SMARTPHONE BASED E-LEARNING*

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Abstract: Children often attend schools intermittently in rural areas in Africa and India due to socio-economic conditions which make pupils augment their family income by working. An e-Learning solution could aid in raising the level of education by making it easier for children to fit schoolwork into the day, acting as a complement to when they are able to attend school. Traditional distance learning solutions based on computers are not suitable due to lack of infrastructure support. In this paper, we evaluate both text and voice based smartphone prototype environments which could provide the tools and services for pupils to download educational content, interact with teachers as well as other pupils to discuss topics. These have been implemented as a proof-of-concept and the initial evaluation feedback, although not from target users, was very promising. We intend to re-implement the prototype and do a proper evaluation with rural-area school children.

1 INTRODUCTION

Access to education remains an impediment towards economic development of rural communities in Africa and India. The reasons include lack of infrastructure, lack of teachers, poor attendance and finally cost; the main problem among these being the low attendance rate – (Azim Premji Foundation, 2004) states that the gap between enrolment and attendance is significant. Due to the prevailing socio-economic conditions, most pupils have to work to augment the family income, thereby affecting their ability to attend classes (Jean Drèze and Geeta Gandhi Kingdon, 2001). This paper presents an interactive e-Learning environment that would allow pupils to learn in a collaborative manner without constant supervision. The proposed system will deliver content in a manner that takes into account restrictions such as poor IT infrastructure, high cost of bandwidth and poor knowledge of electronics.

To achieve this goal, the high availability of more affordable cellular mobile devices in these areas will be leveraged to provide interactive content via mobile phones (Marsden, 2003; Kam et al., 2009a; Parikh and Lazowska, 2006). Mobile phones need very little infrastructure, are low-power devices that can be used in places where the availability of electricity is not very reliable and are the fastest growing technology platform in the developing world (CNN. Weapon against epidemics: Cell phones, 2009). In addition, mobile phones are inherently interactive in nature, as compared to TV and radio, so are the most suitable technology to use to access and share content in rural

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areas.

Our proposed e-Learning environment will provide educational content in the form of lessons, simple tests or quizzes, as well as allowing pupils to interact both with teachers and their peers as they would in a normal school environment. Connectivity cannot always be guaranteed so the system should support downloading educational content for the pupil to read at a later time, and recording input from pupils to upload when a connection is available.

A couple of Masters student projects were used to implement proof-of-concept systems to evaluate suitable implementation technology. The first project - a Virtual Learning Environment for Mobiles (VLEM) used an iPhone and a fairly sophisticated open-source web-based educational system called Moodle (Moodle, 2010) as the back-end for management of text documents. The second project explored the use of an Android smartphone for a Voice-Based Framework (VBF) for delivery of content and interaction with teachers and peers. This was primarily because of increased familiarity with voice systems in rural areas. The proposed methods of educational delivery and interaction were intended to act as a complement (and not a substitute) to attending school. The emphasis of the two projects was on evaluating technology for implementing such a system rather than evaluating the effectiveness of delivering educational content using smartphones. No real educational content was used in the project. Both implementations were evaluated by a few volunteers to obtain some feedback on feasibility and usability. In the future, we plan to merge the different implementations into one to provide a complete solution. The evaluation results are very encouraging and prove that this is a viable means of providing distance education in rural areas. We plan to install the proposed system in a village in India and run field tests to determine the effectiveness of the system and gather valuable data that would help improve the overall solution. Although smartphones can be criticised as currently being too expensive for the target environment, their development environments are much easier to use for a proof-of-concept implementation. Given the rise of the Android open platform, it is very likely that these smartphones will be more affordable in developing countries within a few years.

There has been research on using mobile phones as a means of providing information and services in rural areas (see related work), but as far as we know, this is the first project of its kind to try and provide a comprehensive solution that would allow pupils in rural areas to be able to keep up with their education while not forsaking their livelihood. According to the World bank, "Despite growing hype, there are still precious few widespread examples of the use of [mobile] phones for education purposes inside or outside of classrooms in developing countries that have been well documented, and fewer still that have been evaluated with any sort of rigor" (World Bank, 2009).

The rest of the paper is organised as follows. Section 2 gives an overview of the proposed environment and the requirements we have identified. Section 3 describes the text-based Virtual Learning Environment, while Section 4 describes the Voice-Based Framework. Section 5 provides a detailed evaluation of the two frameworks, while Section 6 outlines areas of future work. Section 7 outlines the related work, while Section 8 concludes the paper.

2 AN E-LEARNING ENVIRONMENT USING SMARTPHONES

2.1 Overview

Figure 1 shows the overall architecture of the proposed e-Learning framework. It consists of (a) a simple user interface on the phone for displaying and recording information and (b) technology and services at the server for content management and dissemination. The required content is developed using normal workstations connected to the internet, and delivered by the content providers (schools, educators) to the content manager. The technology for developing the content will use off-the-shelf tools that are readily available to educators and schools. Each school will be connected to the central server. Pupils will use phones to access content such as available lessons and to collaborate with peers via a forum supported by an educational portal which can easily be extended by adding additional capabilities, such as announcements, tests etc. To show how the proposed framework would work, an example scenario is described in Section 2.2.

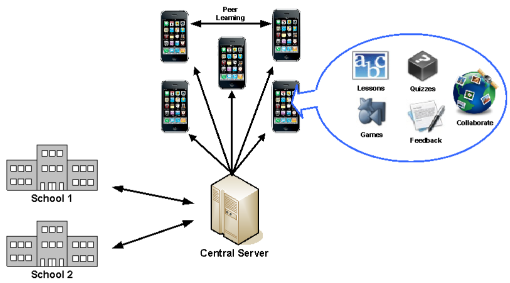


Figure 1: System Design.

2.2 Example Scenario

A teacher updates the content system with the new information based on the lessons that were used in class during the day and also deletes any obsolete information. A pupil living in a remote village goes about his errands in the morning and is unable to attend school for the day. On returning home in the evening, he uses a mobile phone to access his classs information. The pupil checks for any update since last access and if any, downloads the required content on to the mobile phone. After completing required tasks, the pupil will have caught up with some of the material covered in school during the day. Some material may not be appropriate for delivery to a mobile phone. Queries can be sent to his teachers, and he can ask questions or discuss issues with his fellow pupils via the phone.

2.3 Requirements

The following requirements were identified for an e-Learning environment:

- Content management (addition, deletion, updates) must be easy for non-technical educators. A widely used content management system (CMS) is preferable, as educators may already be familiar with it and the system will be maintained and developed to keep it upto date.
- The User Interface on the mobile phone must be intuitive, simple and easy to use. For example, having a very elaborate user menu on the phone to access the system may increase its complexity and make it hard for pupils to use the system.
- The system must enable downloading content for offline perusal and offline recording of questions, discussions etc. by pupils for uploading when a connection is available.
- The system must facilitate peer-to-peer discussion between pupils as well as with teachers to simulate the classroom environment.
- The system must take into account bandwidth usage. This requires recording “changes” to the data; only the data changed since the last request is transferred to synchronise the phone and CMS.
- The system should facilitate peer-to-peer sharing of downloaded content between pupils when they come into contact with each other, using bluetooth or wifi to reduce usage of comparatively expensive cellular networks. Note that neither of the projects had time to implement this.
- The code-base developed must be modular and easily extensible to incorporate future additions.

3 VIRTUAL LEARNING ENVIRONMENT FOR MOBILES (VLEM)

The VLEM system used an iPhone and evaluated Moodle (Moodle, 2010) as the back-end software. Moodle is a well known open-source Course Management System, with a large user community. The functionality is thus continuously being enhanced and the code is well maintained. Another advantage is the ability to send bulk data which will help in bandwidth reduction. The iPhone was chosen for its user interface. The overall architecture along with the different components is depicted in Figure 2.

3.1 Moodle Component

The Moodle component consists of a back-end for content storage and a workstation interface for teachers and administrators, which contains all the internal functionality to facilitate registering users, creating and updating lessons etc. Each teacher has an account to access Moodle and is associated with a number of courses. A teacher uses Moodle to create the lesson, which is stored in a MySQL database. To access this information from outside the Moodle domain, the system was extended in the following ways to support requirements identified in Section 2: (i) implement the external functions used by Moodle using its naming and development conventions, (ii) add functionality required in the workstation to support web-based access to Moodle back-end, (iii) create a table, called *firechanges* in the Moodle database to manage the changes. This table keeps a record for each user of what changes he has received related to his lessons, forums etc. by labelling them with 0 (clean) for received and 1 (dirty) for not received, (iv) create the triggers (Insert, Delete, Update). For every table of interest in the Moodle database we have created triggers to inform the firechanges table of any change that has been made, and (v) create the webservice external functions to retrieve the firechanges data. After the retrieval of the data the tables are reset to 0 and a new request is made to retrieve the changed data.

3.2 iPhone Application Component

The iPhone Application was implemented in Objective C and Figure 3 shows its architecture. The view module contains a main view and many sub views. The observer module monitors the network on the mobile phone and informs the component of the network’s “connectivity”. The action module is a virtual

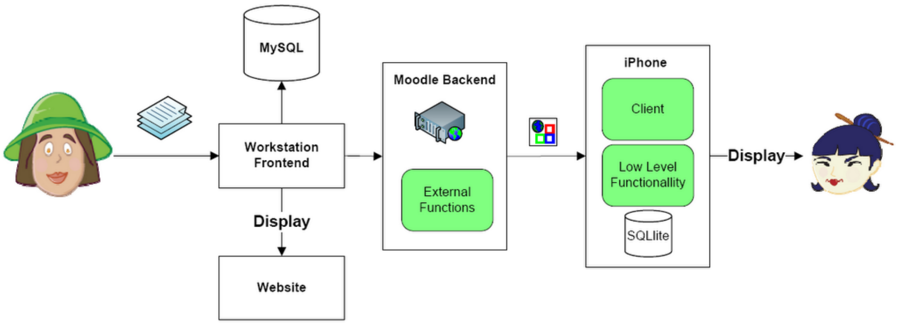


Figure 2: VLEM Architecture.

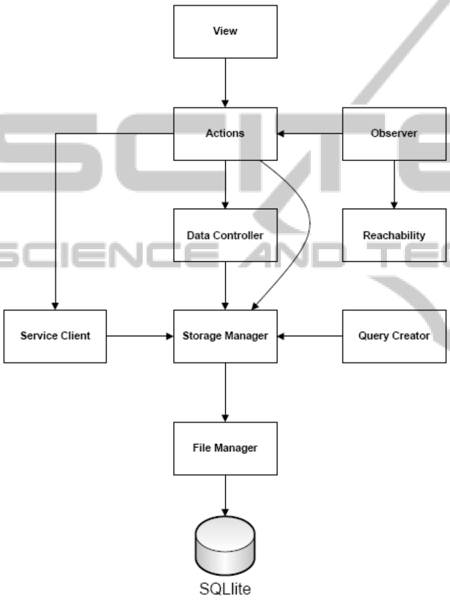
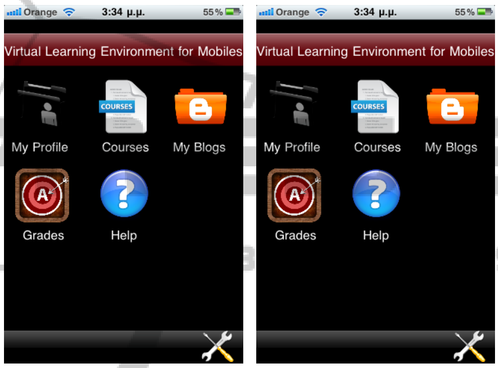


Figure 3: iPhone Application Architecture.

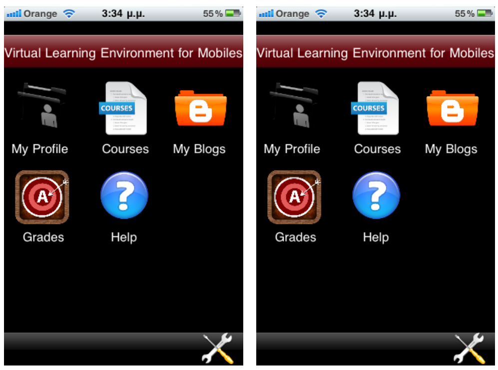
module that is included to ensure that proper emphasis is attributed to the actions performed during the execution phase. The service client supports functions to access the web service. The storage manager sets up every database request and it uses the query builder to create the appropriate query which needs to be executed. All requests to the database are via the file manager. In order to use VLEM, pupils have to be authenticated using the iPhone application (due to space constraints we do not go into detail).

Figures 4 and 5 show example application screens on the iPhone. Figure 4(a) shows the starting screen of the Virtual Learning Environment. Figure 4(b) shows the help menu that explains the functionality of each of the buttons. Figure 5(a) shows the list of available courses in the VLEM and choosing one of them will bring the user to the interface shown in Figure 5(b), which gives the user the options that are available for that particular course.



(a) Main Screen. (b) Help Screen.

Figure 4: VLEM iPhone Screencaptures.



(a) List of Courses. (b) One Course.

Figure 5: VLEM iPhone Screencaptures.

4 VOICE-BASED FRAMEWORK (VBF)

Unlike VLEM, the voice-based framework was not meant to provide an entire e-Learning framework, but to provide a means for pupils to gain some of the interaction that they are missing if they are studying from home. The idea is for a forum where pupils will be able to interact with their teachers and peers, asking questions and finding out answers. Several studies have discussed the success of voice-based mobile applications in rural areas of the developing world due to the fact that they are so used to accessing information and communicating orally (Parikh, 2010; Agarwal et al., 2009). For this reason, the forum was designed and implemented as an asynchronous audio space where pupils can post questions or comments to teachers and listen to those of others.

While using the criteria stated in Section 2, the available software and APIs that best suited our purpose was the Android open-source OS for the mobile phone and Django for the back-end. Android runs on a wide variety of handsets, from top-of-the-range devices to some at the lower end of the smartphone market (Open Handset Alliance, 2010). Another key reason for choosing the Android platform was the availability of an API for sound recording. Django was chosen since it's a fast, extremely reliable open-source framework that comes with a built-in modifiable administration interface.

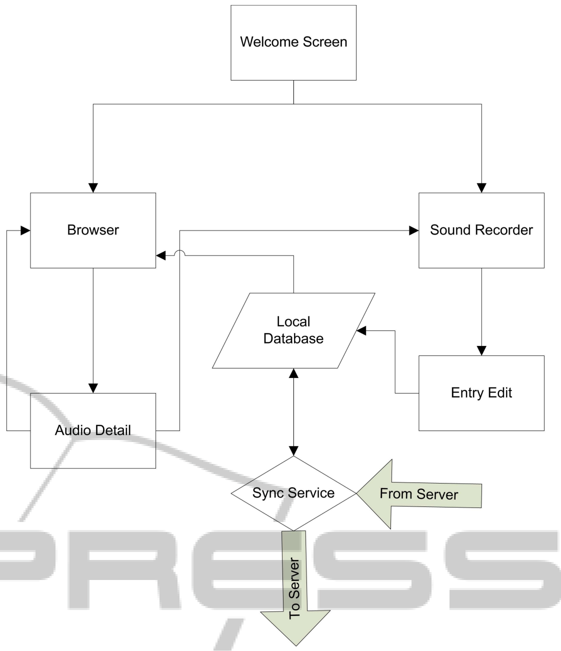


Figure 6: Flow between components of the client.

4.1 Client Component

The aim of the client is to provide a simple interface to the user that will allow them to access the information involved in the system via the following methods: (i) record the user's voice as they ask their question and save it as an audio file, (ii) browse other users' questions and responses, (iii) filter these questions and responses based upon subject area or user, (iv) browse responses to a particular question, and (v) post an audio response to a particular question.

The diagram shown in Figure 6 represents a simplified flow of control between the different components of the client application. There are two main flows from the welcome screen, either the user wants to record a new question or they want to browse existing posts. The former takes the right-hand path through the process of recording the audio for their question and onto the *Entry Edit* activity which will take in additional metadata from the user before saving everything to the *Local Database* and starting up the *Synchronisation Service*. This is a background service which synchronises the local database with the master database on the server.

The left-hand path leads into a browser that lists posts on the system; selecting one will take the user into the *Audio Detail* activity showing more information about the post and allowing playback. There is an option to leave a response to the post, which takes the user to the *Sound Recorder* activity.

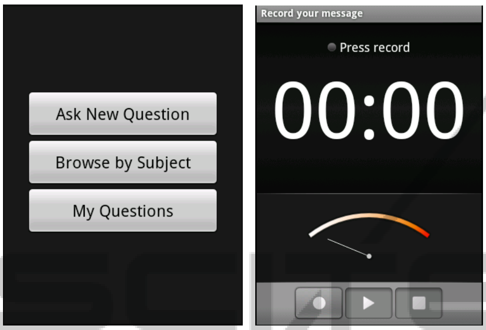
The audio file is encoded using the Adaptive Multi-Rate Narrowband codec, a data compression scheme optimised for speech. It is recorded with a bitrate of approximately 12kbit/s which is higher than the average telephone quality (8kbit/s), but still low enough to ensure that the files will not be too large. An average question is expected to last approximately 30 seconds generating an audio file of roughly 45kB which even on an early GSM network would upload in roughly five seconds.

4.2 Server Component

The server stores and maintain all the necessary data for the application via the following methods: (i) receive an audio file and metadata and store these in the master database, (ii) provide metadata in a machine-readable format about questions that are stored in the master database, filtered by criteria such as subject area and user, (iii) provide metadata about responses to a particular question, and (iv) serve a specific audio file after providing its URL.

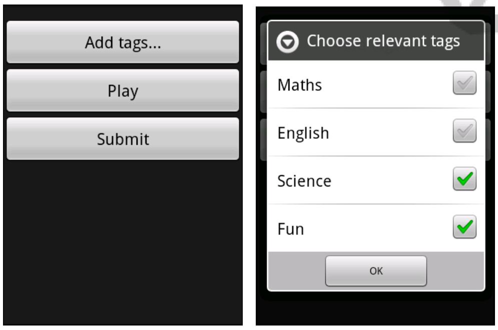
The server has been designed to provide its functionality through a RESTful (Representational State Transfer) API above HTTP to enable it to be used by a wide variety of potential clients. Interactions are stateless, so any client submitting the same request to a particular URL will receive the same response; this means that these URLs can be bookmarked and shared among users. This simplifies creating a new audio post that can then be accessed and responded to by other clients, thus creating a thread of audio conversation.

The server-side components have been built based on the model-view-controller principles, leading to a completely modular environment with in-built support for being run in a variety of environments. The built-in administration interface was also extended to provide a robust web-based interface for the teacher.



(a) Main Screen. (b) Recording Screen.

Figure 7: VBF Android Screencaptures.



(a) Options after Recording. (b) Available Tags.

Figure 8: VBF Android Screencaptures.

Figures 7 and 8 show some application screens on the Android phone. Figure 7(a) shows the welcome screen of the Voice-Based framework. If the user wants to record a new question, they will be taken to the recording interface that is provided by Android (Figure 7(b)). After recording their question, the user can either tag the question, play the question back or submit it (as shown in Figure 8(a)). If the user chooses to tag the question, a list containing the different subjects is presented to them (shown in Figure 8(b)).

5 EVALUATION

5.1 VLEM

We evaluated VLEM using two approaches. In the first approach, we conducted a survey, asking 16 users to use the system and to fill in a questionnaire. 12% of the users were in the age group 8-18, 63% were between 19-35, while 25% were older than 35. In order for the users to use the system, we created a few lessons apriori. The users browsed the available lessons and participated in the forums. Most of the users were competent in the usage of a mobile phone. The questionnaire contained personal as well as questions relating to the usability of the system. In the second approach, we asked an educator (teaching second grade in a school) to use and evaluate the system. Due to the space constraints, we only present the results from the user survey, but the educator did say “The convenience and support of the pupils is the primary goal of this application. I believe that ideas such as this must be carried out because it will help pupils and in general the whole education sector”.

To begin with, we wanted to evaluate the idea of a VLEM before users actually saw the implementation. We asked users to indicate whether they thought the concept of a VLEM was interesting or not. As we can observe from the results in Figure 9, an overwhelming majority thought that the idea would make a difference in education.

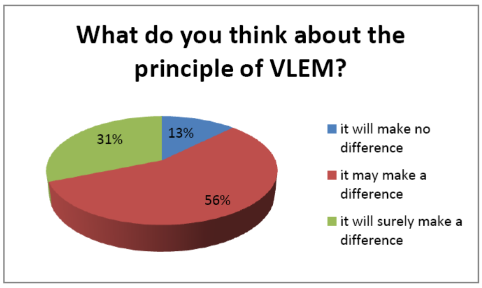


Figure 9: Opinion on VLEM principle.

For the next part of the survey, we asked users to use the application and fill in the questionnaire. Our first concern was the impression the VLEM application created on the users, especially after their opinion about VLEM as a concept. Figure 10 shows that the results were very promising with 25% saying that they were very excited by the application and only 6% saying that they were disappointed. This augurs well for the functionality as well as the implementation.

Our next step was to find out how easy it was to use the VLEM. Figure 11 shows that 13% found the

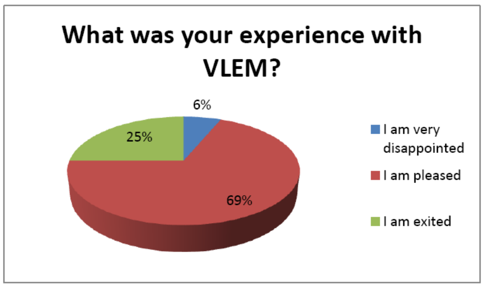


Figure 10: VLEM Experience.

application hard to use. Though this is not a very large number, it is still not small enough to ignore. One of the reasons for this higher number is revealed later.

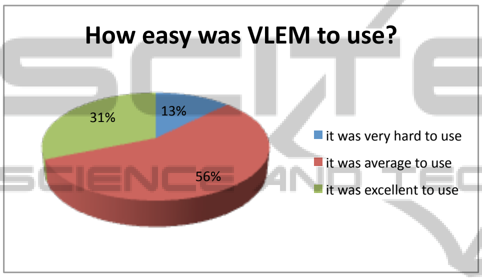


Figure 11: Ease of Usage.

To ascertain why some users had a more positive experience overall as when compared to others, we asked them which feature of the VLEM they liked or disliked. The results for the "best features" and "worst features" of the VLEM are shown in Figures 12 and 13 respectively. As can be seen from the figures, the best feature of the VLEM was considered to be the forums. Users stated that forums were essential because they enabled communication and collaboration. As for the worst features, 25% of the people selected the user profile. One of the reasons for this very high number is the fact that the current system lacks the functionality that allows a user to update his/her profile on the iPhone. The button size was considered as the next worst feature. This suggestion was taken into consideration and has since been incorporated into the application.

Finally, we asked the users their opinion as to what was missing in the current implementation of the VLEM. From Figure 14, we can see that most of the users wished for additional functionality, such as a library. This is a very interesting suggestion, which will be investigated further in the future. Many others wished for quizzes and pictures. The functionality to support quizzes already exists (in terms of communication). As for the ability to have pictures, it may not be feasible because of an increase in traffic. An interesting addition that was also suggested was having a help menu for the buttons. As we see in Figure 4(b), this suggestion was incorporated into the application.

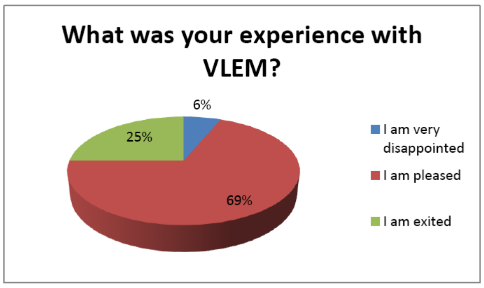


Figure 12: Best features of VLEM.

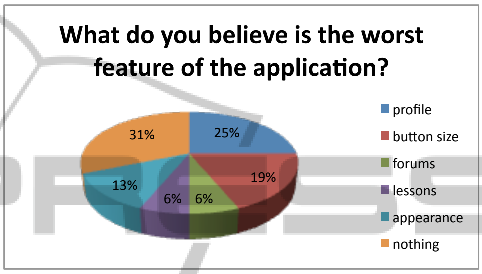


Figure 13: Worst features of VLEM.

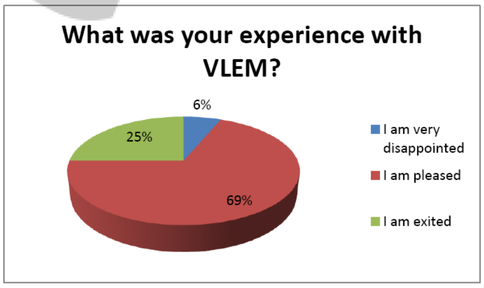


Figure 14: Missing Features of VLEM.

We believe this survey was helpful in providing a direction towards improving specific aspects of the application. It provided us with valuable experience concerning usability aspects and it also gave us fresh ideas concerning implementation issues.

5.2 VBF

Nine fellow-students evaluated our Voice-Based Framework and completed a a survey on the application. The application was explained to the volunteers and each one chose to use the system as they saw fit (a few of them adopted a passive approach by just downloading and listening to existing information, while others were active in posting and answering questions). This survey was structured so that opinions could be harvested on the topics deemed important for the target audience in an attempt to counteract some of the differences between the test audience and the target audience. Much like the Human Access Points (HAPs) discussed in (Gary Marsden, Andrew Maunder and Munier Parker, 2008), the test users have knowledge of what is possible with technology, they just lack the cultural and contextual knowledge that is desired from a HAP. For this reason, they were given a survey to answer, after they had used the application for a period of time, rather than just asking for open-ended feedback. The aim of this was to encourage them to think about the application in terms of what has been deemed important for the target audience based upon existing literature.

First of all the simplicity of the User Interface (UI) was looked into and users were asked questions about how intuitive the interface and structure of the application was. Although most users were able to get to the desired task without much trouble, several users did point out that it was not always obvious what a button would do before they pressed it. This feedback was taken on board, and although all the buttons remain as they are, the layout files have been simplified for ease of editing at a later date and plenty of screen space has been left on most pages to allow some instructional text to be placed.

The next questions concerned the quality of the audio. As might be expected, all responses to the latter question were positive, since the bitrate and quality are higher than that of a telephone call.

The users were next asked about the speed and responsiveness of the application. Although they were using different handsets, with varying components, they all reported that the application was very responsive upon button presses. This is due to the simple interface that has been implemented and the fact that all expensive operations are handed off to a separate thread which will not impede the UI. Users were specifically asked about the time taken for new posts downloaded from the server to appear on screen after the browser was started and what kind of network they were connected to at the time. The results showed that even on the slower 2G network, updates did not take a long time (usually under 3 seconds).

Overall the test was very useful; the interface has been made more flexible to accommodate users' suggestions and some potential extensions have been identified. As stated at the beginning of this evaluation, the test was limited in its scope, but provides a basis for moving forward to test the framework with the intended audience in the future.

6 FUTURE WORK

We aim to integrate the text and voiced based systems on one platform containing both features of VLEM and VBF. This would be based on the use of Moodle as we think its focus on educational content management would prove very useful for teachers. We will also focus on the use of Android phones as, although the user interface development support is not as sophisticated as the iPhone, it is cheaper and so is more likely to be available as a smartphone platform in the future in developing countries

One problem with both applications occurs when a user loses connectivity during an upload or a download. In order to combat this problem, the aim would be to break up the data being transferred into smaller chunks that are monitored so that if the network connection did fail then the transfer would only need to be restarted from the most recent chunk of data.

One of the possible extensions of VBF is a voice recognition system. There are a couple of ways that voice recognition could be used to improve the functionality of the framework; the first involves implementing a voice-based menu system, where a user is prompted to enter the number on the keypad. Another area where voice recognition could really add functionality to the application is in using it to create text transcriptions of the audio posts that have been made. With these text-based questions a decent search functionality becomes a real possibility. It would also give users the option to read the posts themselves rather than listening or use speech synthesis to listen if they are on a particularly slow connection and do not want to download the audio file.

7 RELATED WORK

Mobile phones have been used for implementing rural computing applications e.g. (Derenzi et al., 2008) presents a system for providing the IMCI (Integrated Management of Childhood Illness) protocol using a PDA, and (Maunder et al., 2008) provide a cost-effective way of accessing relevant public information by sharing it using a Bluetooth enabled camera phone. A mechanism to interact with paper documents and automate paper-intensive information processing for micro-finance groups using an interface toolkit is provided in (Parikh, 2005; Parikh et al., 2006). Design principles that address the challenges in designing rural computing applications are outlined in (Gary Marsden, Andrew Maunder and Munier Parker, 2008; Parikh and Lazowska, 2006). All of the above work, while focusing on support for people in rural areas, does not address educational applications. Most of the information flow is one-way and the interface used is passive where the local community do not interact with the system on an everyday basis.

There has been some work on using technology for education in rural areas in Africa through a World Bank survey (Farrell, Glen and Shafika Isaacs, 2007) as well as the SchoolNet project (SchoolNet Africa, 2008). These differ from our approach in that they aim to establish high quality education through the use of Information Technology in existing schools. In (Kam et al., 2008; Kam et al., 2009b) games (based on traditional village games) on cell phones are used to improve the English language skills of the children. In (Jones and Marsden, 2004), the authors use mobile phones and PDAs to allow pupils to communicate with the lecturer during classes. This project though is only helpful in the scenario when pupil attend classes. The BBC Janala project (BBC Janala, 2009) uses mobile phones, TV and radio to improve the English language skills of people in Bangladesh, however there is no feedback from users and the emphasis is on listening to spoken English over the phone. The MobilED (Ford and Leinonen, 2006) project provides a learning and teaching environment that is enhanced with the use of mobile technology and services. The framework consists of an audio wikipedia that can be accessed by pupils by sending an SMS with a keyword and in return they get to hear the article relevant to the keyword. Though this idea has its merits, it is very restrictive since it assumes an advanced level of knowledge. Although the above works uses technology for education in rural areas, none of the projects provide for a complete environment wherein pupils in rural areas can learn at their own time without forsaking their livelihood. Also, these projects do not allow for collaborative learning, which is a very important learning tool.

There has been quite a lot of work on developing voice-based interfaces for rural areas. This is primarily due to the fact that rural communities have significantly different communication needs and patterns as compared to urban communities (Seshagiri et al., 2007; Kolko et al., 2007). Given the fact that people are comfortable using telephones, a voice-based interface would work very well with such communities. (Cervantes and Sambasivan, 2008) is an audio-based classified advert service, where users call in to post, listen or delete an advertisement. An Audio Wiki that acts as a repository of spoken content that can be accessed and modified through the use of any telephone is presented in (Kotkar et al., 2008). The World Wide Telecom Web (Kumar et al., 2007) is a project that allows people to create their own "spoken" web-pages. Users navigate using a simple speech-based interface and the "pages" are organised by user (akin to a web-page). VoiKiosk(Agarwal et al., 2009) is a voice based kiosk that provides access to information in rural areas. This was extended in (Patel et al., 2010) to provide a message board (coupled with some radio broadcast) that serves small farmers and is used primarily as a forum for exchanging agricultural advice.

Most of the related work mentioned above use voice-based solutions to cater to and solve certain problems. None of them, however cater for education. Given the level of technology penetration in rural areas, voice-based systems offer a promising solution due to the fact that people are used to using telephones. However, most of the related work tackles the problem with respect to a particular topic and hence both the complexity of the system and the amount of data managed, is less. Also, having a pupil phoning in and having to scroll to multiple questions belonging to multiple topics will only add to their cost.

8 CONCLUSIONS

In this paper, we have prototyped smartphone systems to enable e-Learning in rural areas in developing countries such as in Africa and in India. One system focused on text-based access to a sophisticated educational content management system, while the voice-based system focused on supporting interactions with teachers and other pupils. These frameworks serve a dual purpose, with the former acting as an educational portal that allows a pupil to be able to keep up with their lessons at their own time, without necessarily forsaking their livelihood, while the latter provides a forum for interactive communication that is achieved through voice messages (since users are more used to using their mobile phones as a tool for calling). The proposed systems were implemented as a proof-of-concept and evaluated. Although the systems have not been tested with the target audience, the framework has been set up as much as possible to allow flexibility in the interfaces. The results were very encouraging and some of the suggestions have been implemented. We also identified areas for future work. We are hoping to be able to deploy these systems and test them out in the field.

The implementations were based on smartphones, which could be criticised as being currently too expensive for developing countries. One reason for our use of smartphones was that their development environments are much easier to use for proof-of-concept systems. Simpler phones do not have the ability to display suitable learning material although they might be adequate for voice based-interactions. It is also likely that the Android open platform smartphones will drop sufficiently in cost to be affordable in developing countries within a couple of years. Though the motivation for this work was for e-Learning in rural areas in developing countries, the ideas suggested can also be used to enhance learning experiences in developed countries.

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