SMARTPHONE BASED E-LEARNING

Keywords: Virtual Learning Environment, Mobile Learning, e-Learning, Voice-Based Framework.

Abstract: Children often attend schools intermittently in rural areas in Africa and India. This is caused by 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 provides 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 was very promising. We hope to implement them in the field and evaluate them.

1 INTRODUCTION

Access to education remains an impediment towards economic development of rural communities in Africa and India. The reasons for this are manifold: lack of infrastructure, lack of teachers, poorly trained teachers, poor attendance and finally cost; the main problem among these being the low attendance percentage (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 (?). 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 burgeoning cellular networks, and high availability of mobile devices will be leveraged to provide interactive content via mobile phones. Advances in engineering and communication technologies have paved the way for more affordable mobile phones, which have in turn found a niche in the rural market (?; ?; ?). Mobile phones also need very little infrastructure and are low-power devices that can be used in places where the availability of electricity is not very reliable. Moreover, mobile phones are the fastest growing technology platform in the developing world. According to an article on CNN (?), there are 2.2 billion mobile phones in developing regions such as Africa and India, as compared to only 11 million desktops. In addition, mobile phones are inherently interactive in nature, as compared to TV and radio. Thus mobile phones are the most suitable technology to use to access and share content in rural areas.

In order to achieve the goal of a flexible system for pupils in rural areas, we propose using mobile phones to provide an e-Learning environment. This would 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 (?) 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. A voice-based solution was used 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 and targets middle school pupils. The emphasis of the two project 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. The authors 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 go towards improving the overall solution.

There has been research on using mobile phones as a means of providing technology, services and information in rural areas (see related work for more information), but as far as we know, this is the first project of its kind to try and provide a comprehensive cost-effective solution that would allow pupils in rural areas to be able to keep up with their education, collaborate with their peers, and do this 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” (?).

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 for Mobiles, while Section 4 describes the Voice-Based Framework. Section ?? provides a detailed evaluation of the two frameworks, while Section ?? outlines areas of future work. Section ?? outlines the research work related to this paper, while Section ?? concludes the paper.

2 An e-Learning Environment using Smartphones

In this section, we will present an overview of the proposed e-Learning environment.

2.1 Overview

Figure 1 shows the overall architecture of the proposed e-Learning framework. It consists of (a) an easy to use interface on the mobile phone for displaying and recording information and (b) technology and services provided at the server that allow 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 the educators and the schools. Each school will be connected to the central server. Using mobile phones pupils will access content such as available lessons that can be used to enhance the learning. The phone interface will also support collaboration with peers via a forum. This interface will act as an educational portal and 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 their 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 class information. The pupil checks for any update since last access and if any, decides to download 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 the school during the day. Some material may not be appropriate for delivery to a mobile phone. If the pupil has any queries, he can send queries to teachers, ask questions or discuss issues with his fellow pupils or wait to question the teacher at the school. The example scenario is shown in Figure 2.

![Figure 2: Example Scenario](image)

2.3 Requirements

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

- Content management (addition, deletion, updates) must be made available using an easy to use system, preferably one that is already widely used. The advantage of this is that educators may already be familiar with the content management system and the system will be maintained and developed to keep it up to 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 the pupils to use the system.

- The system must allow 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 the bandwidth usage. This requires recording “changes” to the data and upon request, only the data that has changed since the last request is transferred to synchronise the phone with the back-end content management system.

- 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 (?) 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 as the mobile of choice due to the ease of the usage of it’s user interface. The overall architecture along with the different components is depicted in Figure 3.

3.1 Moodle Component

The Moodle component consists of the workstation interface for teachers and administrators and the Moodle back-end. The workstation interface contains all the administrative forms and the internal functionality to facilitate registering users, creating and updating lessons and tests etc. Each teacher has an account to connect to moodle and is associated with a number of courses. A teacher uses Moodle to create the lesson, which is stored into the MySQL database. In order to access this information from outside the Moodle domain, the system was extended in the following ways to support requirements identified in Section 2:

- Implement the external functions used by Moodle following the Moodle naming and development conventions.

- Add the functionality required in the workstation in order for the web services to operate i.e if we want to add a new forum we need to call the create forums method which will call the existing insert record method with the correct parameters.

- Create a table, called firechanges in the Moodle database to manage the changes. This table keeps a record of 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.
• Create the triggers functionality (Insert, Delete, Update). For every table of interest in the Moodle database we have created triggers to inform the firechanges table for any change that has been made. When we add a new user a trigger is executed and a new record is added in the firechanges table with the id of the user and entries for each course, or forum for which he is registered.

• 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 4 shows its architecture. The view module contains a main view and many sub views. The observer module monitors the network state on the mobile phone and when it changes the appropriate action is executed to inform the component of the network’s “connectivity”. The action module is a virtual module, in that it does not actually exist but is included to ensure that proper emphasis is attributed to the actions performed during the execution phase. The service client supports function to access the web service. The storage manager sets up every database request and it uses the query builder which contains options which can be sent in order to create the appropriate query which needs to be executed. The file manager is at the lowest level where all the requests to the database take place.

In order to use VLEM, pupils have to authenticate themselves to the system using the application on the iPhone. Figure 5 shows the steps involved in the authentication process. The client sends a username and password to the web server. Then, the web server responds with a session token referencing the username and password sent. The client then calls the web service function providing the required parameters plus the session token which enables the server to authenticate the user by checking if the web service session is still alive. Next, the server calls the requested function which is located in the external definition. Furthermore, the user permissions need to be checked for that operation. Finally, the operation is performed and the result returned to the external function and then to the server. The server then returns the result to the client.

Figures 6 and 7 provide some screencaptures of
the application on the iPhone. Figure 6(a) shows the starting screen of the Virtual Learning Environment. Figure 6(b) shows the help menu that explains the functionality of each of the buttons. Figure 7(a) shows the list of available courses in the VLE and choosing one of them will bring the user to the interface shown in Figure 7(b), which gives the user the options that are available for that particular course. Note that VLEM implemented both blogs where a pupil could give comments about a course and forums for discussion with fellow pupils. Moodle also gives access to grades for marked work.

4 Voice-Based Framework (VBF)

Unlike the 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 (??; ??). For this reason, the forum was designed and implemented as an asynchronous audio space where pupils can post questions or comments and listen to those of others. Instead of hogging up a telephone line to listen to, browse and post questions, the basic idea of this framework is to enable pupils to post voice messages containing their questions so that their teacher and classmates will then be able to listen to and post responses to questions.

While using the criteria stated in Section 2, the available software and APIs that best suited our purpose was the Android OS for the mobile phone and Django for the back-end. The Android OS is built on the open Linux Kernel and uses a “custom virtual machine that was designed to optimise memory and hardware resources in a mobile environment”. Android is made open source through the Apache Licence to enable developers around the world to improve the software. Its openness allows the operating system to run on a wide variety of handsets, from top-of-the-range devices to some at the lower end of the smartphone market (?). Another key reason for choosing the Android OS platform was the availability of a useful 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.
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. In particular, the client needs methods to carry out the following:

- Record the user’s voice as they ask their question and save it as an audio file.
- Browse through other users’ questions and responses.
- Filter these questions and responses based upon subject area or user.
- Browse responses to a particular question.
- Post an audio response to a particular question.

The diagram shown in Figure ?? 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 will take them down the right-hand path which will go 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, as its name suggests, synchronises the information in the local database with the master database held on the server.

The left-hand path will take the user into a browser that will list posts on the system; selection of any of these posts will take the user into the Audio Detail activity that will show the user more information about the post and allow them to play back the recording. There will also be an option from here to leave a response to the post, which will take the user over to the Sound Recorder activity.

The audio file is encoded using the Adaptive Multi-Rate Narrowband codec which is an audio data compression scheme that is optimised for speech coding. 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 which would result in an audio file of roughly 45kB which even on an early GSM network would upload in roughly five seconds.

4.2 Server Component

The aim of the server is to store and maintain all the necessary data for the application. In particular, the server needs methods to carry out the following:

- Receive an audio file and metadata and store these in the master database.
- Provide metadata in a machine-readable format about questions that are stored in the master database, filtered by certain criteria such as subject area and user.
- Provide metadata about responses to a particular question.
- Serve a specific audio file after providing a URL for it.

The server has been designed to provide its functionality through a RESTful API to enable it to be used by a wide variety of potential clients. A RESTful API is one that conforms to the constraints of a style of software called Representational State Transfer (REST). The particular benefit of using a RESTful API implemented on top of HTTP is that most mobile devices will have libraries to enable submitting requests and receiving responses over HTTP and hence many different clients can be written that will be able to access the same API. Additional benefits lie in the fact that the 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, confident in the knowledge that the response will be the same for everyone. Using the functionality de-
scribed above, we can create a new audio post that can then be accessed and responded to by all other clients, creating a thread of audio conversation hopefully leading to educationally valuable material. The server also deals with the desire to limit data throughput because of the costs associated with cellular data connections; it does this by serving up the metadata about posts separately from the actual audio.

The server-side components have been built using an open-source framework built around the model-view-controller principles, leading to a completely modular environment with in-built support for being run in a variety of environments. The server has been developed using the Django web application framework. The built-in administration interface was also extended to provide a robust web-based interface for the teacher.

![Main Screen and Recording Screen](image)

Figure 9: VBF Android Screencaptures

![Options after Recording and Available Tags](image)

Figure 10: VBF Android Screencaptures

Figures ?? and ?? provide some screencaptures of the application on the Android phone. Figure ?? 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 ??). After recording their question, the user then has the ability to either tag the question, play the question back or submit (as shown in Figure ??). If the user chooses to tag the question, a list containing the different subjects is presented to them (shown in Figure ??).

5 Evaluation

In this section, we will detail the evaluation of our proof-of-concept implementation. We will first talk about the results of the evaluation of the Virtual Learning Environment for Mobiles and then detail the results of the evaluation of the Voice-Based Framework.

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. In the questionnaire, we included personal questions and 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 evaluated the knowledge of the users using the mobile phone by asking them about their experience in using a mobile phone. As we can see from Figure ??, we can see that users in general were quite confident about using the mobile phone. This is to be expected, since nowadays users are quite familiar with using a mobile phone.

![Mobile Phone Usage](image)

Figure 11: Mobile Phone Usage
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 ??, an overwhelming majority thought that the idea would make a difference in education.

For the next part of the survey, we asked the users to use the application and tell us their opinion based on certain questions in the questionnaire. Our first concern was how the VLEM appeared to users, especially after we had received their opinion on what they thought about the VLEM as a concept. Figure ?? 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.

Once we discovered what users thought of the VLEM overall, we wished to find out how easy it was to use. Figure ?? shows that 13% of the users found that the application was 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.

To ascertain why users liked or didn’t like the application, we asked them which feature of the VLEM they liked or disliked. This would in turn give us some idea as to why some users had a more positive experience overall as when compared to others. The results for the “best features” and “worst features” of the VLEM are shown in Figures ?? and ?? 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. The lessons were featured next, since users thought that lessons were essential since it enabled pupils to keep up with their studies during their free time. 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 ?? 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 commu-
What do you believe is the worst feature of the application?

- profile: 35%
- button size: 25%
- forums: 13%
- lessons: 6%
- appearance: 6%
- nothing: 19%

Figure 16: Worst features of VLEM

As for the ability to have pictures, it may not be feasible because of an increase in traffic. An interesting addition that was suggested was also having a help menu that explains what all the buttons are for. As we see in Figure 6(b), this suggestion was taken into consideration and has since been incorporated into the application.

We believe this survey was helpful in providing a direction towards improving specific aspects of the application. It helped us realize what people think about this application and its usability. Moreover, it provided us with valuable experience concerning usability aspects and it also gave us fresh ideas concerning implementation issues.

5.2 VBF

We evaluated our Voice-Based Framework by using a group of nine users. It was carried out by providing the application to a number of peers along with a survey being taken to determine their opinions on the application. 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 (?), 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. Was it obvious how to get to a particular task? Was it obvious what a particular button did? The results of these questions are shown in Figure ??.

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. Could the post always be understood when listening back to it? How did the quality compare to a telephone call? 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. Some did respond that often they found it hard to hear the recording when they played it back. After some further questioning it was discovered that a pair of headphones solved this issue; by default when no headphones are attached the recording is played back through the phone’s loudspeaker. The quality of this speaker varies from handset to handset and on some it does not reproduce speech particularly well. Since this was a hardware issue it was deemed unnecessary to upgrade the quality of the audio, particularly when no problems were reported when using headphones to listen to the recording.

The users were next asked about the speed and re-
sponsiveness 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. Figure 19 shows the average of the times stated; as can be seen, even on the slower 2G network the screen generally updates in under three seconds, not an unreasonable amount of time for the user to wait.

Overall the test was very useful to carry out; the interface has been made more flexible to accommodate users’ suggestions in the future, some of the benefits of the application have been seen, 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

The final aim is 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. It is likely that 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.

Neither project had sufficient time to implement the peer-to-peer content sharing. This was to allow pupils who meet up in their villages to share content, via wifi or bluetooth, which they had already downloaded to their phones. This would save on relatively expensive access via operator cellular services.

One problem with both applications occurs when a user loses connectivity during an upload or a download. If this happens then the user will have to start the process over again. If it is an upload, the entry in the local database will still be flagged as needing to be uploaded since this is only changed once a successful response code is received; the upload will start again as soon as a connection is regained since the Synchronization Service will be called again. In order to combat this problem, the aim would be to break up the data that is 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. Similarly downloads of large content should be broken into chunks and reassembled on the smartphone in case connection is lost during the transfer.

6.1 VLEM

A possible extension to the educational content is to provide access to a library of books which could be downloaded for offline reading. In the application a book store view would exist containing all the books the pupil has downloaded. In order to avoid communication costs, the books could be sent when the pupil is at school and connected to the wifi network. It is however unclear as to the copyright aspects of providing such a library. It is possible that the school could have a contract with a few publishers allowing their pupils access to their online resources.

Another extension was an addendum to the existing help system. Though the help system is available as a menu option, this system could be augmented by a video-based system which could show the users the step by step functionality of the system. This would be much more helpful since users can visually see each screen unfold and hence be better prepared to use the system. The only issue with such a system would be to make sure that the size of the video files are small so as to not take up a lot of memory on the phone.
6.2 VBF

One of the first possible extensions 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. This could potentially replace the graphical user interface currently with a voice user interface (VUI), similar to those investigated in (??). The benefits of this are questionable, with the literature suggesting a simple sequence of pressing buttons is preferable to the error-prone voice recognition systems that have been tested. An option to using voice recognition systems is using 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.

A search mechanism for the application could prove particularly useful. Currently users can filter the posts that they browse by subject area or to only show questions from themselves and their respective answers, or even by date in the case of the administrator’s web interface. If they were able to search for a specific query then they would be able to check if someone else had asked a particular question before and then be able to see its responses straight away rather than having to post the question again and wait for responses. Users would also be able to search for particular keywords, say a particular subject they are studying in science at the moment to see what their classmates have been asking about it.

7 Related Work

There has been research in using mobile phones as a means of implementing rural computing applications. In (??), the authors present a system for providing the IMCI (Integrated Management of Childhood Illness) protocol using a PDA. In (??), the authors provide a cost-effective way of accessing relevant public information by sharing the information 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 (??; ??). In (??; ??), the authors outline design principles that address the challenges in designing rural computing applications.

All of the above work, though catering for majority of the 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. Providing education to such communities brings about its own set of challenges that need to be addressed to ensure that the proposed vision is properly realized.

In the realm of using technology for education in rural areas, there has been some work carried out in Africa through a World Bank survey (??) as well as the SchoolNet project (??). These differ from our approach in that these projects aim to establish high quality education through the use of Information Technology in existing schools. Kam et al. (??; ??) uses games on cell phones to improve the English language skills of the children. They analyse traditional village games and design their games based on these, since game-play proves to be more intuitive for the children. In (??), 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 (??) 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 PremaVidya project (??) provides quality education for pupil to earn financially meaningful degrees. This project deals with the lack of trained teachers in government high schools, especially in Science, which causes high dropout rates amongst pupils. The MobilED (??) 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 to it by providing 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, is not very relevant to teaching and does not allow for collaboration.

Though most of the related work mentioned above work in the realm of using 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 towards 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 (\textsuperscript{1}, \textsuperscript{2}). Given the fact that people are comfortable using telephones, a voice-based interface would work very well with such communities. In (\textsuperscript{3}), the authors present an audio-based classifieds service. Users can call in to the system and choose to either post/listen/delete an advertisement. In (\textsuperscript{4}), the authors present an Audio Wiki that acts as a repository of spoken content that can be accessed and modified through the use of any telephone. The World Wide Telecom Web (\textsuperscript{5}) is a project that allows people to create their own “spoken” web-pages. The users navigate through this using a simple speech-based interface and the “pages” are organised by user (akin to a web-page). In (\textsuperscript{6}), the authors propose VoiKiosk, a voice based kiosk that provides access to information in rural areas. This work was extended in (\textsuperscript{7}), where the authors 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 problems pertaining to related areas. 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 the complexity of the system, as well as 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 focussed 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 his/her 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 to further enhance the systems. 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.