USO DE LA TECNOLOGÍA POR LOS DOCENTES

Estimado maestro(a)/docente:

Con el fin de investigar el uso de celulares con tecnología avanzada en diferentes asignaturas de la Educación Básica General estamos realizando esta encuesta, por la cual solicitamos su objetiva colaboración en las diferentes preguntas del cuestionario. ***Las respuestas suministras por ustedes se mantendrá en estricta confidencia.*** Muchas gracias por su apoyo.

I. INFORMACIÓN GENERAL

1. Género: ☐ FemeninO ☐ Masculino

2. Edad:
   - ☐ Entre 18 y 23 años ☐ Entre 24 y 29 años
   - ☐ Entre 30 y 35 años ☐ Entre 36 y 41 años
   - ☐ Entre 42 y 47 años ☐ 48 años y más

3. ¿Cuál es el grado académico más alto que usted posee para ejercer como docente? …
   - ☐ Maestro ☐ Licenciatura en Educación Primaria
   - ☐Licenciatura en Educación Pre-escolar
   - ☐ Profesora en Diversificada con énfasis en ________________________________
   - ☐Licenciatura en (escriba especialidad)____________________________________
   - ☐ Técnico en (escriba especialidad) ____
   - ☐ Bachiller en (escriba especialidad)_______________________________________
   - ☐ Otro (especifique) ____

4. ¿Qué asignatura(s) enseña usted en la escuela/colegio? ________________________
   ____
   ____

5. ¿A qué grado(s) o año(s) usted imparte clases?_______________________________

II. INFORMACIÓN TECNOLÓGICA

6. ¿Tiene usted celular? ☐ Sí ☐ No (pase a la pregunta 12)

7. ¿Qué marca de celular tiene?

- ☐ Nokia
- ☐ Sony Ericsson
- ☐ LG
- ☐ Samsung
- ☐ Blackberry
- ☐ Motorola
- ☐ Otro:________________________________
- ☐ No sé

8. ¿En cuál de las siguientes categorías entraría su celular?

- ☐ **<u>Primera generación</u>**. Mi celular (1) solo hace y recibe llamadas, (2) tiene pantalla blanco y negro
- ☐ **<u>Segunda generación</u>.** Mi celular (1) hace y recibe llamadas, (2) tiene pantalla blanco y negro o de colores, (3) envía y recibe mensajes de texto, (4) incluye juegos.
- ☐ **<u>2.5 generación</u>.** Mi celular (1) hace y recibe llamadas, (2) tiene pantalla de colores, (3) envía y recibe mensajes de texto, (3) incluye juegos, (4) envía y recibe mensajes de texto que incluyen fotos (5) acceso a Internet, pero muy lento (6) incluye cámara fotográfica
- ☐ **<u>Tercera generación</u>.** Mi celular (1) hace y recibe llamadas, (2) tiene pantalla de colores, (3) envía y recibe mensajes de texto, (3) incluye juegos, (4) envía y recibe mensajes de texto que incluyen fotos/audio/video (5) acceso a Internet a velocidad aceptable (6) incluye cámara fotográfica y de video (7) permite realizar video-llamada, (7) incluye reproductor MP3 y (8) permite aumentar la capacidad de memoria

9. ¿Cuál o cuáles de las siguientes actividades realiza usted con su celular? (puede seleccionar más de una respuesta si aplica el caso):

- ☐ Llamar por teléfono
- ☐ Enviar mensajes de texto
- ☐ Enviar mensajes multimedia
- ☐ Tomar fotografías
- ☐ Escuchar música
- ☐ Como alarma o despertador
- ☐ Agenda
- ☐ Jugar
- ☐ Navegar en el Internet
- ☐ Otros usos: ___________________________

10. ¿Utiliza usted el computador?

- ☐ Si
- ☐ No

11. ¿Tiene acceso a computadora/internet en el colegio/escuela?

- ☐ Sí tengo acceso a computadora con conexión a internet en el colegio
- ☐ Sí tengo acceso a computadora en el colegio pero sin conexión a internet.
- ☐ Sí tengo acceso a computadora con conexión a internet en el salón de clases
- ☐ Sí tengo acceso a computadora en el salón de clases pero sin conexión a internet.
- ☐ No tengo acceso a computadora en el colegio
- ☐ No hay computadoras en el colegio (ir a la pregunta 15)

12. ¿Tienen los estudiantes acceso a computadora/internet en el colegio/escuela (por ej. Laboratorio de cómputo)?
    - ☐ Sí, los estudiantes tienen acceso a computadora con conexión a Internet en el colegio
    - ☐ Sí, los estudiantes tienen acceso a computadora en el colegio pero sin Internet.
    - ☐ No, los estudiantes no tienen acceso a computadora en el colegio.

13. ¿Tiene usted computadora en la casa?
    - ☐ Sí tengo computadora con acceso a internet
    - ☐ Sí tengo computadora, pero sin acceso a internet.
    - ☐ No tengo computadora en casa.

14. ¿Cuál de los siguientes programas o aplicaciones ha usado? (puede seleccionar más de una respuesta):
    - ☐ Procesador de texto, como por ejemplo Microsoft Word
    - ☐ Hoja de cálculo, como por ejemplo Microsoft Excel
    - ☐ Programa de diseño de presentación, como por ejemplo Power Point
    - ☐ Acceso a Internet: la web (WWW)
    - ☐ Ninguna de las anteriores

15. ¿Con qué frecuencia utiliza la computadora para realizar actividades relacionadas con la enseñanza?
    - ☐ Una vez al mes ☐ Todos los días ☐ Cada semana
    - ☐ Rara vez ☐ No la uso (pase a la pregunta 19)

16. ¿Cuál o cuáles de las siguientes actividades realiza usted en la computadora?
    - ☐ Planeamiento escolar ☐ Preparar clases
    - ☐ Buscar información por Internet para actualizar los diferentes temas a tratar en clases
    - ☐ Preparar material educativo de apoyo para la clase
    - ☐ Pasar las notas de los estudiantes y/o calcular promedios
    - ☐ Otro (especifique): ____

17. A su juicio, ¿cuál o cuáles son las materias de mayor dificultad que tiene los estudiantes? ¿Por qué?

☐ Matemáticas ☐ Español ☐ Inglés ☐ Ciencias Sociales
☐ Ciencias naturales ☐ Otras: ____
¿Por qué? ____
____

18. En las asignaturas con dificultad para el alumno, ¿cómo usted cree que el estudiante pudiera mejorar su rendimiento?

    ____
    ____
    ____

19. ¿Cómo cree usted, que el uso del celular o la computadora puede servir de apoyo en el mejoramiento o aprendizaje de las materias de dificultad?
    - ☐ A través de ejercicios para ampliar el vocabulario, por ejemplo inglés
    - ☐ Tareas de matemáticas
    - ☐ Otros ____

20. ¿En qué grados y materias piensa usted que los niños se pueden beneficiar de navegar información adicional a través del Internet, como por ejemplo el uso de enciclopedias online como Wikipedia?
    a) Grados ____
    b) Materias ____

21. ¿Qué problemas o dificultades encuentra usted para las siguientes situaciones?
    a) Si cada niño tiene su propia laptop con aplicación educativa

    ____
    ____

    b) si cada niño tiene su propia laptop con internet acceso y con aplicación educativa

    ____
    ____

    c) si cada niño tiene su propio celular con aplicación educativa

    ____
    ____

    d) si cada niño tiene su propio celular con internet acceso y con aplicación educativa

    ____
    ____

22. ¿Cómo considera usted las aplicaciones educativas (software/programas) para realizar prácticas de matemáticas (como por ejemplo ejercicios de aritmética), pudiera ayudar a los niños en mejorar sus conocimientos en matemática? En una escala de 1 a 5, donde ***1 es "no útil"*** y ***5 es "muy útil"*** clasifique los siguientes dispositivos, considerando que los estudiantes desarrollen las tareas ya sea en el bus, en clases o en casa.

Realización de prácticas de matemáticas en computadoras portátiles.

a)En el bus, automóvil
No útil — Útil — Muy útil
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

b)En la casa
No útil — Útil — Muy útil
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

c)En el salón de clases
No útil — Útil — Muy útil
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

d)En museos, zoológicos o parques
No útil — Útil — Muy útil
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Realización de prácticas de matemáticas en teléfonos celulares.

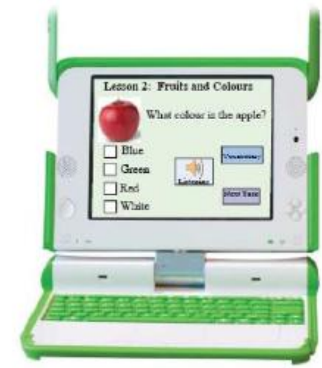
a)En el bus, automóvil
No útil — Útil — Muy útil
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

b)En la casa
No útil — Útil — Muy útil
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

c)En el salón de clases
No útil — Útil — Muy útil
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

d)En museos, zoológicos o parques
No útil — Útil — Muy útil
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

23. ¿Cómo considera usted que las aplicaciones educativas (software/programas) para realizar prácticas de vocabulario (con salida de voz), pudiera ayudar a los niños en mejorar el apren-dizaje de lenguas extranjeras, como por ej. inglés? En una escala de 1 a 5, donde ***1 es "no útil"*** y ***5 es "muy útil"*** clasifique los siguientes dispositivos, considerando que los estudiantes desarrollen las tareas ya sea en el bus, en clases o en casa



Realización de ejercicios de inglés en computadoras portátiles.

a)En el bus, automóvil

No útil		Útil		Muy útil
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

b)En la casa

No útil		Útil		Muy útil
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

c)En el salón de clases

No útil		Útil		Muy útil
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

d)En museos, zoológicos o parques

No útil		Útil		Muy útil
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

Realización de ejercicios de inglés en teléfonos celulares.

En el bus, automóvil

No útil		Útil		Muy útil
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

b)En la casa

No útil		Útil		Muy útil
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

c)En el salón de clases

No útil		Útil		Muy útil
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

d)En museos, zoológicos o parques

No útil		Útil		Muy útil
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

III. ESCENARIOS PARA EL USO DEL CELULAR DURANTE LA MOVILIZACIÓN DE LOS ESTUDIANTES

Considerando que en la ciudad de Panamá, los estudiantes por lo general utilizan más de 1/3 del tiempo escolar para transportarse desde sus hogares a la escuela y luego de la escuela a sus hogares, deseamos proponer un sistema en el cuál los estudiantes aprovechen el tiempo viajando hacia/desde la escuela desarrollando actividades de aprendizaje ya sea formal o informal. Además, considerando la limitación de acceso a internet y/o computadora tanto en los hogares como en las escuelas y a la alta recepción de los celulares, creemos que podemos aprovechar este medio para que los estudiantes tomen ventaja de este tiempo de transporte para tener acceso a la información.

Escenario 1:

María vive en los suburbios de la ciudad a Panamá, ella estudia en una escuela en el centro de la ciudad de Panamá. En su casa María no tiene computadora. María asiste al turno matutino de 7 am a 12:30. Diariamente, María se levanta a las 4:45 a.m. para ir a la escuela. Ella viaja en un bus escolar que la recoge todos los días a las 5:30 a.m., llegando a la escuela a las 6:50 a.m. Durante el viaje, María enciende su celular y accede el internet a través de un router (dispositivo de hardware que permite la interconexión de red de computadoras) inalámbrico instalando en el bus. Al grupo de María se le fue asignado leer sobre Alemania para la clase de Geografía, por lo que utiliza Wikipedia (enciclopedia en Internet de acceso gratis) para obtener la información y preparase para la discusión una vez llegue al salón de clases. La maestra previamente les ha asignado los puntos a discutir por lo que ella se enfoca en los mismos, grabando la página de Wikipedia sobre Alemania.

¿Qué opina usted del escenario 1?

____

____

____

Suponiendo que exista el acceso a internet desde buses escolares u otros vehículos, ¿considera usted de provecho para la educación del alumno y viable el uso del internet presentado en el escenario 1? ☐ Sí ☐ No

¿Por qué?

____

____

____

Escenario 2:

Julia, profesora de inglés, asigna a sus estudiantes una tarea sobre una redacción donde los estudiantes deben utilizar el tiempo pasado (simple y perfecto). Para ello, Julia graba información de diversos temas en el servidor instalado en los buses escolares para que los estudiantes puedan basarse de ésta para desarrollar la asignación. María entonces durante su viaje del colegio a la casa enciende su celular y se conecta l servidor instalado en su busito escolar, graba la información del tema que le corresponde en su celular. Una vez llegado a casa desarrolla la tarea.

¿Qué opina usted del escenario 2?

Suponiendo que exista el acceso a internet desde buses escolares u otros vehículos, ¿considera usted de provecho para la educación del alumno y viable el uso del internet presentado en el escenario 2? ☐ Sí ☐ No

¿Por qué?

¿Qué otros escenarios o ejemplos propondría usted para la utilización de acceso de información como complemento de las clases desde buses escolares, visitas a museos y/o en los salones de clases?

MUCHAS GRACIAS POR SU COLABORACIÓN

Appendix B: Paper Prototypes

Figure 76. Paper Prototype Used during the Teacher Interview (section 4.3). It represents a mobile learning application on teacher´s phone where teachers can customized content and tasks for their students.

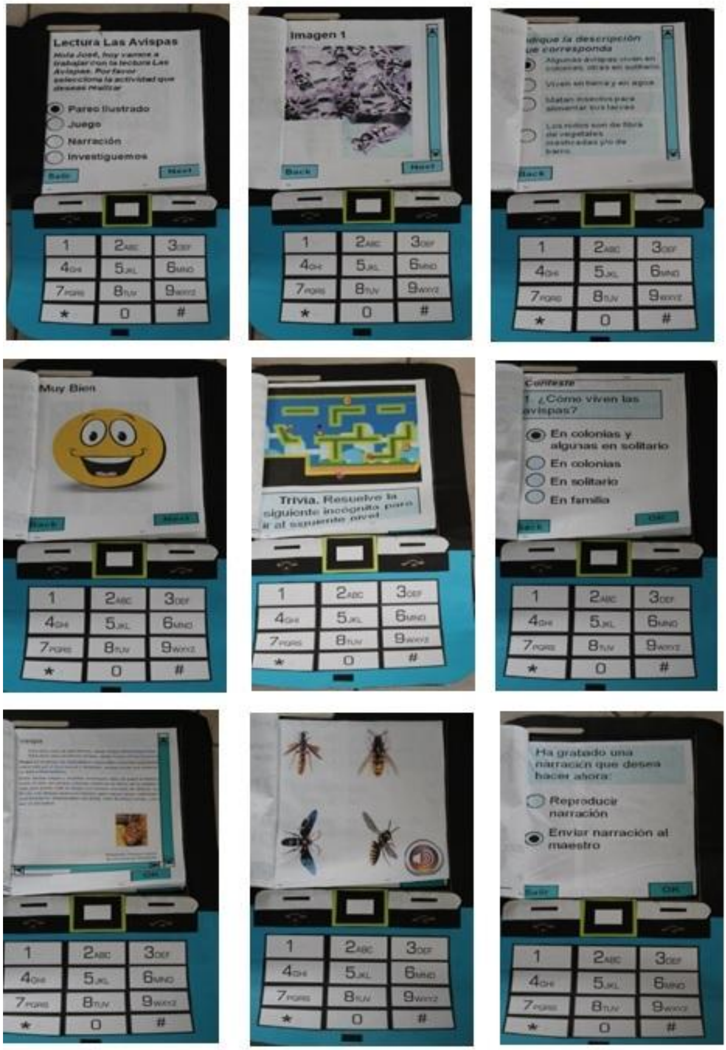


Figure 77. Paper Prototype Used during the Teacher Interview (section 4.3). It represents the mobile learning application on student´s phone with the content and tasks created by teacher on figure 76.

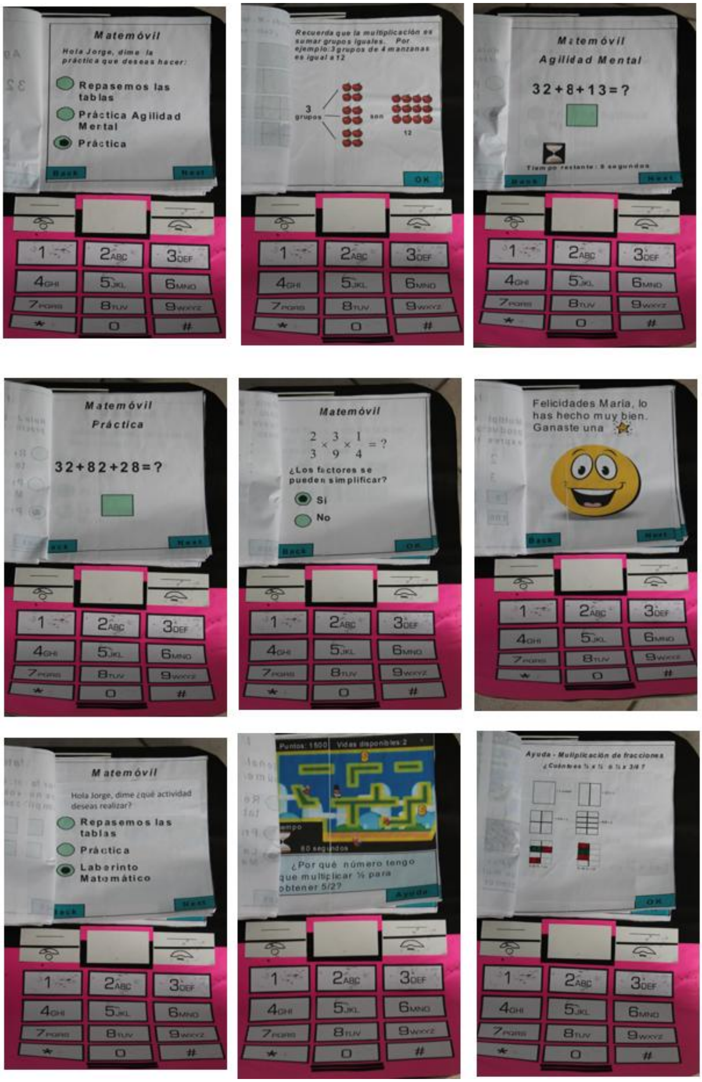


Figure 78. Paper Prototype Used during the Teacher Interview (section 4.3). It represents a mobile learning application on teacher´s phone where teachers can customized mathematics content and tasks for their students.

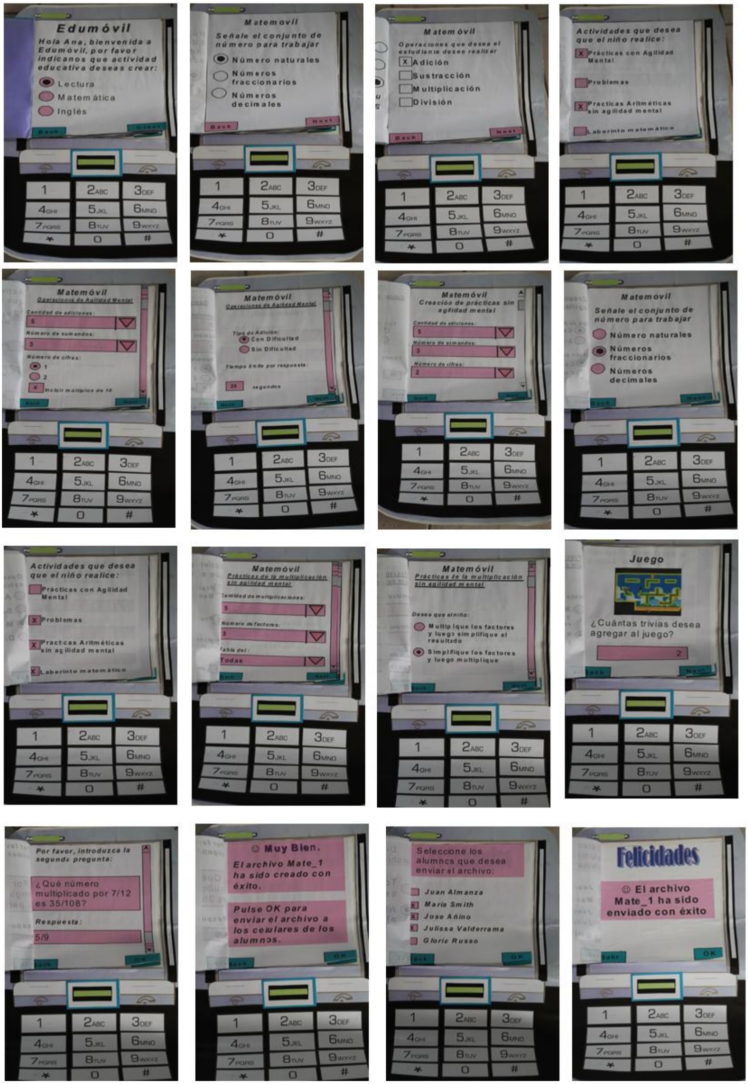


Figure 79. Paper Prototype Used during the Teacher Interview (section 4.3). It represents the mobile learning application on student´s phone with the Math content and tasks created by teacher on figure 78.

Appendix C: Learning Tasks Designed by Teachers during the Field Studies

C.1 Learning Activities created by Teachers during the Study-1

Educational Goal		Learning activities using the mobile phone
Mathematics	History of the measurement of longitude (6th)	❖ Children watched a video about the general history of measurement and the International System of Units as an introduction of the topic. This video was found in YouTube and preinstalled on the children´s phones.
		❖ Students in groups of 2-3 filmed themselves using parts of their own bodies to measure the length of different objects inside the classroom e.g.: blackboard, books, walls, etc.
	Measures of Area using the International Systems of units: square meters (6th)	❖ Children watched a customized video introducing the concept of the square meter, its multiples. ❖ Then in the school yard, children demonstrated the size of a square decameter and took a picture of it using the phones.
	Addition of fractions (4th)	❖ Children watched a video introducing the concept of addition of fractions. This video was made by a Math teacher using the phone.
	Multiplication of fractions (5th)	❖ Children watched a video about the concept of multiplication of fractions r. This video was created by a Math teacher using the phone.
	Division of fractions (5th)	❖ Children watched a video about the concept of division of fractions. This video was created by a Math teacher using the phone.
	Multiplication table (4th)	❖ Children listened an audio file with the multiplication tables recorded by the teacher.

Spanish	Orthography: Writing homonyms in the context of a sentence (6th)	❖ Teacher searched for a video on YouTube about the use of the letters C, S, Z, X; ❖ It was downloaded and installed the video on the children's phones ❖ Children watched the video several times ❖ Children took a picture of an exercise about this theme in their books, and solved the tasks on their phones using PaintPad.
		❖ Teacher searched for a video on YouTube about the use of B and V. ❖ It was downloaded and installed the video on the children's phones ❖ Children watched the video several times ❖ Children took a picture of an exercise about this theme in their books, and solved the tasks on their phones using PaintPad
English English	Practicing future tense (6th); Practicing reading and pronunciation (6th)	❖ Teacher used her phone to record herself (audio) reading an English letter using future tense; ❖ The file was installed on the children´s phones; ❖ Students listened to it while reading the letter from the book, ❖ The children recorded themselves reading aloud the letter; ❖ Then the teacher and children listened to all recorded audio together
	Months of the year and days of the week (5th and 6th)	❖ Children of 5th individually prepared a presentation about these concepts and, filmed in groups of two with children switching roles (speaker/cameraman). ❖ Students of 6th give a speech about the months of the year and days of week, while the rest of the class filmed
	Listening and Pronunciation (4th and 5th)	❖ Teacher recorded English nursery rhymes, ❖ Then the students listened and extracted known words
Nature sciences	Ecology: Fossil fuel energy sources (6th)	❖ Teacher sent a questionnaire for students to fill out, looking up answers on Google; ❖ They then created a video in groups of 3 where the students acted as interviewer, interviewee and cameraman. ❖ They also built a conceptual map about petrol using the stylus and the StickyNotes Application

Nature sciences	Human reproduction and sexuality (4th, 5th),	❖ Teacher took a picture of an exercise about the human reproductive system, ❖ It was sent it via Bluetooth to students, ❖ Then the children did the exercise using PaintPad, which they saved ❖ They then sent it back to the teacher using Bluetooth, ❖ The teacher evaluated the exercises using PaintPad
	Privatization and globalization (6th)	❖ Children prepared for a debate where in groups of 3 students recreated a talk-show using the video camera of the phone. ❖ Then each video was presented to the teacher ❖ At the end of the study the videos were uploaded in a computer and the whole class watched the videos.
	Part of the plants (5th)	❖ Children were asked to go the garden and to make a video about the parts of the flowers
Religion	Love and respect your father and mother (6th)	❖ Students painted (using PaintPad) an history of the Bible; ❖ They then sent it via Bluetooth to the teacher

C.2 Learning Activities created by Teachers during the Study-2

Educational Goal		Learning activities using the mobile phone
Mathematics	Length Measurement Unit (both fifth grades)	❖ A video about the units to measure length was downloaded from YouTube and installed on the phones ❖ Children observed the video individually up to 4 times ❖ The teacher then started a discussion about it
	Multiplication of fractions	❖ Using her phone, the teacher (5^{th} A) created a video where she explained the concept of multiplication, in the same way she usually explained a topic ❖ The video was send to the children using Bluetooth ❖ Children watched the video 3 to 4 times ❖ Teacher discussed the content of the video with the children ❖ Teacher (hand)wrote an exercise about multiplication of fractions on her notebook, and took a picture of it ❖ Then, she sent it via Bluetooth to the class. She demonstrated the concept by sending it to one child, with the instructions to send it on to 2 others who then sent it on to 2 each, etc. ❖ Children filled the exercise using the drawing application ❖ Then students sent the filled out task back to the teacher. ❖ The teacher opened the tasks and corrected them
		❖ The teacher (5^{th} B) used the video created by the other teacher ❖ Children watched the video several times ❖ Children solved tasks from their books, copying them in their notebooks.

English	Touristic places of Coclé Practice of speech (both fifth grades)	❖ Children were grouped in groups of 4 ❖ Teacher prepared information about all the sightseeing places in Coclé and then gave information about one place to each group. ❖ Teacher went group by group and read aloud the content of the respective sightseeing material.. ❖ Each child recorded the voice of her teacher while reading the text. ❖ Then every child listened the audio several times. Each child of the group had to learn one line of the material, and by group present the sightseeing in front the other groups. ❖ In addition, each team created a poster using pictures of the place. ❖ Next day, children presented their lines and described their poster to the class
Spanish	Oratory practice	❖ In group of four, children created the dramatization of the legend *"The Peasant and the Water Sprite"*, adopted from Tolstoy, (5th B) while the rest of the class filmed them
		❖ All children together recited a poem and the teacher filmed them (5th A)
	The use of prepositions	❖ Children of 5th A created a conceptual map about preposition using Sticky notes, ❖ Then they took a picture of a practice about prepositions in a book, ❖ which they filled out using PaintPad
		❖ Teacher downloaded two videos from Internet (YouTube) and installed them via Bluetooth on the children's phones (5th B), ❖ The children watched the two videos. ❖ They then created a drawing about the proposition in their notebooks and took picture of it, ❖ They send this to the teacher using Bluetooth
	Orthography: Writing homonyms in the context of a sentence (both fifth grades)	❖ Teacher found a video on YouTube about the use of S, Z, ❖ It was downloaded and installed the video on the children's phone ❖ Children watched the video several times ❖ Children take a picture from exercise about this theme in their books, and solve the tasks in their phones using PaintPad

Social Science	Introduction to the three branches of the government	❖ Children in group of 4 (5th A), held a debate about the three branches of the government inside the classroom (3 children debated and one filmed them) ❖ The rest of the class watched the debates ❖ Children created a conceptual map using Sticky notes of the three branches of the government (5th B)

C.3 Learning Activities created by Teachers during the Study-3

Educational goal		Activity
Mathematics	Addition of Integers (both 6th grades)	❖ Because the teachers were not confident about the topic, the Math teacher recorded a video about addition with Integers for the teachers and this was installed on their phones, ❖ Then children watched the same video individually. ❖ The children sent the video to other students using Bluetooth, and installed it on their own phone during the class ❖ Children watched the video several times. ❖ The children solved the task in their notebooks. ❖ Teacher assigned as homework to watch the video at home.
	Subtraction of Integers (both 6th grades)	❖ Teacher introduced the topic. ❖ Because the teachers were not confident about the topic, the Math teacher recorded a video about subtraction with Integers for the teachers and this was installed on their phones, ❖ Then children watched the same video individually. ❖ The children sent the video to other students using Bluetooth, and installed it on their own phone during the class ❖ Children watched the video several times. ❖ The children solved the task in their notebooks. ❖ Teacher assigned as homework to watch the video at home.

Mathematics	Multiplication of Integers	❖ Because the teachers were not confident about the topic, the Math teacher recorded a video about multiplication with Integers for the teachers and this was installed on their phones ❖ Each teacher introduced the topic and asked the students to observe the video individually. Students observed the video several times. ❖ The teacher of the 6^{th} A wrote a practice exercise on the blackboard, ❖ The children took a picture of it, solved it using PaintPad and sent their solution back to the teacher via Bluetooth ❖ The children from the 6^{th} C practiced in their paper notebooks. The teacher assigned groups of two each the task of filming each other while solving the multiplication tasks. ❖ Also as homework, the teacher asked each child to film themselves solving the multiplication tasks.
	Division of Integers	❖ Because the teachers were not confident about the topic, the Math teacher recorded a video about division with Integers for the teachers and this was installed on their phones, ❖ Then children watched the same video individually. ❖ The children sent the video to other students using Bluetooth, and installed it on their own phone during the class ❖ Children watched the video several times. ❖ The children solved the task in their notebooks. ❖ Teacher assigned as homework to watch the video at home.
	Use of exponents with Integers	❖ A video of the use of exponents with Integers was recorded by an external Math teacher (6^{th} C) ❖ The video was installed previously in all the mobile phones of the students ❖ Children watched the video individually.
	The Circle and the Circumference	❖ A video about circumference and circle was recorded by an external Math teacher (6^{th} C). ❖ The video was installed previously in all the mobile phones of the students, ❖ Children watched the video as an introduction to the topic. ❖ Then, the teacher explained the concepts again and discussed the topic with the children.

English	The family members	❖ Each student using a poster they created themselves had to talk about his/ her family in the front of the class (both sixth grades) ❖ The rest of the children recorded the student who was talking in front.
		❖ All the children filmed their English teacher explaining about the family member (6th A)
Spanish	Introduction to the kind of poetry	❖ Students went to the yard with their phones to connect to the school WiFi, ❖ Using the Internet, students looked up the term Poetry, and searched not only in Google but also in YouTube ❖ Teacher discussed with the students, then he introduced the lesson about poetry
	Improving writing skills	❖ Teacher of the 6th C asked their students to write and illustrate a story.
Social Sciences	Mineral resources in different American countries (both North and South America)	❖ Students read the text in their books, ❖ Then teacher gave an explanation about the distribution of different mineral resources throughout both American continents, ❖ Then using the mobile phone, students took a picture of a map of America ❖ Using PaintPad, the children painted in and labeled the different mineral resources of different American countries.
	Geography	❖ Students from the 6th C took a picture of a blank map from the Americas with their mobile phones ❖ then they used PaintPad to locate, color, and label with the countries' names on the digital version of the map.
	The Panama Canal	❖ Students from 6th C searched for information about the Panama Canal using the Internet ❖ The teacher and students discussed about the history and importance of the Panama Canal based on this information.
	Children´s rights	❖ Teacher of the 6th C explained about the children´s rights ❖ Children wrote about their rights and duties in the family, in the school and in the community using the CuentoMovil prototype

Nature Sciences	Human reproduction and sexuality	❖ Children took a picture of a drawing about the female and male reproduction systems. ❖ Using PaintPad children labeled the different organs of the reproduction system. ❖ The teacher graded their work ❖ Then, the students recorded a video about reproduction system in groups ❖ as well as individually at home as homework.
	Introduction to the Five senses	❖ Teacher introduced the concept of the human sense (Sight, hearing, taste, smell and touch) while children recorded him giving the class ❖ Teacher and students discussed the five senses
	Part of our body: The Ear	❖ A video from YouTube about the parts of the ear was preinstalled on the phones ❖ Children watched the video in class and this was the basis for a class discussion.
Nature Sciences	The Invertebrates Animals	❖ Students from the 6^{th} C went to the yard, in order to get connection to the school WiFi ❖ they then looked in Google information for about the invertebrates animals, ❖ Once the web page was loaded, they returned to the classroom and discussed with the teacher what they have found
	Ecosystems	❖ Teachers introduced the topic of Ecosystems to the student ❖ Children from 6^{th} C used the CuentoMovil prototype application to write and to illustrate terrestrial and the aquatic ecosystems.
Religion	Values	❖ Students from 6^{th} C were organized into 5 teams, and each team prepared a presentation and poster about values for children attending the 1^{st} grade ❖ Using the mobile phone, two students of each team filmed the presentation
		❖ During the Values Week, students from the 6^{th} C also participated in the Cleanup day, where they cleaned the school. ❖ Children took pictures using the phone. ❖ Later with the pictures and the support of the IT teacher, the grade teacher used the photos students took to create a video using Windows Live Movie Maker, ❖ Later, the grade teacher submitted a video which it was submitted to a Local Contest about Values

Religion	The Creation	❖ Students from the 6^{th} C made a drawing using PaintPad about the Creation after reading it on the Bible
	Ten Commands	❖ Children from the 6^{th} C looked on the Internet about the Ten Commandments using their mobile phones
Olympic Games 2012		❖ The teacher of the 6^{th} grade C, asked their students to find out about what are the Olympic games including the latest news from the Olympic Games 2012, ❖ This started a lively discussion between the students.

Appendix D: Examples of Screenshots collected during the Field Studies

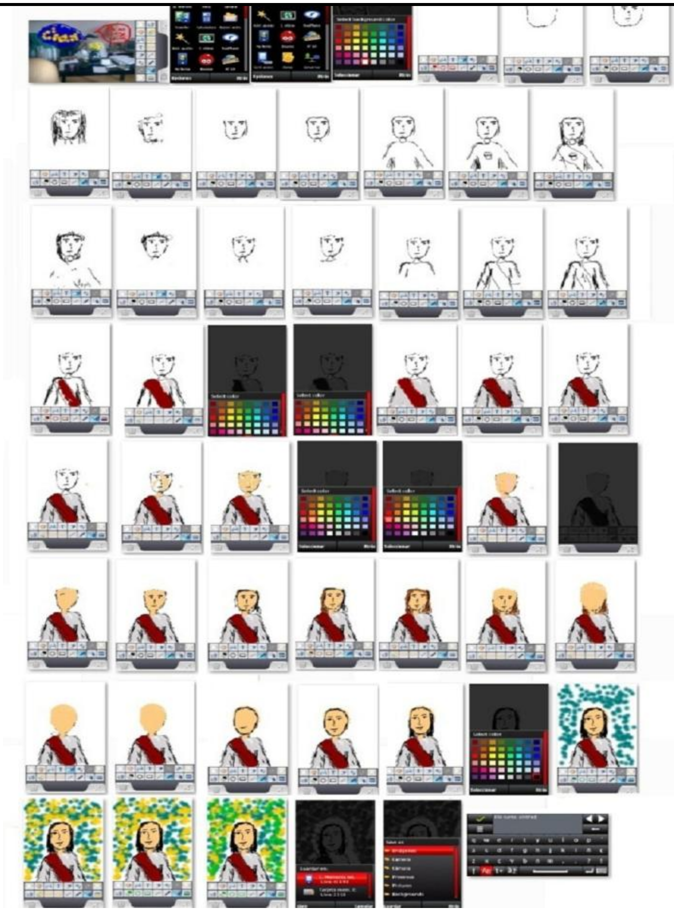


Figure 80. Sequence of the Screenshots that Were Automatically Taken On a Boy's Mobile Phone from the Study-1 using PaintPad

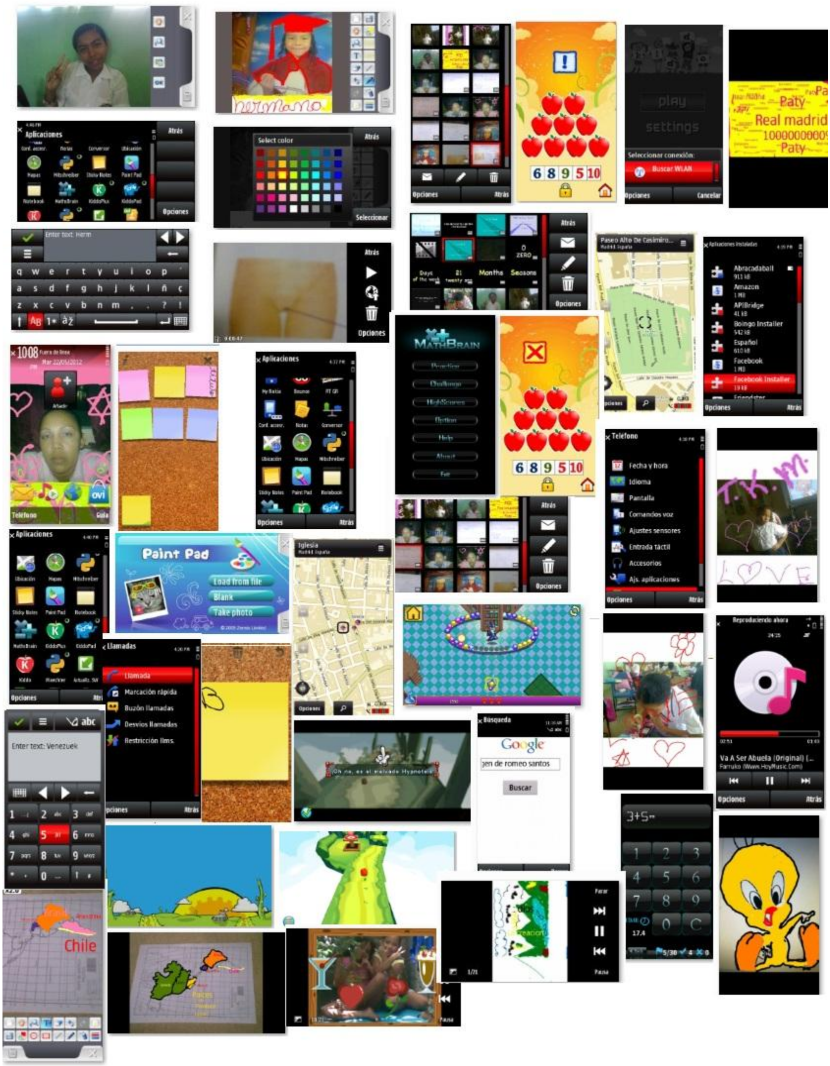


Figure 81. Sample Screenshots that Were Automatically Taken on a Girl's Mobile Phone from the Study-3.

Appendix E: Questionnaires used during the Field Studies

E.1 Feedback from chidlren, Short Studies

Universidad de Essen, -Alemania
Retroalimentación del Uso del Celular en Clases

I. INFORMACIÓN GENERAL

1. Soy ________ niño ____ niña

2. El número de celular que me tocó fue: _______________

3. Tengo _______ años

4. Estoy en ____________ grado.

II. EXPERIENCIA DEL ESTUDIO DE CAMPO

1. ¿Qué te pareció la clase con el uso del celular? Puedes marcar más de una opción según lo que piensas:
   ☐ Más entretenidas
   ☐ Más interesantes
   ☐ Siento que aprendí más
   ☐ Sentí que participe en la clase
   ☐ Se conoce más información
   ☐ Trabajé e hice más actividades con mis compañeros
   ☐ Me pareció igual que sin celular

2. ¿Qué te pareció la actividad de tomar foto a prácticas del libro y luego completarlas usando el programa para pintar y dibujar PaintPad del celular?

a) Fue fácil realizar esta actividad:	☐ Sí	☐ No
b) Me gustó:	☐ Sí	☐ No
c) La clase fue más interesante:	☐ Sí	☐ No
d) Divertido:	☐ Sí	☐ No
e) Me ayudo a entender más fácil el tema dado:	☐ Sí	☐ No

3. ¿Qué te pareció la actividad de ver vídeos sobre los temas dados en clase?
   a) Fue fácil realizar esta actividad: ☐ Sí ☐ No
   b) Me gustó: ☐ Sí ☐ No
   c) La clase fue más interesante: ☐ Sí ☐ No
   d) Divertido: ☐ Sí ☐ No
   e) Me ayudo a entender más fácil el tema dado: ☐ Sí ☐ No

4. ¿Qué te pareció la actividad de grabar audio?
   a) Fue fácil realizar esta actividad: ☐ Sí ☐ No
   b) Me gustó: ☐ Sí ☐ No
   c) La clase fue más interesante: ☐ Sí ☐ No
   d) Divertido: ☐ Sí ☐ No
   e) Me ayudo a entender más fácil el tema dado: ☐ Sí ☐ No

5. ¿Qué te pareció la actividad de grabar videos para presentar información dada en clases?
   a) Fue fácil realizar esta actividad: ☐ Sí ☐ No
   b) Me gustó: ☐ Sí ☐ No
   c) La clase fue más interesante: ☐ Sí ☐ No
   d) Divertido: ☐ Sí ☐ No
   e) Me ayudo a entender más fácil el tema dado: ☐ Sí ☐ No

6. ¿Qué te pareció la actividad de usar Sticky Notes para escribir resúmenes, cuadros sinópticos, anotaciones o mapas conceptuales?
   a) Fue fácil realizar esta actividad: ☐ Sí ☐ No
   b) Me gustó: ☐ Sí ☐ No
   c) La clase fue más interesante: ☐ Sí ☐ No
   d) Divertido: ☐ Sí ☐ No
   e) Me ayudo a entender más fácil el tema dado: ☐ Sí ☐ No

7. ¿Cuáles de las funciones del celular te fue más fácil usar? (ver vídeo, grabar vídeo, tomar fotografías, escribir con el teclado, escribir con el lápiz del celular, grabar voz, escuchar audio, pintar)
   ____
   ____
   ¿Por qué?____
   ____
   ____

8. ¿Cuáles funciones del celular que hemos aprendido usarías en las siguientes asignaturas?
   Ciencias Naturales: ____
   Inglés: ____
   Matemáticas: ____
   Español: ____
   Ciencias Sociales: ____

9. ¿Cuáles de todas las actividades realizadas con el celular sentí que me ayudó más en mis estudios? Explica.
   ____
   ____
   ____

10. ¿Qué otra función o actividad del celular además de las que ya hemos visto crees tú que nos ayudaría en la escuela? ¿En qué materia y cómo crees tú se podría aplicar?
    ____
    ____
    ____

11. ¿Crees tú que si todos los niños y niñas tengan un celular en la clase los ayudaría a entender mejor la clase?
    ☐ Sí ☐ No

12. Querido amiguito o amiguita, gracias por tu valiosa colaboración. Tienes alguna otra sugerencia, comentario o preguntas que nos quieras decir sobre esta experiencia con el celular que nos pueda ayudar a mejorar este proyecto.
    ____
    ____
    ____
    ____

E.2 Feedback from chidlren, Long Study

Universidad de Stuttgart-Alemania
Retroalimentación del Uso del Celular en Clases

1. Nombre:____

2. Número de Celular:

____

3. Tengo ______ años

4. En tu casa hay una computadora:
☐ Sí, con acceso a Internet ☐ Sí, sin acceso a Internet ☐ No

5. ¿Cuántos celulares hay en tu casa?
☐ No hay celulares ☐ Sí ¿Cuántos? _________

6. ¿Cuántos celulares hay en tu casa con pantalla táctil (touchscreen)? _________

7. ¿Tienes tú un celular? ☐ Sí ☐ No

8. ¿Para qué usas tú el celular? (puedes seleccionar más de una respuesta)
☐ No uso celular
☐ Llamar por teléfono ☐Enviar mensajes de texto
☐ Tomar fotografías ☐ Escuchar música
☐ Navegar en Internet ☐ Agenda
☐ Jugar ☐Alarma ☐ Facebook
☐ Twitter ☐ Ver vídeos ☐ Juegos
☐Otros usos: ____

11. ¿Cómo son los celulares que tú o tus familiares que viven en tu hogar tienen?
☐**1era Generación.** El celular permite (a) hacer/recibir llamadas por teléfono, (b) enviar/recibir mensajes de texto SMS y (c) Pantalla blanco y negro
☐ **2da Generación.** El celular permite (a) hacer/recibir llamadas por teléfono, (b) enviar/recibir mensajes de texto SMS, (c) Pantalla de colores, (d) tiene cámara fotográfica y (e) juegos
☐ **2,5 Generación**. El celular (a) hace/recibe llamadas por teléfono, (b) enviar/recibir mensajes de texto SMS, (c) Pantalla de colores, (d) cámara fotográfica, (e) acceso a Internet (muy lento) y (f) juegos

☐**3era Generación.** El celular permite (a) hacer/recibir llamadas por teléfono, (b) enviar/recibir mensajes de texto SMS, (c) Pantalla de colores, (d) tiene cámara fotográfica y de vídeo (e) acceso a Internet (lento), (f) juegos y (g) reproductor de audio mp3.

☐ **3,5 Generación.** El celular permite (a) hacer/recibir llamadas por teléfono, (b) enviar/recibir mensajes de texto SMS, (c) Pantalla de colores, (d) tiene cámara fotográfica y de vídeo, (e) acceso a Internet Wi-Fi/GRPS (velocidad aceptable), (f) reproductor de audio mp3, (g) reproductor de vídeo, (h) permite agregar y usar una memoria externa en el celular.

12. ¿Te ayudo a entender mejor la materia observar los videos educativos en el celular?
☐ Sí Más que antes ☐Igual que antes ☐Menos que antes
☐ No me ayudo
¿Por qué?____
____
____
____

13. ¿Tienen en casa algún aparato para grabar vídeos (que **no** sea el celular Nokia usado en este proyecto)?
☐ Sí, tenemos: ☐Filmadora ☐ WebCam/Cámara en PC
☐ Celular ☐Otro
☐ No

14. ¿Cuál fue el grado de facilidad o dificultad que tuviste durante la grabación de los vídeos educativos usando el celular Nokia de este proyecto? Encierra en un círculo la carita que corresponda a cómo te sentiste.

☹	☹	😐	☺	☺
Muy difícil	Difícil	Ni fácil ni difícil	Fácil	Muy Fácil

¿Por qué?____
____

15. Imagina que tienes que dar una charla. ¿Qué prefieres?
☐ Dar la charla en directo en frente al salón
☐ Traerla filmada de la casa en el celular y presentarla usando el proyector
¿Por qué?____
____

16. Si tuvieras que hacer un video en colaboración con tus compañeros y te dieran la opción de elegir entre ser el/la camarógrafo o la persona filmada ¿Qué rol prefieres durante la filmación de ese video?
    ☐ Prefiero ser camarógrafo ☐ Prefiero estar frente a la cámara
    ☐ Me da igual

¿Por qué?____
____

17. ¿Cuál fue el grado de facilidad o dificultad que tuviste para observar los vídeos educativos usando el celular Nokia? Encierra en un círculo la carita que corresponde a cómo te sentiste.

☹	☹	😐	☺	☺
Muy difícil	Difícil	Ni fácil ni difícil	Fácil	Muy Fácil

¿Por qué?____
____

18. ¿Te ayudo a entender mejor la materia observar los videos educativos en el celular?
    ☐ Sí Más que antes ☐Igual que antes
    ☐Menos que antes ☐No me ayudo

¿Por qué?____
____

19. ¿Tienen en casa algún aparato para ver video (que **<u>no</u>** sea el celular Nokia usado en este proyecto)?
    ☐Sí tenemos: ☐DVD Player ☐Computador
    ☐ Celular ☐Otro
    ☐No

20. ¿Qué prefieres, ver un video educativo en la computadora o en el celular?
    ☐ Ver Vídeo educativo en la computadora ☐ Ver vídeo educativo en el celular

¿Por qué?____
____

21. ¿Cuál fue el grado de facilidad o dificultad que tuviste para trabajar con PaintPad usando el celular Nokia?

☹	☹	😐	☺	☺
Muy difícil	Difícil	Ni fácil ni difícil	Fácil	Muy Fácil

¿Por qué?____

____

22. ¿Te ayudo a entender mejor la materia el uso de PaintPad del celular?

☐ Sí Más que antes ☐Igual que antes
☐Menos que antes ☐No me ayudo

¿Por qué?____

____

23. Imagina que tienes que pintar un mapa y escribir los nombres de los países en él. La maestra te da a eligir entre realizar esta actividad usando PaintPad o usando lápices de colores y papel. ¿Cuál escogerías?

☐PaintPad ☐ Lápices de Colores, Lápiz y Papel

¿Por qué?____

____

24. ¿Consideras que el uso del celular te ayudo a entender mejor las materias?

☐ Sí Más que antes ☐Igual que antes
☐Menos que antes ☐No me ayudo

¿Por qué?____

____

E.3 Feedback from teachers

I. Información General
   a. Género: ☐Femenino ☐Masculino
   b. Edad: _________ años
   c. Años de experiencia como maestro(a): ___________________________
   d. Es usted maestro(a) de grado: ☐Sí ☐No
   e. Tiene usted experiencia en trabajar en escuelas de
      ☐Multigrado ☐Difícil Acceso ☐Áreas urbanas
   f. ¿Considera usted qué el celular se puede usar en grupos multigrados?
      ☐Sí ☐No

II. Retroalimentación en el uso del teléfono celular en el aula de clases

1. ¿Cómo califica usted la utilidad del uso de la función de **reproducción de video** en el aula de clases, por ejemplo ver vídeos de temas dados en clase? La escala de evaluación va de 1 a 5, donde:

1= totalmente en desacuerdo, 2= desacuerdo, 3= indiferente, 4= de acuerdo, 5= totalmente de acuerdo

Asignatura	¿Considera usted que fue **útil** usar la función de **reproducción de vídeo** como parte de las actividades en el **aula de clases**?				
Matemáticas	☐ *Totalmente en Desacuerdo*	☐ *Desacuerdo*	☐ *Indiferente*	☐ *De acuerdo*	☐ *Totalmente de acuerdo*
Español	☐ *Totalmente en Desacuerdo*	☐ *Desacuerdo*	☐ *Indiferente*	☐ *De acuerdo*	☐ *Totalmente de acuerdo*
Ciencias Naturales	☐ *Totalmente en Desacuerdo*	☐ *Desacuerdo*	☐ *Indiferente*	☐ *De acuerdo*	☐ *Totalmente de acuerdo*
Inglés	☐ *Totalmente en Desacuerdo*	☐ *Desacuerdo*	☐ *Indiferente*	☐ *De acuerdo*	☐ *Totalmente de acuerdo*
Ciencias Sociales	☐ *Totalmente en Desacuerdo*	☐ *Desacuerdo*	☐ *Indiferente*	☐ *De acuerdo*	☐ *Totalmente de acuerdo*
Otra: ____________________ ___________________________	☐ *Totalmente en Desacuerdo*	☐ *Desacuerdo*	☐ *Indiferente*	☐ *De acuerdo*	☐ *Totalmente de acuerdo*

2. ¿Cómo califica usted la utilidad del uso de la función de **grabación de video** en el aula de clases, por ejemplo creación de vídeos por los niños con temas dados en clase o investigación? La escala de evaluación va de 1 a 5, donde:

1= totalmente en desacuerdo, 2= desacuerdo, 3= indiferente, 4= de acuerdo, 5= totalmente de acuerdo

Asignatura	¿Considera usted que fue **útil** usar la función de **grabación de vídeo** como parte de las actividades en el **aula de clases**?				
Matemáticas	☐ *Totalmente en Desacuerdo*	☐ *Desacuerdo*	☐ *Indiferente*	☐ *De acuerdo*	☐ *Totalmente de acuerdo*
Español	☐ *Totalmente en Desacuerdo*	☐ *Desacuerdo*	☐ *Indiferente*	☐ *De acuerdo*	☐ *Totalmente de acuerdo*
Ciencias Naturales	☐ *Totalmente en Desacuerdo*	☐ *Desacuerdo*	☐ *Indiferente*	☐ *De acuerdo*	☐ *Totalmente de acuerdo*
Inglés	☐ *Totalmente en Desacuerdo*	☐ *Desacuerdo*	☐ *Indiferente*	☐ *De acuerdo*	☐ *Totalmente de acuerdo*
Ciencias Sociales	☐ *Totalmente en Desacuerdo*	☐ *Desacuerdo*	☐ *Indiferente*	☐ *De acuerdo*	☐ *Totalmente de acuerdo*
Otra: ____________________ ___________________________	☐ *Totalmente en Desacuerdo*	☐ *Desacuerdo*	☐ *Indiferente*	☐ *De acuerdo*	☐ *Totalmente de acuerdo*

3. ¿Cómo califica usted la utilidad del uso de la función de **tomar fotografías?** La escala de evaluación va de 1 a 5, donde:

1= totalmente en desacuerdo, 2= desacuerdo, 3= indiferente, 4= de acuerdo, 5= totalmente de acuerdo

Asignatura	¿Considera usted que fue **útil** usar la función de **tomar fotografías** como parte de las actividades en el **aula de clases**?				
Matemáticas	☐ *Totalmente en Desacuerdo*	☐ *Desacuerdo*	☐ *Indiferente*	☐ *De acuerdo*	☐ *Totalmente de acuerdo*
Español	☐ *Totalmente en Desacuerdo*	☐ *Desacuerdo*	☐ *Indiferente*	☐ *De acuerdo*	☐ *Totalmente de acuerdo*
Ciencias Naturales	☐ *Totalmente en Desacuerdo*	☐ *Desacuerdo*	☐ *Indiferente*	☐ *De acuerdo*	☐ *Totalmente de acuerdo*
Inglés	☐ *Totalmente en Desacuerdo*	☐ *Desacuerdo*	☐ *Indiferente*	☐ *De acuerdo*	☐ *Totalmente de acuerdo*
Ciencias Sociales	☐ *Totalmente en Desacuerdo*	☐ *Desacuerdo*	☐ *Indiferente*	☐ *De acuerdo*	☐ *Totalmente de acuerdo*
Otra: ____________________ ___________________________	☐ *Totalmente en Desacuerdo*	☐ *Desacuerdo*	☐ *Indiferente*	☐ *De acuerdo*	☐ *Totalmente de acuerdo*

4. ¿Cómo califica usted la utilidad del uso de la función de **grabación de voz/audio?** Por ejemplo grabación individual de la voz de diálogos o lecturas en inglés, o poemas en español? La escala de evaluación va de 1 a 5, donde:

1= totalmente en desacuerdo, 2= desacuerdo, 3= indiferente, 4= de acuerdo, 5= totalmente de acuerdo

Asignatura	¿Considera usted que fue **útil** usar la función de **grabación de voz/audio** como parte de las actividades en el **aula de clases**?				
Matemáticas	☐ *Totalmente en Desacuerdo*	☐ *Desacuerdo*	☐ *Indiferente*	☐ *De acuerdo*	☐ *Totalmente de acuerdo*
Español	☐ *Totalmente en Desacuerdo*	☐ *Desacuerdo*	☐ *Indiferente*	☐ *De acuerdo*	☐ *Totalmente de acuerdo*
Ciencias Naturales	☐ *Totalmente en Desacuerdo*	☐ *Desacuerdo*	☐ *Indiferente*	☐ *De acuerdo*	☐ *Totalmente de acuerdo*
Inglés	☐ *Totalmente en Desacuerdo*	☐ *Desacuerdo*	☐ *Indiferente*	☐ *De acuerdo*	☐ *Totalmente de acuerdo*
Ciencias Sociales	☐ *Totalmente en Desacuerdo*	☐ *Desacuerdo*	☐ *Indiferente*	☐ *De acuerdo*	☐ *Totalmente de acuerdo*
Otra: ____________________ ___________________________	☐ *Totalmente en Desacuerdo*	☐ *Desacuerdo*	☐ *Indiferente*	☐ *De acuerdo*	☐ *Totalmente de acuerdo*

5. ¿Cómo califica usted la utilidad del uso de la función de **reproducción de audio/música?** Por ejemplo, reproducción de audio con información educativa. La escala de evaluación va de 1 a 5, donde:

1= totalmente en desacuerdo, 2= desacuerdo, 3= indiferente, 4= de acuerdo, 5= totalmente de acuerdo

Asignatura	¿Considera usted que fue **útil** usar la función de **reproducción audio/música** como parte de las actividades en el **aula de clases**?				
Matemáticas	☐ *Totalmente en Desacuerdo*	☐ *Desacuerdo*	☐ *Indiferente*	☐ *De acuerdo*	☐ *Totalmente de acuerdo*
Español	☐ *Totalmente en Desacuerdo*	☐ *Desacuerdo*	☐ *Indiferente*	☐ *De acuerdo*	☐ *Totalmente de acuerdo*
Ciencias Naturales	☐ *Totalmente en Desacuerdo*	☐ *Desacuerdo*	☐ *Indiferente*	☐ *De acuerdo*	☐ *Totalmente de acuerdo*
Inglés	☐ *Totalmente en Desacuerdo*	☐ *Desacuerdo*	☐ *Indiferente*	☐ *De acuerdo*	☐ *Totalmente de acuerdo*
Ciencias Sociales	☐ *Totalmente en Desacuerdo*	☐ *Desacuerdo*	☐ *Indiferente*	☐ *De acuerdo*	☐ *Totalmente de acuerdo*
Otra: ____________________ ___________________________	☐ *Totalmente en Desacuerdo*	☐ *Desacuerdo*	☐ *Indiferente*	☐ *De acuerdo*	☐ *Totalmente de acuerdo*

6. ¿Cómo califica usted la utilidad del **uso del Internet** (por ejemplo Wikipedia, Google)? La escala de evaluación va de 1 a 5, donde:

1= totalmente en desacuerdo, 2= desacuerdo, 3= indiferente, 4= de acuerdo, 5= totalmente de acuerdo

Asignatura	¿Considera usted que fue **útil** usar la función de **uso del Internet** como parte de las actividades en el **aula de clases**?				
Matemáticas	☐ *Totalmente en Desacuerdo*	☐ *Desacuerdo*	☐ *Indiferente*	☐ *De acuerdo*	☐ *Totalmente de acuerdo*
Español	☐ *Totalmente en Desacuerdo*	☐ *Desacuerdo*	☐ *Indiferente*	☐ *De acuerdo*	☐ *Totalmente de acuerdo*
Ciencias Naturales	☐ *Totalmente en Desacuerdo*	☐ *Desacuerdo*	☐ *Indiferente*	☐ *De acuerdo*	☐ *Totalmente de acuerdo*
Inglés	☐ *Totalmente en Desacuerdo*	☐ *Desacuerdo*	☐ *Indiferente*	☐ *De acuerdo*	☐ *Totalmente de acuerdo*
Ciencias Sociales	☐ *Totalmente en Desacuerdo*	☐ *Desacuerdo*	☐ *Indiferente*	☐ *De acuerdo*	☐ *Totalmente de acuerdo*
Otra: ____________________ ___________________________	☐ *Totalmente en Desacuerdo*	☐ *Desacuerdo*	☐ *Indiferente*	☐ *De acuerdo*	☐ *Totalmente de acuerdo*

7. ¿Cómo califica usted la utilidad del uso de aplicaciones para **dibujar (PaintPad)**? Con PaintPad es posible dibujar desde cero, o bien modificar figuras/fotografías ya guardadas, agregar texto a las imágenes. La escala de evaluación va de 1 a 5, donde:

1= totalmente en desacuerdo, 2= desacuerdo, 3= indiferente, 4= de acuerdo, 5= totalmente de acuerdo

Asignatura	¿Considera usted que fue **útil** usar la función de **dibujar con PaintPad** como parte de las actividades en el **aula de clases**?				
Matemáticas	☐ *Totalmente en Desacuerdo*	☐ *Desacuerdo*	☐ *Indiferente*	☐ *De acuerdo*	☐ *Totalmente de acuerdo*
Español	☐ *Totalmente en Desacuerdo*	☐ *Desacuerdo*	☐ *Indiferente*	☐ *De acuerdo*	☐ *Totalmente de acuerdo*
Ciencias Naturales	☐ *Totalmente en Desacuerdo*	☐ *Desacuerdo*	☐ *Indiferente*	☐ *De acuerdo*	☐ *Totalmente de acuerdo*
Inglés	☐ *Totalmente en Desacuerdo*	☐ *Desacuerdo*	☐ *Indiferente*	☐ *De acuerdo*	☐ *Totalmente de acuerdo*
Ciencias Sociales	☐ *Totalmente en Desacuerdo*	☐ *Desacuerdo*	☐ *Indiferente*	☐ *De acuerdo*	☐ *Totalmente de acuerdo*
Otra: ____________________ ___________________________	☐ *Totalmente en Desacuerdo*	☐ *Desacuerdo*	☐ *Indiferente*	☐ *De acuerdo*	☐ *Totalmente de acuerdo*

8. De acuerdo a sus observaciones hecha durante las dos semanas que los estudiantes utilizaron los celulares en este estudio de campo, considera que: (pueda señalar más de una opción)
   - ☐ Los estudiantes fueron más participativos en clases.
   - ☐ Los estudiantes estuviern más entusiasmados con las asignaciones.
   - ☐ Los estudiantes presentaron un mejor rendimiento alfinalizar el tema.
   - ☐ Los estudiantes estuvieron más distraídos de lo visual.
   - ☐ Los estudiantes se concentraron en la realziación de la actividad con el celular.

9. En qué asignaturas considera el uso de las funciones multimedia (creación/reproducción de video/audio) realmente una ayuda importante (puede señalar más de una opción)
   - ☐ Ciencias Sociales ☐ Matemáticas ☐ Español
   - ☐ Inglés ☐ Ciencias Naturales
   - ☐ Otras:____

¿Por qué? ____
____
____

10. ¿En qué asignaturas o cómo usaría las funciones de dibujo y edición de imágenes del teléfono celular?

____
____

11. ¿En qué asignaturas o cómo usaría la función de grabar videos en el celular?

____
____

12. ¿Con qué facilidad considera usted se integraron los niños a las actividades hechas con los celulares? (Solamente seleccione uno)

   - ☐ Muy difícil ☐Difícil
   - ☐Ni fácil ni difícil ☐Fácil ☐Muy Fácil

13. ¿Considera usted que hubo colaboración entre los estudiantes al usar el celular? Puede señalar más de una opción.
   - ☐ En el aprendizaje, en el uso del celular por ejemplo enseñar/ayudar al compañero en usar el celular
   - ☐ Realizando una actividad en conjunto, por ejemplo en la elaboración de un vídeo
   - ☐ No percibí colaboración entre los estudiantes al usar el celular

14. ¿Qué funciones del celular considera usted fueron las más útiles para las distintas actividades de aprendizaje?

____
____

¿Por qué? ____
____
____

15. De contar los niños con celulares con capacidades multimedia (imagen, audio, vídeo) no necesariamente con celulares de pantalla táctil, recomendaría el uso de los celulares en clases?

☐ Sí ☐ No

¿Por qué? ____
____
____

16. De usar el celular en clase:
    a) Lo usaría:

    ☐ En todas las materias ☐ En algunas materias

    b) ¿Con qué frecuencia lo usaría?

    ☐Diario ☐Algunas veces a la semana

Muchísimas gracias por su valiosa colaboración. Tiene alguna otra sugerencia, comentario o preguntas que nos quiera decir sobre esta experiencia con el celular, por favor indíquenos en la parte de atrás de esta hoja.

E.4 Case Study: Painting Using a Single Mobile Phone versus a Shared Computer Lab Approach (Questionnaire)

Universidad de Stuttgart-Alemania
Cuestionario sobre el Uso del Celular y la Computadora para Pintar Mapas

1. ¿Cuál medio tecnológico te fue más fácil obtener el mapa que usaste para esta actividad de C. Sociales?

☐ Computador ☐ Celular

¿Por qué? ____
____
____
____

2. ¿Con cuál medio tecnológico te fue más fácil pintar el mapa?

☐ Computador ☐ Celular

¿Por qué? ____
____
____
____

3. ¿Con cuál medio tecnológico te fue más fácil pintar el mapa?

☐ Computador ☐ Celular

¿Por qué? ____
____
____
____

4. ¿Con cuál medio tecnológico te fue más fácil enviar al maestro el mapa que pintaste?

☐ Computador ☐ Celular

¿Por qué? ____
____
____
____

5. ¿Comparando el uso del celular y de la PC para el desarrollo de esta actividad de Ciencias Sociales (obtener mapa, localizar, pintar, escribir y enviar) con el uso de lápices de colores y papel. ¿Cuál de los tres medios te gusta más utilizar?

☐ Paint en la PC ☐ PaintPad en el celular
☐ Lápices de colores y mapa en papel

¿Por qué? ____
____
____
____

Muchas Gracias ☺

Appendix F: Protocol of the case studies about Children's Handwriting

F.1 Case Study: Input interaction [handwriting] with school children (Panama)

Grade:_______ School: ____________________ Date: _______

General Information

Name: ____

Birth Date: _______________________________ Age: ____________

Gender: ____ Girl ____ Boy

Own a handy: ____ Yes ____ No

Have ever use a handy? ____ Yes ____ No

Experience with input mode: ____ Keypad ___ Touchscreen

1. Testing with Paper and Pencil

Preferred Hand: _____ left ____ right

Method of writing: _____ block letters ____ cursive _____ mixed

Way the child takes the pencil (see figure): ____

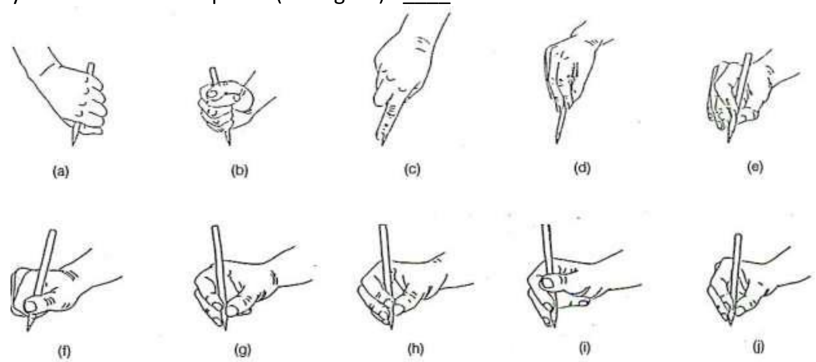


Figure 82. Hand position when taking pencil. Retrieved from Schneck & Henderson (1990)

Task	Speed (s)	Number of traces	Number of time child erase	Fluctuating
Square				
Circle				
Curved lines				
Straight line Vertical				
Straight line horizontal				
Straight line diagonal				
Color figure				
Numbers				
Full name				
Phrase				

Observations:____
____
____
____
____

2. Testing with Stylus and Capacitive Touchscreen Smartphone

Preferred Hand: ______ left ____ right
Method of writing: ______ block letters ____ cursive ______ mixed
Way the child takes the pencil (see figure): ____

Task	Speed (s)	Number of traces	Number of time child erase	Fluctuating
Square				
Circle				
Curved lines				
Straight line Vertical				
Straight line horizontal				
Straight line diagonal				
Color figure				
Numbers				
Full name				
Phrase				

Observations:____
____
____
____

3. Testing with direct interaction on capacitive touchscreen Smartphone

Preferred Hand: ______ left ____ right
Method of writing: ______ block letters ____ cursive ______ mixed

Task	Speed (s)	Number of traces	Number of time child erase	Fluctuating
Square				
Circle				
Curved lines				
Straight line Vertical				
Straight line horizontal				
Straight line diagonal				
Color figure				
Numbers				
Full name				
Phrase				

Observations:____
____
____
____
____

4. Testing with Stylus and Resistive Touchscreen Phone

Preferred Hand: ______ left ____ right
Method of writing: ______ block letters ____ cursive ______ mixed
Way the child takes the pencil (see figure): ____

Task	Speed (s)	Number of traces	Number of time child erase	Fluctuating
Square				
Circle				
Curved lines				
Straight line Vertical				
Straight line horizontal				
Straight line diagonal				
Color figure				
Numbers				
Full name				
Phrase				

Observations:____
____
____
____
____

F.2 Case Study: Input interaction [handwriting] with school children (Germany)

Date: 16-17.07.2012

I. General Information

1. Birth Date (month/year): ______________/________________ Age: ________ years
2. Gender: _____ Girl _____ Boy
3. Have the child ever used a phone? _____ yes _____ no
4. Which kind of phone? _____ Touchscreen _____ Keypad
5. Does the child own a mobile phone? _____ yes _____ no
6. Has the child ever used a touchscreen device (e.g. ipad, nintendo)?
   _____ yes _____ no
   6.1. Input interaction with ______Finger _____ Stylus

II. Testing with Paper and Pencil

Preferred Hand: _____ Left _____ Right

Method of writing :______ block letters _____ cursive ______ mixed

Way the child takes the pencil (see figure attached): __________

Task	Speed in seconds	Number of traces	Number of time child erase	Number of time child re-bold
1. Square				
2. Tree				
3. Numbers				
4. Word "Hose"				

III. Testing with Stylus and Smartphone

Preferred Hand: _____ Left _____ Right

Method of writing: ______ block letters _____ cursive ______ mixed

Way the child takes the pencil (see figure attached): __________

Task	Speed in seconds	Number of traces	Number of time child erase	Number of time child re-bold
1. Square				
2. Tree				
3. Numbers				
4. Word "Hose"				

IV. Testing with the use of the finger on touchscreen Smartphone

Preferred Hand: ____ Left ____ Right
Method of writing: _____ block letters ____ cursive _____ mixed
Finger Used: ___________________________________

Task	Speed in seconds	Number of traces	Number of time child erase	Number of time child re-bold
1. Square				
2. Tree				
3. Numbers				
4. Word ''Hose"				

V. Testing with the Nokia phone and the Stylus

Preferred Hand: ____ Left ____ Right
Method of writing: _____ block letters ____ cursive _____ mixed
Way the child takes the pencil (see figure attached): _________

Task	Speed in seconds	Number of traces	Number of time child erase	Number of time child re-bold
1. Square				
2. Tree				
3. Numbers				
4. Word ''Hose"				