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YouLearn: Offline Media Streaming Application for Rural Uganda

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BE ACCEPTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREES OF

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ABSTRACT

The country of Uganda has implemented universal primary and secondary education. But still, some families cannot afford to send their children to school. When young people drop out of school, they often must resort to working illegal, unsafe, and low-paying jobs. Job prospects are even worse for disabled children. The objective of this project is to bring digital educational resources into rural villages in a low-cost manner.

YouLearn is an educational system that allows for offline media streaming. Our system includes a Raspberry Pi to store the media locally and allows for streaming without WiFi being necessary. Our system supports those most in need by bringing them the health and educational resources to help their families and communities thrive.

0.1 Acknowledgement

We are profoundly thankful to everyone who helped us through the development of this report. A special thank you to our advisor, Dr. Figueira who has been a guiding light since the project's conception. Also, Allan Baez Morales and Susan Stasi for their wonderful insight and ingenuity. Finally, thank you to Santa Clara University School of Engineering and Xilinx, Inc. for helping fund this report.

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Chapter 1

Introduction

1.1 Background

Uganda is a country of young people with more than seventy-five percent of its population below the age of thirty (1). However, the disparity in the country is high due to inequality problems. While wealthier families send their children to private schools, those who live in poverty, especially in rural Uganda, cannot even afford the simplest school materials such as pens, books, or menstrual pads for girls. Many of the families in rural Uganda live off of just one dollar a day and cannot afford to buy their child's school uniform or their daily lunch (2).

Uganda implemented the Universal Primary Education (UPE) program to help the young people of Uganda, as well as a universal secondary education program. However, neither of these programs cover the whole cost of attending school, including uniforms, lunch, and menstrual pads. These programs do not address the lack of teachers, resources, or parental support for schoolchildren in rural Uganda, all of which contribute to children dropping out at early ages (3). Universal education programs may aim to make Uganda better for future generations, but there are young people in Uganda now that cannot be helped by this program and are suffering despite it.

Rose Academies is an organization serving Central and Eastern Africa's population by promoting access to education for young girls, women, and disabled and deaf individuals in rural villages. Since 2014, Rose Academies has taught the poorest rural communities about reproductive health, puberty, menstruation, and vocational skills development (4). Rose Academies operates in Uganda, and is dedicated to transforming those that are most vulnerable into significant contributors to society. Led by CEO Susan Stasi, Rose Academies came to us with a problem.

1.2 Problem

In Uganda, a lack of education and vocational skills has been passed down by older generations to younger ones. The youth unemployment rate is thirteen percent, one of the highest in sub-Saharan Africa that constitutes a whopping 4.4 million young people actively seeking work who are unemployed (5). Other reports show that only a quarter of the workforce has a skill or essential trade that is needed by the labor market (5). With so many young people, a large disparity in education, and little hope for their future careers, a large number of Ugandan youth have no choice but to accept informal or illegal employment. Of these vulnerable youths, more than two-thirds were found to receive extremely low to zero earnings and faced dangerous work conditions (4).

Universal education programs are currently not enough to give Ugandan youths and young adults the opportunity they need to counteract the generational poverty issues in the country. While measures may be taken to better the universal education programs for the next set of Ugandan toddlers and babies, there are youth and young people who are falling through the cracks. To counteract this reality, Ugandan rural youth need to be educated in health education and vocational skills that will open the door to legitimate jobs and a different, brighter future.

1.3 Stakeholders

Our team identified the following stakeholders in our project:

- Good Shepherd Primary School.
- Katwadde Vocational Centre.
- Ugandan youth and rural community.
- Rose Academies.
- Rose Academies high school volunteers recording skills videos.

1.4 Existing Solutions

Various educational tools for children are available in Uganda which vary in content and cost. There exist websites in Uganda that offer tutors, eBooks, tutorial videos, notes, quizzes, career guidance, and other services. Many of these are free to use, but to access premium features and content users must pay additional fees; thus, they are not suitable alternative for frugal education. Also, many of these services rely on Ugandans having internet access, but the reality in rural Uganda is that internet access is dismal and spotty. A child's lack of internet access should not prevent them from achieving their full potential.

1.5 Our Solution

Our solution is an educational system that includes a Raspberry Pi computer and Android application. Rose Academies is a non-profit organization that operates in the United States as well as Uganda and other African countries. It is working with high schoolers in the U.S. to record videos that teach vocational skills like Microsoft Word and Excel with the intended audience of rural Ugandans. Once videos are prepared, video creators will upload the media to a

YouLearn Google Drive. While these videos are under production, Rose Academies has also provided a slue of PDF resources and videos that educate the population on disease prevention, life skills, feminine health, sanitation, and American Sign Language (ASL).

Once the media content is on the Google Drive, a Raspberry Pi (RPi) will pull the Drive contents. The RPi will act as a local database to store the videos and PDF resources offline, and act as a server to stream the media onto tablets when requested. Our system will also consist of an application on the tablets that will display all the videos and PDFs available.

Our system will solve the major problem of the existing solutions: it will not require pre-existing Internet access to stream the media content. The media content will persist on the RPi and be streamable by any tablet in the nearby vicinity. Internet will only be occasionally necessary to download any newly uploaded content from the Google Drive to the RPi. Our solution aims to empower the rural poor with knowledge and skills that will help communities and children live and thrive.

1.6 Alternative Solutions

Most of the existing solutions for video streaming require internet access, for example YouTube and Khan Academy. Unlike those websites, our system will persist offline allowing for minimal-range streaming. One alternative solution is RACHEL, a plug-and-play server that stores educational websites that's streamable offline on a local connection. RACHEL is a tool for the 53 percent of the world without an internet connection to access the best free educational resources (6). RACHEL models range from 170 dollars to 500 dollars. However, the creators also have an open-source tool, OER2Go, which is a collection of educational websites repackaged for download and offline use. But for the purposes of this educational system, Rose Academies wants a minimialized application that is easy to understand and deploy in rural communities. That is YouLearn.

Chapter 2

Requirements

The top priority of our system is that it streams multi-media content to local Android tablets. The next priority is that the system can retrieve new content without the need to travel to the system to update it. Instead, the system should be able to remotely gather any newly added PDFs or videos to the application. The final priority of our system is that it is easy to use for non-technical persons. These priorities can be further broken down into functional requirements, non-functional requirements, and system constraints.

2.1 Functional

The functional requirements in order of importance are:

1. The system will stream media content to Android tablets.
2. The system will store content on an external storage device.
3. The system will support at least five users on the network streaming content at a time.
4. The Raspberry Pi will automatically retrieve and download any newly uploaded content.
5. The application will retrieve the externally stored content upon launch.

2.2 Nonfunctional

The non-functional requirements in order of importance are:

1. The streaming should be done locally, without the need for internet connection.
2. The media will load in a reasonable amount of time and play with limited lag.
3. The system will be accessible for persons with limited to no technical experience.
4. The application user interface will be simple and intuitive.

2.3 Constraints

The system constraints are:

- The system must be low-cost.
- The system must function without the presence of preexisting internet connections.
- The system must be low-powered and function without the presence of persistent electrical power connection. Solar-powered charging is available.
- The application must run on old and new models of Android tablets.

Chapter 3

Use Cases

3.1 Description

Our system has only one use case, the user. The user will have access to the Raspberry Pi to turn it on and off, charge it, access the wireless network, and to download Android application packages (APKs) from the local file system. On the application, the user will be able to view files, watch videos, and read about the application. This can be seen further in Figure 3.1 and 3.2 below.

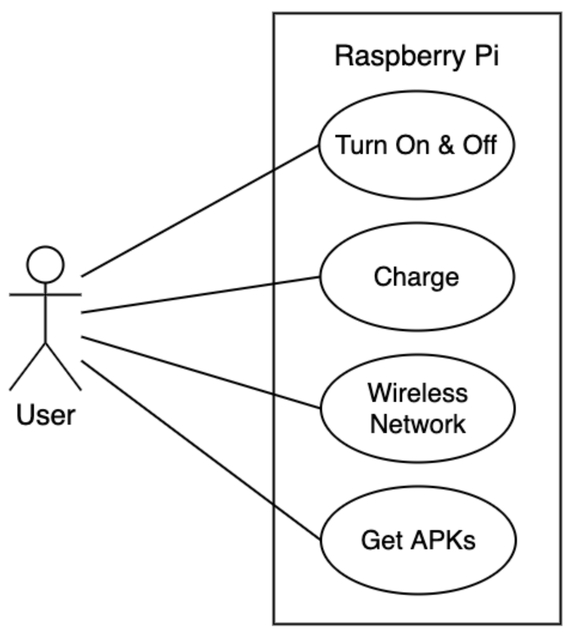

Figure 3.1: Use Case Diagram for the System's Raspberry Pi

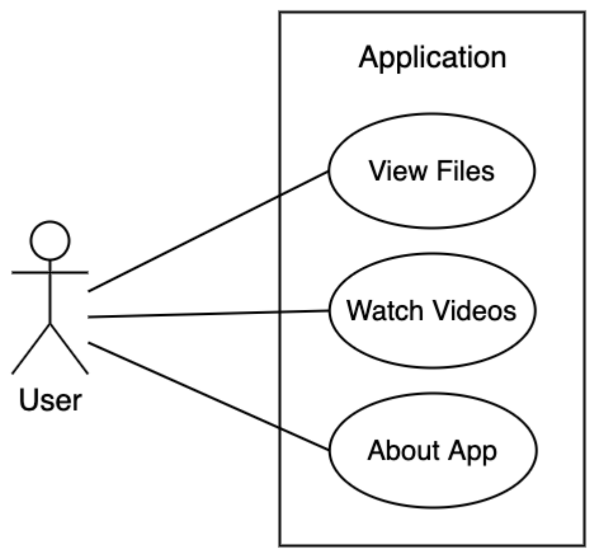

Figure 3.2: Use Case Diagram for the System's Application

Chapter 4

Activity Diagram

4.1 Description

The activity diagram outlines the tasks a user can complete when using our application. As shown in the figure below, when a user opens up our application on a tablet a flash screen with our logo ”YouLearn” will open up. Once the application has fully loaded, the the user will be redirected to the Home Screen of the app. From the Home Screen, the user can either go to the Files Screen, the Videos Screen or the About Screen.

If the user clicks on the ”Files” button they will be redirected to the Files Screen where they can either browse all the files, click on the file they would like to view, or return to the Home Screen. When the user clicks on a file they would like to view, they will be redirected to a full screen view of that file where they can read the file or return to the files screen.

Once the user is back on the Home Screen, if the user clicks on the ”Videos” button they will be redirected to the Videos Screen where they can either browse all the videos, click on the video they would like to view, or return to the home screen. When the user clicks on a video they would like to view, they will be redirected to a full-screen view of

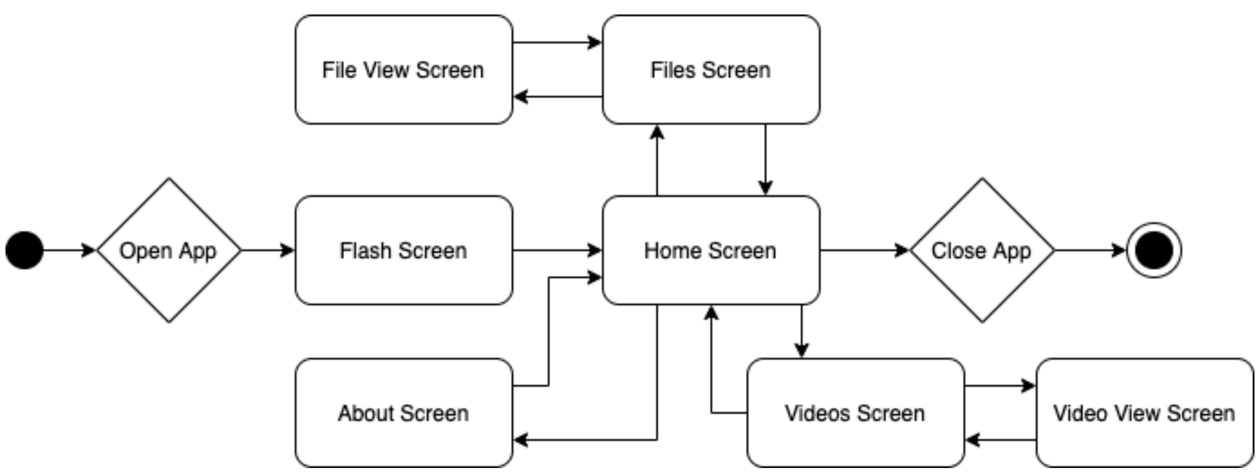

Figure 4.1: Activity Diagram for the Application

that video where they can watch the video or return to the Videos Screen.

Once the user is back on the Home Screen and clicks on the ”About” button, they will be redirected to the About screen where they can learn a little bit more about YouLearn and Rose Academies.

Chapter 5

Technologies Used

Here is a list of devices/software we are using to develop our system:

- Rclone module for Raspberry Pi to download videos from a Google Drive.

  Since we want to provide a simple way to download videos anywhere, we wrote a script to use rclone to synchronize files from the remote directory to the local directory.

- RCA 7 inch tablet, a basic Android tablet with 1GB of RAM with 16G storage and Wi-Fi and Bluetooth functionality.

  Due to the constraint of device ownership in our deployment area, we are limited to using the RCA tablet for our client. This tablet runs on Android 7.0, and it will be able to install and run our app and have basic video playback functions.

- Raspberry Pi 3B/4B, 2GB or 4GB RAM with a micro SD card containing an image of the operating system.

  Raspberry Pi is the best solution on the market for our needs for a highly portable, general-purpose computer. For its tiny size, it supports 32GB or more onboard storage, USB and HDMI ports, as well as wireless connections via Wi-Fi and Bluetooth 5, which are all crucial for our system.

- Raspbian OS.

  Raspbian is the official operating system of Raspberry Pi, which is a Linux(Debian)-based, low-resource operating system. Installing Raspbian will be a breeze. It will maximize our development time as well as dedicating the most CPU processing time, RAM and storage space on our Raspberry Pi for the server processes.

- React Native.

  React Native is one of the most popular UI library for mobile development with a relatively flat learning curve. It has lots of easy-to-use development tools to choose from. Learning a new mobile development framework can be very difficult, that's why we chose React Native so we can spend less time debugging the system and more time on developing better features and achieving more non-functional requirements.

Since the scope and requirements of this project are minimal, we can simultaneously keep our system design robust and simple. This limited the range and likelihood of bugs and other problems during development. Before we could use the Pi Network, we installed the necessary software and setup the auto-sync mechanism.

Chapter 6

Architectural Diagram

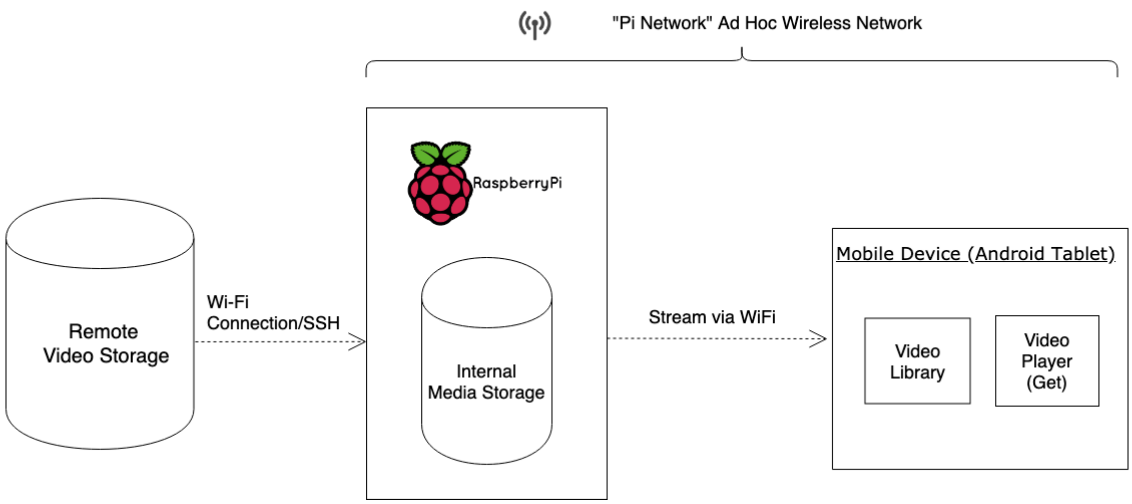

Figure 6.1: Architecture Diagram for the System

6.1 Description

Our architecture is data-centric, with one or more clients processing data retrieved from the storage. The system consists of two parts which happen asynchronously. In the first part, video data is pulled from our computer to the storage on the Raspberry Pi computer. It requires an installation and setup of required modules on our Raspberry Pi for it to function as a media server. In the second part, Raspberry Pi provides an ad hoc wireless network in a 25-30m range, serves media, accepts client connections and streams media data to all connected clients in the network. The client, an Android application running on the tablet, will display a library of media and handle video playback and PDF viewing.

Chapter 7

Design Rationale

7.1 Design Goals

We are deploying our project in Uganda's rural areas, where technology is scarce in general and infrastructure for internet access is underdeveloped. There are many major technical constraints such as limited to no Ethernet/wireless network coverage, a power source with very limited capacity, limited storage space, hardware/memory constraints of low-end devices, and limited knowledge of technology. Thus, our main goals for the system are: low power, ad hoc, computing resource conservation, and intuitive user interfaces.

7.2 Rationale for Each Goal

Raspberry Pi is a highly versatile computer with a lot to give that takes limited power. They only use 0.4-3.4 watts/hour. We can limit power consumption even further by disabling HDMI and onboard LEDs. We have used the Raspbian operating system to conserve computing resources used by system processes and dedicate the most resources to our application. Most importantly, Raspberry Pi can create an ad hoc wireless network that accepts connections from all sorts of Wi-Fi enabled devices: desktop computers, laptops, tablets, phones, etc.

Finally, there is no better tool to rapidly develop cross-platform mobile applications with intuitive user interfaces than React Native. It offers a wide range of developer tools and environments for us to learn in, without the headache of installing packages and setting up an environment from scratch.

Chapter 8

System Implementation

8.1 Overview

Our system consists of a solar powered battery, a Raspberry Pi, and a tablet with our application YouLearn installed on it. The solar powered battery is used to charge the tablet and serves as a power source for the raspberry pi. The Raspberry Pi serves as a local database that stores the files and video supplied by Rose Academies and a local server enables the streaming of files and videos offline to the tablets through our application called YouLearn.

8.2 Raspberry Pi

For our system, we decided to use a Raspberry Pi due to its versatility, price, size, and power usage. A Raspberry Pi is a computer that can be used for a variety of things due to its versatility as a system. The possibilities are endless. Because of its multifaceted nature, we were able to use the Raspberry Pi as a local server and local database.

We wanted to make our system as affordable as possible so it would be scalable for Rose Academies. The Raspberry Pi we chose for our system is only about sixty dollars. Since it will be used with multiple tablets and multiple students, the cost is almost negligible.

Since our system is going to be deployed in Uganda, we wanted something that could be easily carried onto an airplane. Since the Raspberry Pi is 3.5 by 2.3 by 0.76 inches, it is a very portable option.

Because we developed this system for communities in low-technology settings, we wanted our system to require as little power as possible. A Raspberry Pi only requires 3 amps power supply which can be produced from a solar powered battery easily.

8.3 UI/UX

One of the main goals of the project was to make our system very simple and easy to use. User interface design and user experience are very important elements to consider when developing an application because if an application is not easy to understand, a user will get frustrated with it and will not want to use it.

Since we are developing an application for people who are not as familiar or comfortable with technology as we are, we wanted our application to be as simple and intuitive as possible so it would be accessible to all users of all backgrounds. For this reason, we decided to utilize a minimalist design using a small color palette and a simple font when developing YouLearn.

Since we did not want to overwhelm the users with unfamiliarities, we decided to organize YouLearn by type and topic. Since items being organized by type and topic is fairly common, we believed it would make our application more approachable to first time users.

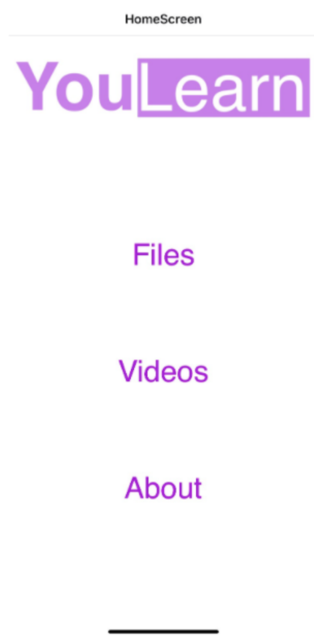

Figure 8.1: Home Screen of YouLearn

Figure 8.2: Files Screen of YouLearn

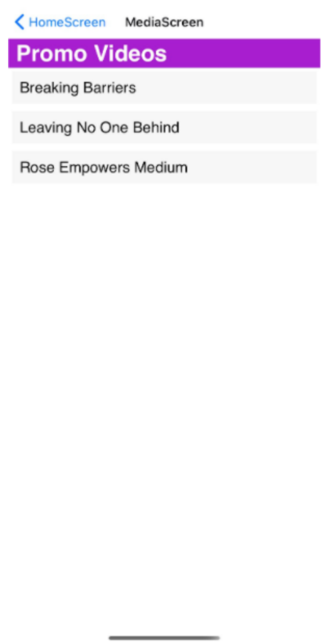

Figure 8.3: Video Screen of YouLearn

Chapter 9

Testing

9.1 Objective

The objective of testing was to detect defects in the system as early as possible. Once detected, defects were for the most part fixed and documented. Testing was done on the whole system, including the Raspberry Pi, application, and user experience. The test plan prioritized the system's functional and non-functional requirements as well as constraints.

9.2 White Box Testing

The first phase of testing was focused on unit, system, and integration testing. The development team tested individual units as developed for functionality and clarity of code, including each link on the React Native application. Unit testing prioritized the following:

1. The application should allow users to view the media library and stream media.

2. The Raspberry Pi should be set up and configured to support a wireless network accessible by at least five persons.

As units were completed, the development team shifted to integration testing to ensure the parts of the system worked together cohesively. It was essential for our system that the application on the Android tablets can receive locally stored media on the Raspberry Pi. Then, system testing was done, prioritizing the following:

1. The application receives media stored locally on the Raspberry Pi.

2. The Raspberry Pi can receive newly uploaded media hands-free and remotely.

3. Newly downloaded media to the Raspberry Pi will appear in the application video library and be streamable.

Our testing met our requirements, except for the last. Our application statically loads all content, including buttons and media content to stream. Future iterations of the project should aim to make the application dynamically create buttons for each file on the Raspberry Pi media server.

9.3 Black Box Testing

The final phase of testing was focused on the ease-of-deployability and ease-of-use of the system. The system should be easy to deploy in the sense that any person could take our system to school with no internet connection or electricity, and set up the system to stream media to local tablets. The system should be easy to use, and include necessary tutorials for scaling the system. In order to test these parts of the system, we had planned on doing black box testing locally and user acceptance testing in Kampala, Uganda. However, due to Coronavirus-19 shutting communities down globally, we had to cancel our deployment trip to Kampala.

In lieu of this, our team was adaptive with testing. We worked diligently with our partner organization to sculpt our delivered project into one that will meet all of their needs. We adapted our system to include a means by which any Android-owner can download the YouLearn APK, as well as other APKs that have been developed for Rose Academies, onto their device. From there, the Raspberry Pi can be turned on, the ad hoc wireless network is automatically enabled, and users can visit the YouLearn app and stream files and videos to educate their families and communities.

We had our nearby family and friends test our system's UI for simplicity and intuitiveness. We also asked about the effectiveness of the Android APK Installation Guide (see A.2). The instructions, as well as the system as a whole, should be easy to use for a person who may not have used or had limited use of technology before. Apart from just an intuitive interface and straight-forward instructions, this also means the system must perform as expected, and when it must, handle errors gracefully.

Finally, we performed acceptance testing with our partner organisation, Rose Academies. After a final system demonstration, Rose Academies accepted the system, and was enthusiastic about the results.

Chapter 10

Ethics and Societal Impact

10.1 Ethical Justification

The purpose of our project is to provide access to educational information for a community that does not have access to it. Since we are all human beings, we should all be treated equally and should all have access to the same information. It is within our capabilities to create a solution that can bring life-changing information to rural communities, and so that is what we should do.

Our system is economical because the cost of our system is minimal especially compared to comparable alternatives. Rose Academies has already supplied tablets and although the Raspberry Pi does cost money, it will be used with multiple users and multiple tablets, making the cost negligible. In addition, our application was free to develop and to distribute. Our system is also sustainable because our system will be using a solar powered battery to charge the tablets and provide power to the Raspberry Pi. Furthermore, our system is usable since it has a minimalist design which makes it very simple and straightforward to use.

10.2 Virtues of a Good Engineer

Throughout the development of this project, we each reflected inward and asked ourselves: "What makes a good engineer?" We reflected on the virtues required to implement a just and sustainable project and decided that a virtuous engineer is techno-social sensitive, has respect for nature, and is committed to the public good.

Techno-social sensitive engineers are aware of the way social forces affect the evolution of technology and the way technology affects society. When developing our system, we acknowledged the fact that technology is very influential towards society and communities. Since we developed a system for an underprivileged community that is less technologically advanced, this consideration was particularly important.

An engineer who has respect for nature will try to ensure that the product they are developing does not negatively affect the environment or take advantage of its resources. For our project, we wanted to minimize our carbon footprint and use a renewable energy source. For that reason, we decided to utilize low powered devices and solar powered batteries.

An engineer who is committed to the public good is an engineer who is actively trying to produce products that positively impact society. We as a group developed this project because we wanted to enact change; we want to make the world more equitable and just. Our system will allow people, who have little to no access to the internet, learn important health and educational information. We aim to bridge the unequal gap between developing and developed countries by providing underprivileged communities access to health, educational, and vocational resources.

10.3 Safety, Risk , the Public, and Informed Consent

10.3.1 Safety and Ethics

Our system is safe because no one is in harm's way when using our system, emotionally or physically. All the information our system provides to the community has been vetted by Rose Academies who has people on the ground in the communities we are deploying in. The potential physical risks are minimal; the only thing that could physically harm a user is if a wire short circuited and was exposed to water, which is a highly unlikely incident. By providing our system and detailed documentation of our system's functions to Rose Academies, we can prevent any potential risks from occurring.

10.3.2 Risk and Ethics

Since we are working with a non-profit organization, Rose Academies, we have tailored our system to their specifications. We have diligently taken into account their concerns and the potential risks that our system could have. We have addressed those risks by trying to make our system as simple and easy to use as possible, so any user will be able to use it and by giving Rose Academies documentation on how to utilize our system.

10.3.3 The Public and Ethics

The ”public” in our project is the rural underprivileged population of Uganda that Rose Academies has been helping. We are trying to provide access to health and educational information to this community. Since our project has minimal environmental impact and has been specifically tailored to this community, no population is being exposed to risk from this project.

10.3.4 Principle of Informed Consent

The principle of informed consent applies to our project because we are developing a system for a specific group of people. Rose Academies has asked us for our help and is tightly partnered with people inside the community we are developing this system for. We have been asked to develop this system so we are not putting anyone at risk without their consent and as stated above the risk of our project is minimal.

Chapter 11

Conclusion

To conclude, we will address the obstacles we encountered, the lessons we learned, and potential next steps for the project.

11.1 Obstacles Encountered

Throughout this project, our team faced a variety of obstacles, some within and some beyond our control. One obstacle we encountered was underestimating the difficulty of working with new technologies like the RPi. Our solution was to start early, thoroughly researching and reading the documentation on RPi, Wi-Fi access points, and connecting to a Google Drive.

Debugging was also a challenge we faced. There may have been days at a time when we were stuck on one small problem. But we talked about these issues as a team, helping each other with fixes. Often, after sleeping on the problem we could come up with a simple fix.

A final obstacle we faced, which no one expected or could control, was the spread of Coronavirus-19 around the world. Consequently, our deployment trip to Uganda was cancelled which greatly altered our testing plan. Our solution was to be flexible, and have our friends and family test our system, and get input from stakeholders on final uncertainties.

11.2 Lessons Learned

Throughout the development of our project the design requirements and system constraints changed. Our entire project shifted from focusing on vocational training resources to health and safety information. But that is simply a part of software development. The customer has the right to redirect the course of a project and it is our jobs as software developers to cope with those changes and alter the project accordingly.

Our team also learned a great deal about working in engineering teams. When working with a group of people it is crucial to heavily document the tasks you performed. This way, your teammates can replicate your procedure to troubleshoot or recreate what you did. Which also brings up communication. Our weekly team meetings were very useful throughout the development of this project because we could solve issues together, hold each other accountable, and ensure that the project was progressing.

A final lesson we learned in the context of software engineering was the importance of incremental change and version control. As individuals and as a team, we learned to change one thing at time, test it, and save the progress we had made. Before we learned this lesson, there was a lot of lost work and accidents that prolonged development.

11.3 Future Work

Our system meets all of the functional requirements, non-functional requirements, and constraints we set out to accomplish. Nonetheless, there are steps that can be taken to enhance and further this project. First, we recommend the React Native application be converted to a dynamic application that can generate buttons and links based on the RPi file system. Second, deployment testing or stress testing could still reveal issues with our system relating to power, performance, and stress. A final step would be making the RPi setup a script to make the system more scalable. Currently, each RPi in the system needs to be manually setup, a process that takes many hours. Rose Academies would prefer if the RPis could be set up automatically with all of the settings and features needed for the YouLearn system. These steps would make YouLearn an educational system Rose Academies can deploy in all of its partner communities.

Appendix A

Appendices

A.1 Source code

Full source code available at: https://github.com/jluo9612/you-learn-android

A.2 APK Installation Guide

PDF available at: https://github.com/jluo9612/you-learn-android/blob/master/APK

A.3 RPi Setup Documentation

PDF available at: https://github.com/jluo9612/you-learn-android/blob/master/Setting

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