An Exploratory Study on the Use of Camera Phones and Pico Projectors in Rural India

Akhil Mathur[*†], Divya Ramachandran[#], Edward Cutrell[Δ], Ravin Balakrishnan[†]
[*] Alcatel-Lucent Bell Labs, Bangalore, India
[†] Department of Computer Science, University of Toronto, Toronto, Canada
[#] University of California, Berkeley, USA
[Δ] Microsoft Research, Bangalore, India
akhil@dgp.toronto.edu, ravin@dgp.toronto.edu

ABSTRACT
We explore the potential of using camera phones and pico projectors in rapid creation and presentation of digital content in a development context. A camera phone based content authoring application was designed and deployed with three different user populations in the domains of classroom education and health care. Our findings show that despite the variations in education levels, cultural background, and technology exposure, users successfully created and presented different forms of digital content using the camera phone and pico projector.

Author Keywords
Digital content, ICTD, developing regions, camera phones, pico projectors, education, health workers

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

General Terms
Human Factors, Design

INTRODUCTION

There is an abundance of digital content on the Internet, which is both produced and consumed by millions of users around the world. However, those who are on the other side of the so called 'digital divide' are unable to benefit from this digital revolution due to limited or no access to the Internet. Even when the accessibility problem is solved, issues such as low literacy levels, low computer proficiency of users, and lack of local relevance of the existing content to the users still can hinder the production and consumption of such content in the developing world.

In this paper, we explore how people in the developing world might use mobile phones and handheld projectors to create and disseminate locally relevant digital content, in the domains of classroom education and health care. We chose to focus our work in these domains primarily because past research has shown them having benefitted from the use of digital content. There is extensive evidence in the literature to support the claim that the use of digital visual content in the classroom instruction process can raise students' attention levels and can also significantly improve their performance in retention and comprehension tasks [4, 9]. Similarly, anti-polio television campaigns by UNICEF and the Government of India have been successful in reaching its intended audience in endemic areas and the disease is almost on the verge of extinction [6].

We argue that a camera phone can be an effective tool for creation of digital content in developing regions due to the technology advancements such as increased camera resolution, high storage capacity and the rapidly falling prices. A recent study shows that global camera phone shipments in 2009 were 89% of the total mobile phone shipments [7]. Today, a touch-screen enabled camera phone can be purchased for as low as USD 80 in India [22]. Camcorders, digital cameras, audio recorders are few other alternatives for creation of digital content, but they are much less prevalent in developing regions as compared to mobile phones.

Pico projectors [19] are battery powered handheld projectors which can be connected to a mobile phone with audio-video output capability. They are currently priced in the range of USD 150 to USD 250, but market predictions suggest that the prices will drop below USD 30 in 2012 [20]. Perhaps most interesting is that pico projectors are starting to be integrated into mobile phones [23], resulting in combination capture, presentation and communication devices that will soon become as commonplace as camera phones are today. As such, we argue that such combination projection camera phones will soon become a viable low- cost content creation and dissemination platform. It is thus timely to explore their possible use for such applications. When we began our study, there were very few projection camera phones on the market that were programmable. Hence, we emulate the functionalities of a projection camera phone by connecting a pico projector to a camera phone as shown in Figure 1.

MobileHCI 2011, Aug 30–Sept 2, 2011, Stockholm, Sweden.

Figure 1. Camera phone (right) connected with pico projector (left) to emulate the functionality of a projection camera phone

Therefore, the two motivations behind our work were – 1) lack of availability of digital information in the developing world and 2) new technology artifacts such as projection camera phones. We wanted to understand the challenges faced by people in creating digital content and explore ways in which projection camera phones can address them. We also wanted to understand the limitations of using projection camera phones in resource-constrained regions.

After a brief review of related work, we describe the three local population groups who participated in our study. We then discuss the design process of a camera phone based content authoring application developed for the study. Finally, we present the results of the study followed by a discussion on the feasibility and value of using projection camera phones for content creation and dissemination applications in developing regions.

RELATED WORK

There are a number of studies on the use of mobile imaging in the developed world. Research by Kindberg et al. [10] and Van House et al. [24] showed differences in the types of images taken on camera phones compared to those taken on conventional cameras. Images on camera phones were often taken for their communicative value rather than as memory triggers. Jokela et al. [8] developed a mobile multimedia presentation editor and reported positive reactions by the users. Lambert [14] initiated a digital storytelling movement which promotes the creation of personal stories using still images and an audio narrative.

Despite the huge penetration of mobile phones, there has been little research on mobile content creation and dissemination in the developing world. Maunder et al. [16] developed *Big Board*, a system that allows multimedia content to be transferred wirelessly between a mobile phone and a situated display. The *StoryBank* project by Frohlich et al. [3] aimed at using mobile digital storytelling to increase access to information in rural India. Ramachandran et al. [21] researched the role of persuasive and motive videos on camera phones in motivating health workers in rural India to better perform their duties. Outside the camera phone context, projects such as the One Media Player per Teacher initiative in Africa [17], Digital Study Hall [2] and Digital Green [1] are exploring the role of user-generated content in education and agriculture extension. Hutchful et al. [5] have developed Cloze, a PC based content authoring tool for low computer proficiency teachers in rural India. Panjwani et al. [18] have developed Collage which is a content presentation tool for teachers in developing regions. None of these projects have explored the combination of camera phones with pico projectors for content creation and dissemination, which is the focus of our work.

FORMATIVE FIELD OBSERVATIONS

Participants

As discussed earlier, we chose to focus our work in the domains of classroom education and health care. Twelve teachers (9 female, 3 male) from a rural private school participated in our first study. The teachers were selected by the school administrators. Their teaching experiences varied from 2 to 16 years and their salaries were in the range of USD 200 – USD 400 per month. They were middle school teachers (grades 5-8) and taught a variety of subjects including English, mathematics, science, social science and computers. The school has about 820 students (grades K-12) and the medium of instruction is English. All students attending this school are from low income families (monthly family income less than $100) and are given free education. The school is equipped with 2 room projectors and a computer lab that has nearly one computer per student per class. The computer labs also have internet access. It should be noted that this school has much better infrastructure than a typical rural Indian school and hence is not a representative school. However, given the early stage nature of our exploration of using projection camera phones in this domain, it was important for our study to choose a school where teachers have some exposure to technology and the school administration provides the right support to the teachers if they want to use technology in their teaching.

Our second field study was done with seven health workers (2 male, 5 female) and four doctors (3 male, 1 female) in a rural area in northern Karnataka (Southern India), about 400 km from Bangalore. The health workers were employees of a private hospital and had education levels ranging from Grade 8 - 12. Northern Karnataka has a very high rate of oral cancer, caused mainly due to tobacco chewing. Hospitals across Karnataka organize health camps and run awareness programs to educate people about the benefits of early detection of oral cancer[1]. They employ health workers from the local communities to encourage people to go for oral cancer screening. However, due to the limited education, training and influence of health workers within the community, their effectiveness is limited.

Our third field study was done with four health workers (1 male, 3 female) and two doctors (1 male, 1 female) in rural parts of Rajasthan (Northern India) who worked at a private

[1] Cancer specialists in Bangalore told us that the detection of oral cancer in early stages can significantly increase the survival rate and reduce the cost of cure to 1/4th when compared to advanced stages of oral cancer.

hospital. They too were employed from the local community, but their education levels were relatively lower than the health workers in Northern Karnataka, ranging from Grade 6 to Grade 10. One of the main reasons for choosing this user population was to explore whether cultural differences between Southern and Northern India and different education levels have any impact on the usage of projection camera phones.

For brevity, in the rest of this paper, we refer to the three user populations as Teachers, HealthWorkers-1 and HealthWorkers-2 respectively.

Results

Teachers

For a period of two weeks, we observed and interviewed twelve teachers in the school as they prepared lessons and taught in class. We attempted to make classroom observations as unobtrusive as possible, and abstained from any interactions with the students or the teachers while making observations. Notes were taken during the classroom sessions. The interviews were semi-structured and consisted of one teacher and one researcher.

There were two aims to this exercise: first, we wanted to know how these teachers created and used digital content, if they did it at all. Second, we sought to understand their familiarity with technology and to get their views on the applicability of technology for classroom instruction.

The teachers had hectic schedules in which administrative tasks consumed a lot of their non-teaching time. Hence, they were inclined towards classroom activities that involved little time and effort to prepare, and did not require too much time to present in the 45 minute classroom session.

Technology usage

We asked the teachers about their technology ownership in the interviews. Nine of the twelve teachers reported that they did not have access to a computer at home. Every teacher owned a personal mobile phone, with five of them having a camera phone. We observed that teachers used digital content mainly in two ways: a) Presentations created in Microsoft PowerPoint and b) Screening of videos downloaded from the internet on the room projector. Both these activities took place in the computer lab and it required the teachers to take the entire class to the lab. We analyzed seven PowerPoint presentations created by the teachers for their composition and found that 63% of the slides had at least one image and the use of text was minimal. 11% of the slides had background sound added to them.

We categorized the teachers, into three categories based on their computer usage: there were 3 *Non-User* teachers, 5 *Low Proficiency* teachers and 4 *High Proficiency* teachers. Table 1 shows the technology usage in each of the three categories. It should however be noted that the proficiency of even the *High Proficiency teachers* was below the average skill level of a *digital native* [15].

	Non user	**Low proficiency**	**High proficiency**
Frequency of computer usage (weekly)	0-1	2-3	6-7
Frequency of use of technology for teaching (monthly)	0-1	1-2	3-4
Familiarity with mobile phones	High familiarity	High familiarity. Have used camera phones	High familiarity. Have used touch-screen phones
Familiarity with content creation software like MS PowerPoint	None	Low familiarity. Required help from more proficient users	High familiarity. Have created presentations with text animations

Table 1. Categories of teachers based on technology usage

Teachers expressed frustrations that the previous technology initiatives in the school were all based inside the computer lab and did not have much benefit for students as they go to the computer lab only twice a week. A teacher, referring to a past technology project, said –

"I really like that software, but I cannot take my students to the computer lab on a daily basis [to use the software]."

Teachers cited three main reasons for low usage of technology in teaching:

1) *Lack of proficiency in using computers:* Due to the limited access to computers, most teachers did not feel confident about using computers. 5 of them said that their slow typing speed on the keyboard is the main hindrance to computer usage. 7 teachers reported a lack of expertise with content creation software like Microsoft PowerPoint as the main reason for not using computers frequently.

2) *Lack of sufficient time to prepare digital content:* Teachers said that it was difficult to find time to prepare digital content due to their hectic schedules. 6 teachers expressed the desire to digitize textbook content and show it to their students using PowerPoint. This involved going to the scanner room, scanning particular textbook pages, transferring the scanned images to a USB drive, and later importing them into PowerPoint. Because the school has only one scanner which is shared by both the teachers and the administrators, teachers sometimes have to wait for the scanner to become available. Data transfer using the USB

drive also consumes lot of time because teachers are asked to run an antivirus scan before using the USB drive. Two teachers also reported that they do not possess a USB drive and have to go to the school administration to borrow it every time they want to use it. All these factors make the process of preparing digital content time consuming for the teachers.

3) *Scheduling conflicts with computer lab*: Every grade has two 45 minute computer sessions in a week. These sessions are mainly intended for training students to use word processors, presentation and spreadsheet programs. Very rarely, the subject teachers would go to the computer lab and present digital content on the topics being taught in the classroom. Teachers reported that arranging extra lab sessions for presentation of digital content was hard due to schedule conflicts.

The above reasons suggest that there is a need for a content authoring and presentation platform which helps the teachers to create digital content rapidly, avoid the scheduling conflicts with computer lab and can be used by teachers with low computer proficiency. We argue that projection camera phones are a possible way for fulfilling this need.

HealthWorkers-1

We conducted semi-structured interviews with the doctors and the health workers. Each interview involved one participant and one researcher and was about 30 minutes long. Doctors told us that every health worker is made in-charge of three nearby villages where he/she goes at least twice a week. Their duties include collecting patient data, counseling people on maternal health, educating them about the benefits of early detection of oral cancer and encouraging them to go to the nearby hospital at least once in six months for oral checkups.

Our interactions with the health workers revealed that they are motivated to perform their job. They enthusiastically showed us the patient data collected by them, information on patients who they had referred to the hospital, and innovative methods used by them to create heath awareness in the village. For instance, two health workers had collaborated with a village drama group and prepared a skit on sanitation practices which was performed during the festival period. Despite the motivation to perform the job, health workers said that people in the village often do not take their advice seriously, due to their limited education. One health worker reported being told by a group of people:

"Who gives [you] all this information? You are not a doctor. Why should we believe this [information] is true?"

Technology usage

Five of the health workers possessed a mobile phone, with 2 of them having a camera phone. Only one health worker had used a computer in the past for doing numeric data entry in a spreadsheet.

The local hospital had a mobile dental van which consisted of dental equipment, a waiting area for patients, a TV and a DVD player (Figure 2). The TV and DVD player were supposed to be used for screening health awareness videos, but doctors said that they have not used them for the last one year. Unavailability of video DVDs and inability to produce video content on their own were cited as the reasons for not using the technology.

Figure 2. Television set inside the mobile dental van. Mobile dental van is shown on the top right.

Projection camera phones can be useful to create health awareness videos easily and quickly. Because of their portable nature, these devices can be carried by the health workers to the remote villages for video screenings.

An important question in this study was – what kind of digital content should the health workers create for persuading people to go for oral cancer screening? For this purpose, we held a brainstorming session with 3 cancer specialists in Bangalore who have been involved in cancer awareness initiatives in the past. All 3 doctors agreed that local language videos are a good way to reach out to the target audience. One suggestion that came up was to involve mimicry artists, who can imitate the voice of movie actors[2], in the video production process. The videos can have a set of images depicting stories of patients who were successfully cured of oral cancer, with an audio narration of the story in a movie actor's voice. However, we did not follow through with this idea due to concerns about scalability and cost of hiring a mimicry artist.

Another alternative was to create a digital story which has a local doctor talking about symptoms, causes, cure of oral cancer along with narrating the stories of patients who were successfully cured of oral cancer. Local doctors are generally respected by rural people and health workers also have weekly meetings with the doctors, which can be utilized for recording videos using the camera phones. Hence, we decided to go ahead with having local doctors in the digital stories.

[2] Movie actors have a great influence on people in India. In some locales, movie actors even have temples dedicated to them.

HealthWorkers-2

We conducted semi-structured interviews with the doctors and the health workers. Each interview involved one participant and one researcher and was about 30 minutes long. Doctors told that every health worker is in-charge of one village which he/she visits twice or thrice a week. Their duties were similar to HealthWorkers-1, except that they did not do focus on oral cancer awareness.

Health workers in this group did not appear to be as motivated as HealthWorkers-1, and they complained about low salaries, hectic work schedules and lack of respect from the community. Only the male health worker possessed a mobile phone. While the three female health workers did not own a mobile phone, they reported that they use their husband's mobile phones whenever required. None of the health workers had used a computer. There was also no usage of technology for creating health awareness due to lack of technology infrastructure. We discussed the digital story formats with the doctors and they told that they would also prefer the story format that is being used for HealthWorkers-1. Hence, we used the same story format for both HealthWorkers-1 and HealthWorkers-2.

Design guidelines

Based on the initial field explorations, five design guidelines were established to inform the development of content authoring applications for projection camera phones:

i) Majority of the people in our user populations are low proficiency technology users. Hence, applications should have a very simple user interface.

ii) Applications should allow the users to create digital images and videos. Users should be able to add ink or audio annotations to the digital content.

iii) Since all our user populations have busy schedules at work, applications should facilitate rapid content creation. The interface and interaction modes should also reflect this property.

iv) Many participants reported that they are uncomfortable with typing on keyboard, and we argue that typing on a mobile phone is even more challenging. Hence, applications should minimize the need for text entry by the users.

v) We observed some teachers showing videos downloaded from the internet to the students. Thus, applications should allow the users to import digital content from external sources.

PROTOTYPE SYSTEM DESIGN

A prototype of the content authoring application was developed for touch-screen enabled HTC Touch Pro 2 camera phones. The prototype had the following major features:

(i) Record or delete images and videos, (ii) Add or delete ink annotations to the images and videos, (iii) Add or delete audio annotations to the images and videos, (iv) Write ink notes on a blank canvas, (v) View the content in slideshow mode, (vi) Save the content for future use, and (vii) Import previously created content or other content from the file system into the application.

To facilitate rapid content creation, we used marking menus [11] in the application for quick command invocation instead of linear menus. Marking menus are a variant of radial menus which allow a user to perform menu selection by either selecting an item from a popup radial menu that appears directly under the cursor (menu mode) or by drawing a mark in the direction of the desired menu item (mark mode). Marking menus have significant advantages over linear menus in terms of selection speeds and also support a seamless transition from novice to expert usage [12, 13]. Each time a novice user makes a mark to select an item from the popup menu; the user is essentially rehearsing the input gesture that an expert user would make to effect the same selection without popping up the visual menu. Eventually, the novice simply makes the mark without waiting for the visual menu to popup, thus seamlessly transitioning to expert behavior.

Now we walk the reader through a possible usage scenario of the application. Suppose a teacher named Meera has to conduct a class on "Human Respiratory System" and she wishes to present digital visual content in the class. Meera can open the Biology textbook and take pictures of the human respiratory system using the camera phone application. She can then add audio annotations to each picture to explain the contents of the picture. Figure 3 illustrates. Meera can also download videos on respiratory system from the internet, and import them into the camera phone application. She can finally save all the content for future use.

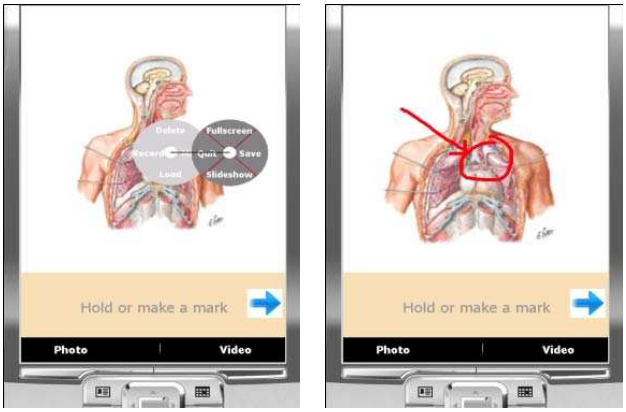

Figure 3. Content authoring application. Ink annotations on an image (Left) and use of marking menus (Right)

When Meera goes to the classroom, she connects her camera phone to the pico projector, starts the authoring application and opens the saved lesson. While explaining a digital image in the class, she can add ink annotations to emphasize some parts of the image.

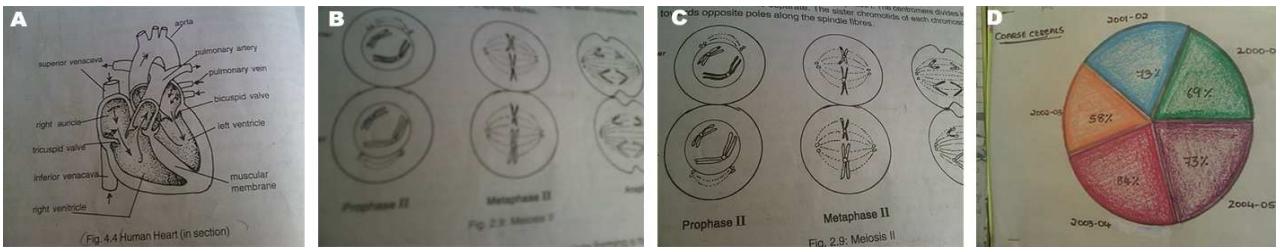

Figure 4: Content created by teachers. (a) Image of human heart digitized from a textbook. (b) An attempt to digitize a diagram resulted in a blurred image. (c) A clear image was captured after three unsuccessful attempts. (d) A chart prepared by a student was digitized using the camera phone.

FIELD EVALUATION

Methodology

Teachers

Out of the twelve teachers we interviewed, four decided not to participate in the study due to their busy schedules. Two other teachers also declined to participate because they did not want to carry the equipment loaned by us to their homes as they were expensive. Eventually, six teachers participated in the study - two *Non-User*s, two *Low Proficiency* and two *High Proficiency* teachers. We loaned one HTC Touch Pro2 phone and one Optoma PK-102 pico projector [19] with their chargers, to each of the six teachers for a period of 2 weeks. Our content authoring application was pre-loaded on the phones. Participants were allowed to carry the equipment home.

Teachers were told to create digital content relevant to their classroom instruction and show it to their students on the pico projector. The authoring application had a data logging mechanism which recorded data on time of usage, duration of usage, menu actions performed, and type of content created by the user. A researcher was present in the classrooms observing the teachers' and students' reactions only when content was being presented using the pico projector. At the end of two weeks, we collected the phones and analyzed the data logs. Semi-structured exit interviews were also conducted with every teacher.

HealthWorkers-1

Two health workers (1 male, 1 female) participated in the study which ran for a period of one week. We initially intended to give the equipment (one HTC Touch Pro2 phone and one pico projector) and let the health workers carry them home. However, because of concerns of safety and recovery of the equipment, local doctors insisted that we collect them back at the end of each day. As the health workers were not proficient with English, we translated our content authoring application into the local language (Kannada) and loaded it onto the phones. We demonstrated the application to the health workers and asked them to create digital stories as per the format discussed earlier.

HealthWorkers-2

Three health workers (1 male, 2 females) participated in the study which ran for a period of one week. The methodology was the same as with HealthWorkers-1 because we wished to find out the effect of different education levels and cultural backgrounds on the usage of the projection camera phones. We translated the application into the local language (Hindi) and loaded it on the phones.

Results

Teachers

Content Creation

The logged data indicated that a total of 138 images (μ = 22.83, σ = 9.06) and 16 videos (μ = 2.66, σ = 1.96) were authored by the 6 teachers over a period of two weeks. Figure 5 illustrates these results.

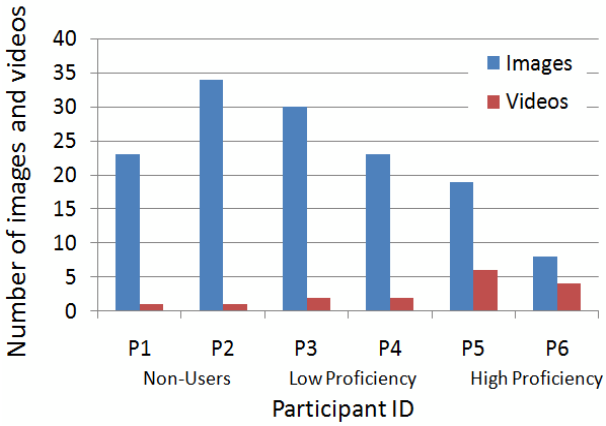

Figure 5: Number of digital contents created by teachers

The authored digital content can be classified into five categories:

a) Digitized textbook content (57% of total content) – This consisted of images of complex biological diagrams such as the digestive system, and human heart (Figure 4a) which require a lot of time and effort to be drawn on a blackboard. Multiple choice quizzes with images as their answer options were also digitized.

b) Images of physical object (14% of total content) – Teachers took pictures of the physical objects which they believed would be difficult to bring inside the classroom. This included images of different varieties of flowers planted at their homes, sea shells at their homes, and science laboratory equipment like flasks, beakers, and test-tubes which are not allowed to be taken outside the laboratory.

c) Images of student homework (11% of total content) – If a student did a good job at his/her homework, teachers took a picture of the homework and showed it to the entire class. Teachers commented that it motivates other students to work hard. Figure 4d illustrates this.

d) Content created by students (10% of total content) – To our surprise, teachers reported that they also asked students to create digital stories by taking pictures of the stories in the textbooks. In another activity, teachers gave students a list of words, asked them to capture images of those words and annotate the images with the part-of-speech (noun, verb, etc.) associated with the word. For example, if the word is 'Blackboard', the student would capture a picture of a blackboard using the camera phone and write 'Noun' over the image using the inking feature.

e) Content imported from external sources such as the internet (8% of total content) – One high proficiency teacher (P5) downloaded videos on the Solar System, Human Digestive System, and other basic science topics from the internet. With help from the research team, she transferred the videos into the camera phone and imported them into the authoring application. Later, she transferred the same videos into the phones of P2, P4 and P6.

It was surprising that the *Non-User* P2 and *Low Proficiency* user P3 were the top two users of the application, while *High Proficiency* user P6 used it the least (Figure 5 illustrates). During exit-interviews, we learned that since the *High Proficiency* users had more access to computers, they preferred to prepare the content on a computer. They complained that the mobile authoring application did not have support for text animations and writing in WordArt – functionalities provided by Microsoft PowerPoint. P1, P2 and P3 commented that they found the application very useful as they could create classroom content without much help from other teachers.

There was no effect of subject matter on the overall usage of the system; however the content category differed for various subjects. The Science and Social Science teachers created content belonging to all the categories (a-e), while the content created by English and Math teachers was limited to categories (a) and (d).

41% of the total content was created between 7 A.M. and 8 A.M. Exit interviews revealed that this was the time when teachers were on their way to the school via school bus and they wanted to make use of the free time. This result is interesting because digitizing content while traveling on a bus is particularly challenging. We found that many images captured by the teachers were blurred (Figure 4b) in the first attempt and teachers made several attempts to capture a clear image (Figure 4 c). Nonetheless, it illustrates teachers' interest in using the authoring application to create digital content.

Figure 6 shows the duration of usage by all participants over the period of two weeks. Usage was highest on the day when phones were loaned to the users due to the novelty effect. There was very little usage of the application on weekends; while school holiday was the primary reason for this low usage, 2 teachers reported that their phones got discharged on Saturdays and they did not want to charge them at home due to their concern of high electricity consumption.

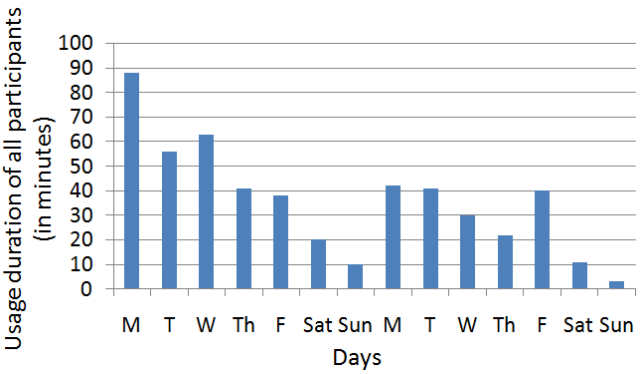

Figure 6. Usage duration of all participants on each day of the study

Teachers used ink annotations extensively to highlight portions of the digitized content, with 34% of the total content having ink annotations added to it. On the contrary, there was very little use of audio annotations (2.1% of the total content). Teachers reported that they prefer explaining the content themselves in the class, rather than adding audio annotations to it.

Content presentation

We observed eight sessions conducted by the teachers where they used the pico projector. Each session lasted for nearly 20 minutes and content was projected on a white smooth wall in front of the classroom.

Classrooms in the school received plenty of sunlight, which made it difficult to see the pico projector display. Covering the windows with curtains solved this problem to a great extent, but still the display was not clearly visible at the rear of the room. Hence, all teachers asked the students to gather near the front of the classroom. The built-in speaker of the pico projector was also not very powerful; hence we had to use external speakers for audio output.

One common pattern of usage observed was *Point and Teach*. Teachers would draw (ink annotate) arrows or circles over the digital image to point to some of its parts, and explain the pointed parts to the students. Then they would delete the ink and annotate other parts of the image to explain them. Analysis of the logged data shows that 'Delete Ink' was the most-used menu function in the application. Overall, 64% of the marking menu actions were performed in 'Menu mode' and 36% in 'Mark Mode', which shows that teachers started attaining expert behavior over a relatively short period of time.

There was plenty of excitement among the students about the pico projector display. In particular, students looked

excited about the multiple-choice quizzes and they wanted to answer the quiz questions before others do. Teachers reported that the level of excitement was similar to that which students exhibit in computer lab sessions. Apart from whole-classroom viewing, pico projectors were also used for small-group viewing. P1 showed a Math problem to the entire class using the pico projector. Three students solved the problem very quickly and wanted to know the answer from P1. She called them at her table and showed the solution of the problem by projecting the image on her table, hence ensuring that the other students could not see the solution.

Near the end of the study, one teacher who had initially refused to participate in the study (because of high costs of the equipment) met us and said that she would also like to use the camera phone application in her classroom. She had seen two other teachers using the projection camera phones and felt that she too can take care of the equipment.

HealthWorkers-1

Two digital stories were created by the health workers on oral cancer awareness. The script for both stories was mutually decided by local doctors and health workers. The first story was 4.5 minutes long and talked about two persons who got cured of oral cancer. Local doctors have a collection of printed photographs from past cancer cases. Health workers digitized two of these photographs, one showing a small lesion in patient's mouth and the other showing a bigger lesion. At the beginning of the story, the image of the small lesion is shown for approximately 8 seconds. This is followed by the doctor's video where he says that a patient with a small lesion came to their hospital and was cured in a few hours time. The doctor then talks about causes, precautions, dangers of oral cancer and the importance of its early detection. Then he gives an example of another patient who had a big lesion in his mouth which took weeks to get cured and where the cost of treatment was also high. This is followed by the digital image of a bigger lesion. It took nearly 45 minutes to prepare the storyline, record the video and capture the required images.

The second story was 3 minutes long and had a doctor explaining various kinds of oral cancer by means of images. The story starts by showing images of mouth cancer, lip cancer, tongue cancer, etc. followed by video of the doctor explaining each of them. It took 20 minutes to prepare the storyline, record the video and capture the required images. One health worker wanted to embed the images in the middle of the video, but he could not do so as our authoring application did not have advanced video editing features.

A team of dental students, health workers and a researcher went to a manufacturing factory where health workers screened both the videos to 116 factory employees. Screenings were done in the factory owner's room which was relatively dark as shown in Figure 7.

People came in groups of 20 for the screenings and each session was 25 minutes long. After the video screenings,

Figure 7. Screening of a digital story to factory employees. The pico projector output is displayed on a wall.

every person got checked by the dental students for lesions in their mouth. We cannot claim that people went for oral checkups due to watching the videos, but we did observe a lot of interaction between the viewers and the health workers after the video screening. Questions around cost, duration, procedure of the cancer cure were raised and were answered by the health workers. One factory employee asked,

"How much time does it take for an oral checkup in the hospital? I can come [for the checkup], but cannot take a full day leave from the factory."

Another factory employee, referring to the image of the bigger lesion in the first story, commented -

"That was frightening. I can't believe that he (the patient) got cured even after [having] such a big cancer."

Later, we interviewed the health workers for their reactions on using the projection camera phone for health awareness. Both health workers believed that the video screening sessions were productive as people asked several questions and looked interested in knowing more about prevention of oral cancer. One health worker told that the presence of local doctor in the video added credibility to the whole process and people paid more attention to the videos.

"They asked me questions and listened to me carefully. It was because doctor sir was in the video. They realized that I am close to the doctor."

HealthWorkers-2

At the time of this study, a wave of Dengue fever had gripped many parts of northern India. For this reason, health workers decided to create digital videos discussing causes, symptoms and precautions against Dengue fever.

Three health workers (2 female, 1 male) used the application to prepare 2 digital stories. The two female health workers collaborated on one story (3 minutes long) and the male health worker prepared the other story (4 minutes 10 seconds long) alone. Female health workers took 55 minutes, while the male health worker took 30 minutes to create the story. Both stories were similar in

terms of content – each had a doctor talking about causes and symptoms of Dengue and the precautions one should take to avoid the spread of the disease.

The story created by the male health worker was shown to a group of 15 people in the local health center using the pico projector, with external speakers connected to it. The video screening session was 10 minutes long. We did not observe the same level of interaction between viewers and health workers as we did in HealthWorkers-1. Health workers told us that many viewers already knew about Dengue, its causes and precautions, and hence the video was not engaging enough for them. The male health worker said,

"This [story] got little boring. Next time, I will prepare a story on an interesting topic."

DISCUSSION

Feasibility and usability

Results of the three exploratory studies show that the users succeeded in creating digital content despite having different levels of education, and exposure to technology. We argue that it was due to the simple user interface and limited use of text in the authoring application. Translating the interface into local language was sufficient to adapt it to different environments.

Teachers used the authoring application to create teaching content, which was presented in the classroom and hence, saved teachers the time and effort required in scheduling a session in the computer lab. While presenting the digitized textbook content in the classroom session, teachers used the *Point and teach* technique. The same technique is used by the teachers while presenting content on a blackboard. This shows that teachers adapted a technique from the physical world into the digital world.

Doctors and health workers used the system to create awareness about different diseases. They felt that local language videos are a good way of reaching the target audience and the authoring application helped them to create and present such videos. HealthWorkers-1 found the entire exercise of creating and presenting digital stories on health topics useful. They told us that the digital stories helped in initiating a discussion on different aspects of oral cancer between viewers and health workers, which eventually led to awareness about the disease.

Results of the first study show that 64% of the marking menu actions were performed in 'Menu mode' and 36% in 'Mark Mode'. This shows that teachers started attaining expert behavior in a relatively short period, and hence were able to create content at a faster pace. To the best of our knowledge, it was the first study which looked at use of marking menus as interaction accelerators for low computer proficiency users and they indeed proved to be effective.

Lack of continuous availability of power poses a big challenge for technology adoption in developing regions. Since camera phones and pico projectors are portable and battery operated, it makes them much more resistant to the infrastructural constraints such as continuous power availability. The portability of pico projectors allowed the teachers to use them both for classroom viewing as well as small-group viewing. A female health worker in HealthWorkers-2 study told us that due to the socio-cultural norms, women in the villages do not come for public gatherings. When videos are screened at public places (using TV or DVD players), women are unable to benefit from them. However, the portability of pico projectors will allow the health workers to do the video screenings inside a house where women can also attend the sessions.

Empowering the content creator

The mobility associated with a camera phone *empowered* the teachers to create digital content when they were traveling on the school bus. This was extremely valuable as it helped them to utilize the time that would have been otherwise wasted. Previously, their only opportunity to create content was at the school's shared computers, which were available only for limited periods of time.

The authoring application invoked *creativity* among the teachers and they asked the students to do more engaging in-classroom activities such as digitizing stories from their textbooks. Teachers reported helping the students to use the authoring application, which suggests that they themselves felt confident about using the application. The authoring application also helped in invoking *enthusiasm* among the users. In the HealthWorkers-2 study, a health worker commented that the digital story prepared by him was not engaging enough for the viewers and he will make more interesting stories in the future. Teachers created digital content on a moving bus, which is not an easy task and they sometimes had to make multiple attempts to capture a clear image. This result highlights that there was some enthusiasm among the teachers to create digital content.

Misconceptions among the users

When we first showed the phone to the teachers, one teacher commented, *"Can this (phone) be used to make a phone call?"* Later, she reported that she has never seen a mobile phone being used for educational purposes and thus, she was curious if it can still be used for communication.

Out of the five teachers who owned a camera phone, three did not know that it can be used for video recording. In most camera phones, when the default camera application is launched, it starts in 'Image' mode. Users need to invoke a menu and switch to 'Video' mode for recording videos; but the teachers were unaware of this functionality. On the contrary, our authoring application had separate options to invoke 'Image' mode and 'Video' mode, and hence did not require any mode switching by the user.

We also observed that HealthWorkers-1 were hesitant to use the touch-screen because they felt that it will cause scratches on the screen. In any future research which involves use of touch-screen camera phones in developing regions; we suggest the researchers spend some time and effort to allay such misconceptions among the users.

Challenges

Content presentation using pico projectors posed several challenges. Ambient light made it difficult to view the pico projector display in the classrooms and we had to cover all windows with curtains. We also had to connect external speakers to boost the audio output of pico projectors as the built-in speakers were not very powerful.

The 90 minute battery life of the pico projector is also a cause of concern. In developing regions, availability of power is always an issue and charging the pico projector after every 90 minutes of usage is not feasible.

Next steps

Because our work is in early stages, we only focused on a small number of participants and two application domains (education and health care). We received valuable initial insights on the feasibility and usability of projection camera phones in developing regions. We also learned about the kinds of content that the users like to create and the various scenarios of usage of projection camera phones. However, our results are not generalizable to the entire education or health care domain because the number of participants was small and at least one study setting was not representative. We plan to conduct user studies with more participants to make our results generalizable and also to understand the similarities in practices of content creation and presentation across various application domains.

We observed content sharing among teachers although it was very little. Because our application did not allow content sharing over Bluetooth, teachers had to involve a computer in the sharing process. We will incorporate Bluetooth content sharing in the authoring application and study if the Bluetooth transfers, by virtue of being faster and more efficient than a mobile-computer-mobile transfer, encourage more content sharing among users.

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