Proceedings of the 7th International Conference on M4D Mobile Communication Technology for Development

M4D 2022, 28-29 April 2022, Kigali, Rwanda

Louis Sibomana, Sana Skandrani, John Sören Pettersson (eds.)

Faculty of Arts and Social Sciences

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Foreword

After the COVID19 pandemic breakout that shifted priorities and agendas, the Mobile for Development (M4D) conference series has the pleasure to settle in Kigali, Rwanda, for its seventh (7th) edition, and to be held hybrid for the convenience and safety of its participants. The College of Science and Technology is delighted to host the conference locally at University of Rwanda in Kigali, and it is a pleasure for Karlstad University to host the online meetings for the conference. The conference continues to encourage the dissemination of theoretical and empirical contributions as well as practitioners' experiences by organising paper presentation tracks and discussion panels.

The organising committee is very happy to welcome keynote speakers from academia and industry. These speeches add greatly to the paper presenters in a year like this when many have been hindered by pandemic restriction to submit papers and participating at the conference venue. The keynote speakers offer inspirational individual and organisational experiences and collaboration work in research, education, and application. This supports developing collaboration that involves individuals, universities, governmental agencies, companies, and NGOs, and raises the discussion, afresh, about the need to strengthen the practical work with locals and to involve users and potential adopters in the research process.

The M4D conference in 2018 showed a trend and a constant need to continue to work with mobile technology adoption and use by individuals and in businesses in order to improve the social and economic services, to strengthen social inclusion and to enhance the economic growth. In this year's edition of the M4D conference, the participants underline the need to continue to work with inclusive and sustainable solutions at individual and organisational levels as they investigated new ways to use new technologies. Together, researchers, educators and practitioners show that exploring and testing technologies such as Internet of Things, Edge AI, and drones to overcome local challenges in the health, agriculture and educational sectors and connectivity problems.

Finally, we would like to recognise the support from several sources. The University of Rwanda has generously supported the event. At the College of Science and Technology several staff members have spent many hours preparing the conference. The African Centre of Excellence in Internet of Things (ACEIoT) and the UR-Sweden Digital Health subprogram have sponsored for conference materials and health break and lunch refreshment during the conference. SPIDER (The Swedish Program for ICT in Developing Regions) supports the conference financially, and IPID (International Network for Post-graduate Students in the area of ICT4D) organises the Post-graduate Workshop the day before the conference and awards travel grants for a number of the participants. Karlstad University and its Information Systems group at the Karlstad Business School has covered the cost of the conference proceedings and the online meeting platform and technical assistance during the conference.

Louis Sibomana

College of Science and Technology
University of Rwanda

Sana Rouis Skandrani

Karlstad Business School
Karlstad University

M4D 2022 Conference Organisation

Reviewing process: double-blind peer-reviewing with either reject or conditional accept. For the latter category, revised papers have been subjected to renewed but non-blind reviews.

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Other Presentations

Keynote Speakers

Creative Industry – Perspectives from Tunisia

Samia CHELBI
NetInfo and DigiArtLivingLab
3dnetinfo.com and dall4all.org

Biography

Samia Chelbi is a University Lecturer with more than 25 years of experience in different fields and sub-fields on creative technologies.

Mrs Chelbi is founder of the first school of 3D animation and Video Game development in North Africa since 1999. She contributed extensively at educating and training young and more experienced talented North African and African candidates, that facilitated their entry to the labour market, thus to develop the industrial competences in Tunisia and Africa.

Her Passion for this realm pushed her into the community work development as she founded in 2004 the Tunisian Association of Creative Technologies (CREATEC).

This double vocation, social and professional, gave her the means to contribute to extending her business development work as well as actual contribution to the local social and economic spheres shaping the ecosystem in collaboration with the public and private actors.

Currently, she is leading the DigiArtLivingLab project which is the first living lab in North Africa specialized in Digital Arts and certified by ENoLL (European Network of Living Lab).

She also founded 3DAFRICAMAKER and AfricanGameDev, a network to develop the creative industry ecosystem in Africa supported by Autodesk and Epic Games.

African Center of Excellence in Internet of Things – Perspectives from Rwanda

Jimmy NSENGA
UR-ACEIoT, Rwanda, and 2GuiZ SPRL, Belgium
https://aceiot.ur.ac.rw/

Biography

Jimmy Nsenga defended his PhD thesis at Katholieke Universiteit Leuven in 2009. Now he is a Senior Polytechnician Software Lead, Lecturer and Research Scientist, with more than 10 years of experience in applied research related to wireless embedded DSP and 5 years of experience crafting production-ready user-centric software in different industries such multimedia, rail transportation, HR and IPTV. He daily leverages this diverse experience over the full value-chain of ICT technology development to smooth the transfer of emerging technology from academic research to business. Main scientific achievements include 3 US patents in the domain of wireless multi-antenna DSP and fingerprint-based watermarking of audio songs; and more than 50 research publications. Current research interests include integrating real-time resource constrained IoT devices with emerging technologies such as AI and Blockchains.

Dr. Nsenga's keynote highlights the importance of the African Center of Excellence in Internet of Things (ACEIoT). The keynote bears the title "*Leveraging and Development of Emerging Technology in Rwanda and in the Region, ACEIoT a Leading Key Player*."

Information about UR-ACEIoT

African Center of Excellence in Internet of Things (ACEIoT) is established at the University of Rwanda, College of Science and Technology in 2017 under by the World Bank funding.

Its aim is to **educate and train African researchers in the field of IoT**, who will develop and deploy innovative IoT enabled services, to address development challenges across all Eastern and South African (ESA) countries. It offers **Master and PhD programs in Internet of Things**, with a specialization in Embedded Computing systems and Wireless sensor Networks. The main objectives of the center is to build a critical mass of African scientists and engineers in IoT through higher education and research, and set up an **IoT living lab** in Rwanda for open innovation and co-creation of IoT4D. ACEIoT is built on UR's existing collaborations with the **local and international partners**.

Digital Transformation – Perspectives from Mali

Amadou DIAWARA
Center for Innovation in Technological Research and Creative Industry
https://cirtic.com/

Biography

Amadou Diawara, Knight of the National Order, grew up both in Mali and France. He has an extended experience in various large international companies. He settled in Mali in 2010 working with computer engineering and consulting.

CEO and founder of *Center for Innovation in Technological Research and Creative Industry* – CIRTIC, which is a consulting company and IT solutions publisher present in Mali with representations abroad. CITRIC employs about a hundred collaborators.

Diawara is also President of the *Digital Africa Cluster*, a collective intelligence and co-construction platform that has implemented a range of digital solutions: CDA social; CDA Event; CDA Virtual Academy; CDA Crowdfunding; CDA Biography; CDA survey and many other tools including SMS banking service.

Diawara is President and founder of the network *Cluster Digital Africa Virtual Academy* (https://clusterdigitalafrica.com/), he occupies different roles in a large and extended international network that works with technology development and implementation in Africa, but also educating for and about technology. Among his main roles one finds:

- Vice-president of the Forum on Internet Governance in Mali
- Member of the Malian chapter of ISOC (Internet Society)
- Member of the Training and ICT Commission of the Council of European Investors in Mali (CIEM) and Member of the Union of Franco-Malian Ambassadors (UDA-FM)
- Member of ASIM (Association of Computer Companies of Mali)
- Representative of Mali at CINVU (COMSTECH Inter – Islamic Network on Virtual University)
- Member of CAUDEV (African University Consortium for the Development of Virtual Education)
- Member of AUNEGe (Association of Universities for the development of digital education in Economics and Management) in France, network of Thematic Digital Universities (UNT), and
- Ambassador of the Club of Moroccan Leaders.

Research and Position Papers

Conceptualising Digital Resilience Factors for Mobile Payment Services

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ABSTRACT The advent of mobile payment services has enabled users to move funds quickly using their mobile devices. This has led to a proliferation of consumers adopting and using mobile payment services in emerging markets. However, in recent years, incidents of mobile payment fraud have been on the rise. Mobile payment users have been victims of fraud attacks from individuals who use illegal means to access users' financial information and funds. As this causes financial loss, it is imperative to ensure user continuity of mobile payment services after fraud has occurred. However, there is a lack of empirical evidence on the factors that enable users to continuously use mobile payment services after fraud. Based on the concept of **digital resilience**, a systematic literature review was carried out to identify these factors. In line with the psychological resilience theory, the study identified five (5) personal attributes and one (1) environmental factor enabling individuals to continuously use mobile payment services post fraud. These factors may enable technology developers, service providers and governments to prioritise their limited resources, promote intended benefits and support resilience at the individual level.

Keywords: digital resilience, mobile payment services, continuance use, psychological resilience theory, systematic literature review

1. Introduction

The growing mobile payment services sector has influenced how cash transactions are carried out (Fan, Shao, Li, & Huang, 2018). The proliferation of mobile phones has played a vital role in the diffusion of mobile payment services to millions of individuals (Liébana-Cabanillas, Sánchez-Fernández, & Muñoz-Leiva, 2014). Mobile payments is a payment method that enables the payment of goods and services through a mobile device (preferably a mobile phone) (Gao & Xu, 2019).

Mobile payment service initiatives such as M-PESA in Kenya and Tanzania have become ubiquitous mobile payment platforms (Varga, 2017) that enable users to move funds at their convenience (Iman, 2018). However, mobile payment services have become an avenue for fraud (Akomea-Frimpong, Andoh, Akomea-Frimpong, & Dwomoh-Okudzeto, 2019; Senyo, 2021). This is particularly evident in developing countries where high levels of fraud are apparent (Provencal, 2017; Subex, 2011). Fraudsters often rely on particular illegal means to lure mobile payment subscribers into revealing their personal identification numbers (PINs) and other information that can be used to withdraw funds from their mobile payment wallets (Annan, 2017; Pradigdya, Venantius, & Ginardi, 2019).

Annan (2017) and Provencal (2017) argue that with widespread fraud occurring in mobile payment services, service providers should pay more attention to the safety of users' information and financial assets (Humbani & Wiese, 2019; Ofori, Boateng, Okoe, & Gvozdanovic, 2017). If mobile payment services are secure and service providers guarantee that users' information and funds will not fall into the hands of fraudsters, their trust in the services will increase, thereby promoting continuance use of the service (Kumar, Adlakaha, & Mukherjee, 2017; Odoom & Kosiba, 2020).

Despite several measures instituted by mobile payment service providers to help curb fraud (Priezkalns, 2020), an increasing number of users report being victims of mobile payment fraud (Ankiilu, 2017). This calls for research on the factors that may enhance consumers' continuance use of mobile payment services after these negative events. This study proposes the concept of **digital resilience** as a potent attribute that will enable users to continuously use mobile payment services after fraud has occurred.

2. Literature review

2.1 – Overview of resilience

The concept of resilience emerged from ecological studies during the 1970s. Holling (1973) introduces the concept in his seminal work "Resilience and Stability of Ecological Systems" and is the basis for most research conducted on ecological and other forms of resilience. The term "resilience" has gained a broader meaning with the terms "ecological resilience" and "engineering resilience," respectively (Gallopín, 2006; Holling, 1996). Holling (1973, p.18) argues that ecological resilience "determines the persistence of relationships within a system and is a measure of the ability of these systems to absorb changes of state variables, driving variables and parameters and still persist" (Holling, 1973, p.18). Ecological resilience allows systems to cope with disruptive events through adaptation and evolution (Fiksel, 2003).

Systems with engineering resilience are structured to recover quickly from small disruptive events while attempting to recover from larger ones. Engineering resilience improves a system's performance, consistency, rigidity and predictability (Holling, 1996).

2.2 – Digital resilience

In recent years, the term "resilience" has emerged in the academic field of Information Systems research that uses the term "digital resilience" (Burns, Posey, Roberts, & Benjamin, 2017; Heeks & Ospina, 2018).

Digital resilience can be described as the ability to recover from pervasive online risks (Sage, Randolph, Fitch, & Sage, 2020). The concept of digital resilience relates with Holling's (1973) ecological concept of resilience in systems that recover from adversities through adaptation and evolution (Fiksel, 2003).

Literature in the area of digital resilience has largely explored how individuals cope with online risks (Sage et al., 2020; Vandoninck, d'Haenens, & Roe, 2013). For example, in their study of cyberbullying victimisation amongst adolescents, Navarro, Yubero, and Larrañaga (2018) show that assets, such as perseverance and hardiness, operate as protective factors that moderate the nexus between cyberbullying victimisation and fatalism amongst adolescent senior high school students in Mancha, Spain.

Although the value of prior studies cannot be underplayed, Camp et al. (2019) and Majchrzak, Andr, and Sandvik (2018) have called for future studies to examine digital resilience from different perspectives to ensure comprehensive coverage. For instance, Bermes (2021) calls for research to explore the factors (personal attributes and environmental factors) that enable users to develop resilience to information and communication technology (ICT) related stressors. Moreover, research needs to identify how resilience influences the continuous patronage of ICT services. Thus, it is prudent for research to explore the personal attributes and environmental factors that enable individuals to be resilient after being affected by stressors related to ICTs (Bermes, 2021).

3. Research problem

In recent years, the use of mobile payment services in developing countries has been marred by several reported instances of fraud (Chen & Li, 2016; Ofori et al., 2017). Fraudsters continuously rely on sophisticated ways to access the information and funds of users of mobile payment services (Akomea-Frimpong et al., 2019; Wang, Hahn, & Sutrave, 2016).

This has led to the investigation of how service providers can promote user continuity of mobile payment services amidst the prevalence of fraud (Akomea-Frimpong et al., 2019; Humbani & Wiese, 2019). Chen and Li (2016), Glavee-geo, Shaikh, Karjaluoto, and Hinson (2020) and Raman and Aashish (2020) argue that to mitigate fraud attacks, mobile payment service providers need to focus on ensuring that mobile payment platforms are safe and secure. The existence of safe platforms will increase users' trust in the service, thereby promoting their continuance use of the service.

Mobile payment service providers should offer security options, such as authentication, encryption and PINs, to ensure safety benefits to users (Kang, 2018; Wang et al., 2016). Similarly, service providers need to intensify mobile payment fraud education to bring users up to speed with the current strategies that fraudsters use to ascertain their information and funds (Gao & Xu, 2019; Ozturk, Bilgihan, Salehi-Esfahani, & Hua, 2017).

Despite mobile payment service providers' implementation of these recommended measures (Annan, 2017; Priezkalns, 2020), it is key to highlight the year-on increases in mobile payment fraud in developing countries (Ankiilu, 2020; Larnyoh, 2020). Mobile payment users are continuously faced with social engineering fraud (Ali, Dida, & Sam, 2020), including false promotions, anonymous calls from fraudsters and scams (Ankiilu, 2020; Annan, 2017). The existence of mobile payment fraud causes financial loss to users and mobile payment service providers and damages the image of the mobile payment service industry (Gilman & Joyce, 2012).

Given this, it is essential to ensure users' continuance patronage of mobile payment services after fraud to eliminate issues of financial exclusion and mitigate losses that may arise from users' discontinuance use of the service. The continuance use of mobile payment services post fraud necessitates an investigation into the factors that enable users to cope with these events after they have occurred.

However, there is a dearth of studies that explore these factors. This study proposes the concept of digital resilience that will enable individuals to rely on certain factors to cope with mobile payment fraud effectively.

The primary objective of this study is **to identify digital resilience factors for mobile payment services post fraud**. The following research question will help achieve the objective:

RQ. What factors enable mobile payment users to develop digital resilience after fraud?

4. Methodology

To identify digital resilience factors for mobile payment services post fraud, a systematic literature review (SLR) is employed. Unlike traditional literature reviews, SLRs exhibit thoroughness and rigor and follow detailed methodology (Snyder, 2019).

To achieve a holistic coverage and complete review process, we followed the PRISMA 2020 guidelines for SLR and a combination of approaches for SLR in Information Systems (Senyo, Liu, & Effah, 2019; Templier & Paré, 2015; Webster & Watson, 2002). We used a six-stage systematic review procedure to follow these approaches, as shown in Table 1.

Table 1: The study's SLR steps

S/N	Steps
1	Literature search
2	Inclusion and exclusion criteria
3	Quality appraisal
4	Refinement of literature
5	Data extraction and analysis of data
6	Presentation of findings

4.1 – Literature search

After testing several search terms in relevant digital libraries, the search terms ("cybervicti*" OR "internet victi" * OR "social media victi*" OR "social networ* victi*" OR "online victi*" OR "online") AND ("risk" AND "resilien*" AND "protective factors") were deemed appropriate as they produced the best results for this study. This search string was used in the Web of Science and EBSCOhost databases. We relied on these databases because they index several Information Systems journals and conference proceedings (Webster & Watson, 2002).

4.2 – Inclusion and exclusion criteria

The search was limited to 10 years (2012-2021) to provide current factors that can apply to mobile payment services. The study's inclusion and criteria are shown in Table 2. We relied on only peer-reviewed journals and conference proceedings as Webster and Watson (2002) asserts that quality contributions in a field are found in peer-reviewed journals and conference proceedings. Using the defined terms, we searched the titles, keywords, and abstracts. The search resulted in 403 results for further refinement.

Table 2: Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Peer-reviewed journal papers and conference proceedings	Review articles, books; book chapters
Articles between 2012-2021	Papers related to prevention of online risk
Articles published in English	Papers related to Covid19, disasters and death
Articles relating to victims' resilience after online risk exposure	

4.3 – Quality appraisal

It is essential to evaluate the quality of studies in an SLR. This helps the research refine which papers to include or not and determine if the difference in quality influences the outcomes of the review (Templier & Paré, 2015). To assess the quality of papers included in this review, two key considerations were followed (Okoli & Schabram, 2010):

i. If the research article applies to our study's research question

ii. If the research article meets the review criteria shown in Table 2.

4.4 – Refinement of literature

We carefully screened the sampled articles for duplicates and rejected those that did not match the inclusion criteria at this point. Reading the title, abstract, and main text of the sampled articles served as the basis for the literature refining procedure. For example, articles that focused on online risk prevention, online risk detection using artificial intelligence techniques, among others, were discarded. A total of 21 articles were selected after refinement. Forward and backward searches resulted in a further 8 articles. In total, 29 articles were used for analysis.

4.5 – Data extraction and analysis

Data extracted from the 29 papers revealed that 28 of the 29 papers included in this review were journal articles (representing 96.6%). Each of the 29 articles was read and coded using ATLAS.ti for digital resilience factors applicable to mobile payment services. This included several passes over the data by one author and verified by the other author to eliminate issues of bias.

During the coding process 52 codes were identified. Table 3 shows the outcomes of codes in ATLAS.ti. After grouping the codes, they were categorised into personal attributes and environmental factors (Richardson, 2002). Personal attributes are internal to a person, and environmental factors are external to a person (Richardson, 2002). This is in line with the psychological resilience theory (Bermes, 2021; Richardson, 2002).

The combination of codes resulted in six (6) digital resilience factors, categorised into personal attributes and environmental factors, as shown in Table 4. After combining codes, five (5) personal attributes and one (1) environmental factor were realised. Table 5 presents digital resilience factors, their sources and the factors per source after combinations.

Table 3: Codes from ATLAS.ti

Identified codes			
Persistence	Goal efficacy	Structured style	Gratitude
Hardiness	High self-esteem	Family cohesion	Humour
Locus of control	Life satisfaction with family	Social support from family and friends	Joke
Forgiveness	Optimism	Social support from family	Planning behaviour
Social skills	Platform support	Peer support	Positive emotions
The belief of universality	Positive mental health	Social support from friends	Positive parenting
Personal competence	Positive reappraisal	A thick skin	Positive refocusing
Social competence	Positivity	Acceptance of self and life	Pragmatic outlook
Social resources	Professional outlook	Affirmation	Prosocial peer affiliation
Been easy going	Resolution	Changed privacy or contact settings	School connectedness
Confidence	Secure attachment	Deleting unwelcoming messages	Sense of meaning and purpose
Direct confrontation	Spiritual orientation	Eating family meals together	Social support from the community
Ethnic identity	Strong personality	Exploration	Block sender

Table 4: Digital resilience factors from the categorisation of codes

Personal attributes	**Environmental factors**
Acceptance of self and life	Social resources
Personal competence	
Positive emotions	
Social competence	
Structured style	

Table 5: Digital resilience factors and sources

Sources	*Acceptance of self and life*	*Personal competence*	*Positive emotions*	*Social competence*	*Social resources*	*Structured style*
Brighi et al. (2019)		X				
Mitchell & Štulhofer (2021)		X				
Rey, Quintana-Orts et al. (2020)		X	X			
Vissenberg & D'haenens (2020)		X			X	
Vandoninck et al. (2013)		X			X	
Papatraianou et al. (2014)	X	X			X	
Tobias & Chapanar (2016)		X			X	X
Yubero et al. (2021)		X				
Steven et al. (2021)			X			
Worsley et al. (2019)			X		X	
Bester et al. (2017)		X			X	
Dredge et al. (2014)	X	X	X			
Santos et al. (2020)		X		X	X	X
Fredrick et al. (2021)		X				
Lee et al. (2021)					X	
Lin et al. (2020)	X	X				
Wang et al. (2020)					X	
Craig et al. (2020)			X		X	
Víllora et al. (2020)		X		X	X	
Navarro et al. (2018)		X				
Hinduja & Patchin (2017)		X				
Brailovskaia et al. (2018)			X			
Chang et al. (2019)					X	
Jiang et al. (2021)					X	
Shaw et al. (2019)					X	
D'Cruz & Noronha (2018)	X	X	X		X	
Collen & Onan (2021)		X				
Tynes et al. (2012)		X			X	
Umaña-Taylor et al. (2015)					X	

5. Discussion of results

5.1 – Social resources

Social resources were the highest scored digital resilience factor. From Table 6, results from 16 studies indicated social resources as a factor leading to resilience. Social resources measure the access and quality of external support an individual receives from family, friends, and the community (Friborg, Barlaug, Martinussen, Rosenvinge, & Hjemdal, 2005).

Given that social resources relates to support derived from parties within and outside a person's environment (Hjemdal et al., 2006), the codes (see Table 3), platform support; prosocial peer affiliation; positive parenting; secure attachment; eating family meals together; life satisfaction with family; school connectedness; social support from family and friends; social support from friends; social support from family; social support from the community; peer support; ethnic identity and family cohesion were found to be associated with social resources. Therefore, these codes were combined to form the factor **social resources.**

5.2 – Personal competence

According to Hjemdal et al. (2006), personal competence assesses a person's self-esteem, self-efficacy, realistic outlook in life, drive, and the ability to stick to daily routines and plans. Personal competence was the second most occurring factor after codes were combined. The factor was found in 14 of the articles reviewed. Based on the studies of Hjemdal et al. (2006) and Wagnild & Young (1993), the codes; confidence, high self-esteem, confidence, blocking sender, change privacy or contact settings, deleting unwelcoming messages, goal efficacy, pragmatic outlook, strong personality, a thick skin, direct confrontation, persistence and professional outlook were found to be associated with personal competence.

Findings from Vandoninck et al. (2013) study on the coping strategies of children and teenage victims of online risk across Europe show that older children changed their privacy or contact setting when faced with online bullying. This made them effectively cope and develop resilience to online risks such as online bullying. However, to change their privacy or contact settings, block a sender or delete an unwelcome message, children needed to possess some level of digital literacy (Vandoninck et al., 2013) and therefore reflects personal competence (Hjemdal et al., 2006).

5.3 – Positive emotions

Positive emotions are elicited when desired outcomes are achieved. Joy, happiness, elation or pleasure, courage, hope, love, and interest are all part of it (Lucas, Diener, & Larsen, 2003). According to Amir (2012), positive emotion is a key component of resilience, as it brings tranquillity, creativity, and swift decision-making to a stressful scenario. Individuals' ability to keep an optimistic viewpoint in the face of hardship is thus described as a positive emotion.

Following positive emotions relate to individuals elicitation of positive feelings when faced with adversity (Amir, 2012; Ong, Bergeman, & Chow, 2010), the codes joke; humour; positivity; positive reappraisal; positive refocusing; positive mental health; optimism; easy-going; gratitude and forgiveness were combined to create the factor **positive emotions**.

Studies in online risks show how individuals' elicitation of positive emotions enabled them to build resilience after being victims to online risks (D'Cruz & Noronha, 2018; Worsley et al., 2019).

5.4 – Acceptance of self and life

Acceptance of self and life is a psychological notion that has been shown to improve mental health and well-being (Plexico, Erath, Shores, & Burrus, 2018). Acceptance of self and life is linked to feelings of self-worth and interpersonal fulfilment (Wagnild & Young, 1993).

Regardless of what others may believe, the term refers to an individual's realistic and non-judgmental acceptance of both positive and negative aspects of oneself and one's past, without attempting to change, ignore, or control them (Ellis, 2010). Given this, the codes, belief in universality; spiritual orientation and locus of control were associated with acceptance of self and life.

Studies on online bullying show that bullying victims who appraise their self-worth have a low risk of adverse outcomes (Lin et al., 2020). Dredge et al. (2014) highlighted the protective effect of acceptance of self and life in the form of a 'belief of universality' that enabled individuals to mitigate the negative effect of cyberbullying.

5.5 – Structured style

The degree to which an individual wants to plan and structure their daily activities is measured by structured style (Smith et al., 2008). Individuals who can effectively structure their lives in times of adversity are characterised as resilient persons (Friborg et al., 2005; Jowkar, Friborg, & Hjemdal, 2010). Following this, the code **planning behaviour** was associated with structure style.

Outcomes from Tobias and Chapanar (2016) study indicated that email and computer cyberbullying was a strong predictor of structure style. Persons with higher structured style scores are categorised as being more resilient to bullying prior to its occurrence. Results from the study further indicated the significant effect of structured style post bullying, implying that persons who intrinsically possessed structured style after bullying could cope with the adverse effects of cyberbullying.

5.6 – Social competence

Social competence measures the degree to which an individual is socially adept, their ability to induct initiatives, flexibility in social matters, good communication skills (Hjemdal et al., 2006). Studies show that socially competent individuals can thrive in times of adversity (Friborg et al., 2005; Ruvalcaba-Romero, Gallegos-Guajardo, & Villegas-Guinea, 2014). Based on the definition of Hjemdal et al. (2006), the code **social skills** were found to be associated with social **competence**. Therefore, they were combined to form a social competence factor**.**

The study of Santos et al. (2020) supports the mediating role of social competence on the link between cyberbullying and depressive symptoms. Resilient individuals are socially competent and can control the adverse effects of cyberbullying on depressive symptoms, thus improving their life satisfaction.

6. Conclusion and Implications

This study answers the need for research into factors that enable individuals to continuously use mobile payment services post fraud. Based on the concept of digital resilience, a systematic literature review was carried out to identify these factors. Six (6) digital resilience factors were discovered in the literature that can apply to the context of mobile payment services.

Research may rely on these factors to investigate mobile payment fraud resilience in developed and developing countries. Furthermore, studies may apply digital resilience factors found from this review to other research areas. Using these factors, studies may explore how individuals cope and build resilience to ICT-related stressors. These may include stressors from individuals' use of social networking sites (SNS), electronic commerce platforms, among others.

Furthermore, digital resilience factors identified may enable technology developers, service providers and governments to prioritise their limited resources, promote intended benefits and support resilience at the individual level. This may include constant education on sophisticated techniques fraudsters employ to access mobile payment users' funds and financial information. Educating victims on these sophisticated techniques may enhance the personal competence of victims to promote their resilience to mobile payment fraud. Furthermore, service providers may engage cyber forensic experts for solution finding to stolen money after fraud has occurred to ensure that victims are able to recoup funds lost.

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Use of Mobile Phones to Enhance Households' Access to Agricultural Information in Nyamira North Sub-County, Kenya

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ABSTRACT Access to agricultural information is critical in optimizing agricultural production by rural households. However, weak economies have rendered most governments in developing countries like Kenya incapable of providing requisite agricultural information to households engaging in farming. To bridge this gap, mobile phones network operators in Kenya have launched a platform where households can use mobile phones to access agricultural information. However, little is known about how the use of mobile phones has enhanced households' access to agricultural information. Therefore, this study sought to investigate how the use of mobile phones has enhanced households' access to agricultural information in Nyamira North Sub-County. Specifically, the study sought to determine the level of awareness of households on the use of mobile phones to access agricultural information, analyse how the use of mobile phones to access agricultural information has influenced households' agricultural productivity, and investigate the challenges encountered by households in using mobile phones to access agricultural information in Nyamira North Sub County. By use of quantitative and qualitative methods, the study established that there is a low level of awareness among households on the use of mobile phones to access agricultural information, use of mobile phones in accessing agricultural information has enhanced household agricultural production, and that possession of non-smartphones, language barrier, and high cost are the notable challenges facing households from using mobile phones to access agricultural information. The study recommends awareness creation on the access of agricultural information through mobile phones, use of suitable language to suit household members with diverse education levels, and reduction of cost of accessing the agricultural information using mobile phones.

Keywords: Mobile phones, agriculture, information, Kenya

1. Background

Rural life revolves around agriculture. Almost 80% of the world population eke out a living out of the land. Rural folk relies on agriculture for food, and income through the sale of food or cash crops to industries for processing (Musungwini, 2018). Thus, agriculture is critical to the rural economy and is synonymous with rural life. Although agriculture is the backbone of the rural economy in most developing nations, there are shortcomings in the dissemination of agricultural information to keep farm production at par. Since the countries have limited capacity in terms of resources to invest in rural agricultural information dissemination, agricultural productivity is negatively affected. Continuous dissemination of agricultural information is paramount in optimizing farm production (Mittal and Mehar, 2012; Amir, Peter, and Muluken 2016). Such agricultural information encompasses communication on the use of hybrid seeds, chemicals, fertilizers as well as farm operations relating to crop and animal husbandry (Amir, Peter, and Muluken, 2016).

The dissemination of agricultural information is essentially supposed to be done by the government through government agricultural extension officers (Mittal and Mehar, 2012; Maqsood, 2015). However, weak economies in most developing countries, have rendered governments incapable of disseminating agricultural information to enable households to optimize farm production (Nyamba, 2017). For instance, in Kenya agricultural extension services are a toll order with the majority of rural households have not seen an agricultural extension officer on their farms for their entire farming career. This means that the transfer of agricultural information hardly reaches farmers on the ground. In response to the Kenyan government's limited capacity to disseminate agricultural information to households, mobile phones network operators have created a platform to disseminate agricultural information to households to address their agricultural-related needs through mobile phones. This is usually via Short Messages Services (SMS) or calls.

Among the agricultural information disseminated via mobile phones include information on agricultural extension services through learning modules to help farmers gain practical guidance and support, information on farm inputs, financial advice, and loans to aid farmers buy farm inputs as well information on market facilities for farm produce.

There exists global literature on mobile phone use in accessing agricultural information by households. A study by Abdullahi, Oladele, and Akinyemi (2021) revealed that farmers used mobile phones in agricultural operations because their attitude towards mobile phones applications was positive. However, the use of mobile phones according to Abdullahi, Oladele, and Akinyemi (2021) was marred by some challenges among them poor networks, high cost of mobile phones, and complexities of operating a phone by the farmers. Similarly, Krell et al. (2021) reported that farmers in Central Kenya accessed agricultural information notably information on agriculture and livestock as well as agricultural market information via their mobile phones. On the same note, Tinzaara et al. (2021) indicated that farmers utilized mobile phones to access information on banana farming and that the most sought agricultural support information was on meteorological, pest and disease control, fertilizer use, and market.

Furthermore, Quandt et al. (2020) argued that the use of mobile phones had enhanced agricultural information access and that through such information, farm productivity had improved tremendously to extent of farmers realizing huge profits due to improved farm productivity and reduced costs related to farming operations. As reported by Muasa and Matsuda (2018), the use of mobile phones among rural households in Kenya has fostered access to agricultural-related information including them extension services, weather, and farm product market information. This study argues that this phenomenon has been occasioned by farmers owning smartphones. A study by Kiberiti, Sanga, Mussa, Mlozi and Haug (2016) established that mobile phones enhanced farming business because of affordable and easy access to agricultural support information among farmers. It is evident that the above studies have concluded that farmers are using mobile phones to access agricultural-related information and that through such information-sharing platform farm production has improved.

However, some studies have indicated that access to agricultural information by farmers through mobile phones is non-existent. Chhachhar, Qureshi, Khushk, and Maher (2014) observed that most farmers did not use mobile phones in accessing information on farm operations as well as getting information on farm products. According to Musungwini (2018), the use of mobile phones has not in general enhanced households' access to important information such as market prices. In addition, Emeana, Trenchard, and Dehnen-Schmutz (2020) reported that the use of mobile phones in accessing agricultural information and support by farmers is unlikely to bear fruits because of issues such as social norms, education level, and demands of farmers in using the mobile phones platforms to access agricultural related information.

From the reviewed literature, there is no clarity on how the use of mobile phones has enhanced households' access to agricultural information. Therefore, this study sought to investigate how the use of mobile phones has enhanced households' access to agricultural information in Nyamira North Sub-County. Specifically, the study sought to determine the level of awareness of households on the use of mobile phones to access agricultural information, analyze how the use of mobile phones to access agricultural information has influenced households' agricultural productivity, and investigate the challenges encountered by households in using mobile phones to access agricultural information in Nyamira North Sub County.

2. Methods

The study was conducted in Nyamira North Sub County, western part of Kenya between January and May 2021. The region was purposively selected because of two reasons. First, it's a high agricultural potential region with almost 99% of households practicing small-scale farming, particularly the production of tea, coffee, corn, bananas, arrowroots as well as cattle farming for subsistence. Second, the region was chosen because of the high population growth rate that has resulted in diminishing land acreage due to intensive land sub-division and inheritance in which the majority of households nowdays possess less than an acre of land. Thus, the households in this region highly require agricultural information to optimize agricultural productivity from the limited land.

This study utilized both quantitative and qualitative research methods. Simple random sampling was used to draw a sample of 200 household heads from a target of 44460 households. In addition, a purposive sampling procedure was used to select participants for four Focus Group Discussions (FGDs) and key informant interviews to cross-check information obtained through the questionnaire method.

The semi-structured questionnaire was administered by a researcher who documented respondents' responses. In addition, FGDs comprising six to ten participants, as well as five key informant interviews, were conducted. The selection of participants in FGDs was informed by regional balance, gender, and the type of farming. The researcher also ensured the reliability of the tools by pretesting them in the neighboring Borabu Sub-County.

Prior to the data collection exercise, permission was sought from relevant authorities including the sub-county commissioner, Sub-County agricultural officer, and village elders. The researcher articulated the purpose of the study and addressed emerging concerns from the administration regarding the study. While in the field the researcher made it clear from the start that participation in the study was voluntary and there were no handouts for participants. The village elders aided the researcher to access the data source. The data collection exercise lasted for two months.

The quantitative data collected was analyzed by descriptive statistics whilst qualitative data were coded and analyzed using salient and recurrent themes relating to the use of mobile phones to enhance households' access to agricultural information in the study area. The data then formed a source of interpretations of meanings and experiences on the use of mobile phones to enhance households' access to agricultural information in Nyamira North Sub County, Kenya.

With regard to ethical considerations, the researcher provided correct and adequate information to respondents about the study for them to make an informed decision on whether to participate or not. In addition, the researcher, ensured that any identifiable information of respondents was removed to uphold the principle of confidentiality.

3. Results

This section is divided into four subsections. First, demographic data for the respondents in this study are presented. After this come results and discussion of three key questions, namely what is the awareness among households on the use of mobile phones to access information related to agriculture, has the use of mobile phones for this purpose enhanced farm production among the aware households, and finally what challenges to access information have the aware households encountered.

3.1 – Demographic Information of Respondents

Tables 1-4 provides information about gender, age, education level, and the type of farming by respondents involved in this study. Field data were collected in 2021. All responses were valid.

Table 1: Gender of Respondents

	Frequency	Percent
Male	152	76.0
Female	48	24.0
Total	200	100.0

Table 2: Age of Respondents

	Frequency	Percent	Cumulative Percent
Below 20	1	.5	.5
21-30	27	13.5	14.0
31-40	34	17.0	31.0
41-50	75	37.5	68.5
51 and above	63	31.5	100.0
Total	200	100.0	

Table 3: Education Level of Respondents

	Frequency	Percent	Cumulative Percent
Primary	92	46.0	46.0
Secondary	81	40.5	86.5
College	22	11.0	97.5
University	5	2.5	100.0
Total	200	100.0	

Table 4: Type of Farming Practiced by Respondents

	Frequency	Percent	Cumulative Percent
Mixed Farming	168	84.0	84.0
Crop Farming	24	12.0	96.0
Livestock farming	8	4.0	100.0
Total	200	100.0	

As depicted in table 1,152 (76%) respondents were male while 48 (24) % were female. This implies that the majority of households in the area of study are headed by male. On age, as shown in table 2, most respondents (38%) were aged between 41 and 50 years. Regarding the education level of respondents in table 3, most respondents (46%) had primary education while in table 4, most households (84%) in the area of study practice mixed farming probably to diversify farming activities for any eventualities and to maximize the farm yields.

3.2 – Awareness of Households on the Use of Mobile Phones to Access Agricultural Information

The ultimate goal of agricultural information is to positively transform the livelihoods of households and foster humanity. This can only be possible if the agricultural information is given high publicity to enhance high uptake levels among the households. The study sought to determine the level of awareness of households on the use of mobile phones to access agricultural information in the study area. Findings are shown in Table 5.

Table 5: Awareness of Households on the Use of Mobile Phones to Access Agricultural Information

	Frequency	Percentages
Aware	92	46
Not aware	108	54
Total	200	100

As depicted in Table 5, 92 (46%) respondents were aware of the use of mobile phones to access agricultural information dissemination while 108 (54%) respondents had no knowledge of access to agricultural information through mobile phones. This indicates that the majority (54%) of households in the study area are unaware of the use of mobile phones to access agricultural information. This depicts a low level of awareness of households in Nyamira North Sub County on the use of mobile phones to access agricultural information. During a focus group discussion, a participant noted that:

> *"I have heard of dissemination of agricultural information through mobile phones from a friend but I don't know what it is all about. Otherwise, most households here do not know anything about the use of mobile phones to access agricultural information."*
>
> *(Male, 43 years)*

The sentiments of this focus group discussion participant show that some households have knowledge of the use of mobile phones to access agricultural information but they lack requisite details on how such information can be obtained for use. Furthermore, during focus group discussions, some participants argued that it is difficult for households to access agricultural information through the phone because of their limited knowledge of operating a mobile phone. One of the focus group participant averred that:

> "*Like most of the households in this area and even participants in this forum, operating a mobile phone is a challenge. I look for assistance when making a call. If I don't know even how to search for a contact on my phone, how will I access agricultural information?*"
>
> (Female, 56 years)

The sentiments of the fifty six years focus group participant indicate a low level of awareness of households on the use of mobile phones to access agricultural information in the study area. This finding concurs with a study by Musungwini (2018) that established low levels of household mobile phone use in accessing agricultural information to support their farming activities in Zimbabwe.

3.3 – Use of Mobile Phones to Access Agricultural Information and Households' Agricultural Productivity

The use of mobile phones to access agricultural information was initiated to help households to foster agricultural productivity. This study sought to analyze how the use of mobile phones to access agricultural information has influenced agricultural productivity at the household level. Results are shown in Table 6:

Table 6: Use of mobile phones to access agricultural information and Household Agricultural Productivity among the Aware Respondents

Has use of mobile phone to access agricultural information enhanced farm production?	Frequency	Percentages
Yes	61	66
No	31	34
Total	**92**	**100**

From the study findings, it emerged that 61 (66%) respondents aware of the use of mobile phones to access agricultural information argued that the platform has enhanced farm productivity in most households while 31 (34%) respondents reported that the use of mobile phones to access agricultural information by households had no impact on agricultural productivity in the study area. Based on the findings it is evident that the use of mobile phones to access agricultural information has fostered households' farm productivity. The findings were echoed by an agricultural expert during a key informant interview who noted that:

> *"Use of mobile phones to disseminate agricultural information has made our work easier. Nowadays households or farmers are able to acquire information on the available quality seeds, chemicals, crop planting procedures, and even information on farms loans that can support their farming activities. I can confidently say that the use of mobile phones has improved agricultural production in this Sub County even though land sizes are small"*
>
> (Agricultural officer, 49 years).

The assertion by the key informant clearly indicates that household agricultural productivity has improved courtesy of the use of mobile phones in agricultural information access by households. Such improvement in agricultural productivity in limited land will greatly ensure household food security in the study area.

During focus group discussion, participants agreed that the use of mobile phones to access agricultural information has resulted in an increase in farm production especially maize because they are able to plant the best seed variety, the right fertilizers, and chemicals that have revolutionized their farming career. A focus group discussion noted that:

"Although access to agricultural information via mobile phones has its challenges, since I started accessing the information through my mobile phone, my farm production has improved. Nowadays I am able to know the best maize seed variety for this area, the best variety of fertilizers to apply, and the best chemicals to use to foster maize farming on my two-acre farm. I also know information about crop spacing and other farm operations via mobile phones. Since I started accessing information through mobile phones and applying it, my maize production has increased from seven bags an acre to twenty bags an acre. This technology is so helpful"

(Male, 45 years)

Based on the sentiments of the forty-five years focus group participant, it is evident that access to agricultural information through mobile phones has improved farm production in the study area. This is because households are able to access essential information about agriculture especially information about the best seeds, fertilizers, and chemicals as well as important farm operations like crop spacing. This has ensured improved agricultural productivity for improved household food security in the study area.

3.4 – Challenges Encountered by Households in Using Mobile Phones to Access Agricultural Information

After revealing that the use of mobile phones to access agricultural information has enhanced household agricultural productivity in the study area, the study sought to investigate the challenges households encounter in the use of mobile phones to access agricultural information. The overall proportions among the aware respondents are given in Figure 1.

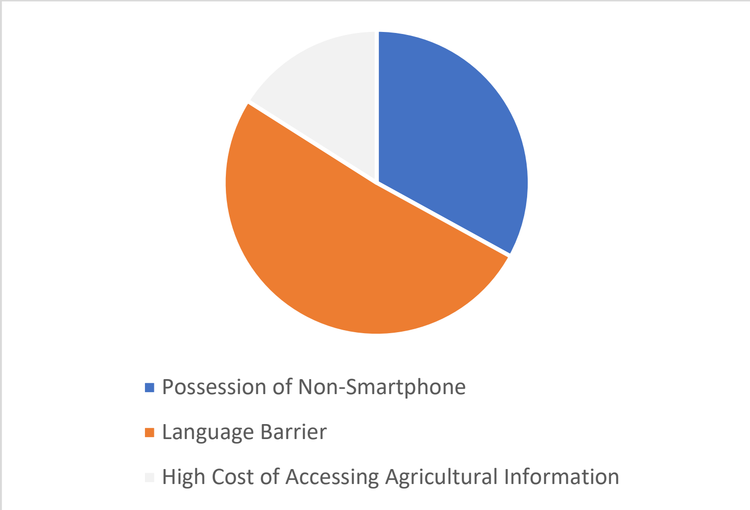

Figure 1: Challenges Encountered by Households in Using Mobile Phones to Access Agricultural Information

The numbers behind Figure 1 are as follows: 31 (33%) of respondents argued that possession of a non-smartphone, 47 (51%) language barrier, and 14 (16%) argued that the high cost of accessing the information are the challenges encountered by households in accessing agricultural information via their mobile phones.

The data indicates that half of the households in the study area may encounter a challenge with language in their pursuit of agricultural information through their mobile phones. The study revealed that little exposure of households to western education has rendered it difficult for households to comprehend agricultural information in the form of SMS and to act accordingly to deal with various issues associated with farming. For instance, during a focus group discussion a participant showed us an SMS sent by one of the telecommunication network providers on agricultural-related information. The message was sent on 12th October 2020 at 0043hrs and it read:

> *"Dear farmer, as you learn farming ways, we offer loans to get appropriate inputs depending on your learning and available limit. Dial *283*3*1# to learn more."*
>
> *(Telecommunication network operator in Kenya)*

From the message, it is evident that the target group for the message is learned households since it is written in English and requires further information access about the loans and farm input. This implies that household heads or members with no or little exposure to western education may not comprehend such information; hence the agricultural information cannot reach all households engaged in farming. This finding concurs with Kieti et (2022) who revealed that a lack of literacy skills to operate smartphones impedes the use of mobile phones to access agricultural information in Kenya. The findings also concur with Kaske, Mvena and Sife (2018) revealed that SMS related to agricultural information was poorly utilized by farmers in Southern Ethiopia. The study also agrees with a study by Maqsood (2015) which revealed that the educational level among rural women in Pakistan determined their use of mobile phones to access telecommunication-based agricultural extension information.

In addition, the study revealed that possession of other phone types than smartphones disadvantaged quite a number of households (31%) in accessing agricultural information.

Respondents in this study reported that the majority of households lack appropriate gadgets (mobile phones) that can aid to access agricultural information hence they miss out on crucial agricultural-related information. During a focus group discussion, a household head lamented that:

> *"The challenge with accessing agricultural information using mobile phones is the use of unsuitable phones (non-smartphones). This has hindered many households from using their mobile phones to access agricultural information in this area"*
>
> *(Female, 39 years).*

This is a clear indication that households in the study area using non-smartphones is a perceived obstacle to using mobile phones in accessing agricultural information is concerned. However, what the respondents did not know is that agricultural information is sent as SMS to phones with prompts that can lead to access to required information. In addition, from the SMS call, contacts are provided that non-smartphones can call. Thus, the issue of the type of phone in agricultural information access is associated with a low level of awareness on agricultural information access via mobile phones.

Lastly, the study revealed that the high cost of accessing the information is a hurdle to some households (16%) in using mobile phones to access agricultural information. Respondents argued that money in the form of airtime is required for a household to access agricultural information either through SMS or call which has proved costly to some households. This discouraged households from accessing agricultural information through the mobile phone platform. During a focus group discussion, a participant averred that:

> *"Access of agricultural information through mobile phones is expensive since airtime is required to SMS or call."*
>
> *(Female, 45 years)*

The sentiments of the forty-five years focus group participant show how the cost of accessing agricultural information hinders households from accessing agricultural information through phones. This might affect household agricultural productivity and food security.

4. Conclusions and Recommendations

Agricultural information dissemination through mobile phones is a fundamental strategy to bridge the existing gap in agricultural information flow between the government and households. Access of agricultural information through mobile phones enables households to easily access vital information that supports their farming career. Although the use of mobile phones in accessing agricultural information has enhanced agricultural productivity, there is need for: (1) awareness creation on the access of agricultural information through mobile phones, (2) use of suitable language to suit household members with diverse education level and (3) reduction of cost of accessing the agricultural information using mobile phones. These three measures would ensure better use of mobile phones to access agricultural information to foster optimal household food productivity and food security. We have recently learned about another study in Kenya (Kieti et al., 2022) which was published too late to be considered for our study. Nevertheless, three out of six themes found are similar to ours: service discoverability, service usability, and service affordability.

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Towards Intelligent Offline Mobile Applications Using Edge AI

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ABSTRACT Mobile phones have become an integral part of human life with most smart devices having inbuilt sensors and Application Programming Interfaces (API) that can be exploited to develop more intelligent applications. Indeed, attempts have been made collect data using mobile phones and to integrate machine learning with mobile application so as give intelligent decisions. However, due to the need of compute and storage resources that are not readily available in most affordable smart mobile phones, such applications are always linked to the cloud where the Machine Learning (ML) model is based. Data is then transmitted from the device to the cloud ML engine for inference with results being transmitted back for display on the mobile devices. Given the challenges of connectivity especially in developing countries, cost constraints, privacy concerns and the need for immediate response in some applications, using a cloud-based ML architecture becomes a challenge. This study therefore proposes the use of Edge Artificial intelligence (AI) to enable offline intelligent application with inference being done on the mobile phone without the need for connectivity. This is achieved by using tiny machine learning (tinyML) to generate light models to deploy in the devices. The concept of Edge AI is explained and thereafter as a proof of concept an offline braille interpreter is presented with the results showing the benefits that can be drawn from using Edge AI.

1. Introduction

Mobile devices have become an integral part of the modern lifestyle. It is estimated that there are 5.3 billion unique mobile subscribers in the world. In sub-Saharan Africa the percentage of mobile devises that are smart devices is 64% (globally the percentage is 75%) [1]. The use of mobile phones can inspire new opportunities in businesses while at the same time increase efficiency by enabling reliable and timely access to information [2]. Mobile phones have eliminated the physical barriers and distance and improved access to information across the globe. The way industries operate has been drastically changed by the evolution of mobile phones by the improvement of interaction network and provision of services in sectors that had been under explored such as education, healthcare and banking [3]. Accordingly, tailor made mobile application development has been on the rise with a focus on the following; Business interactions, payment solutions, medical monitoring and consultation, staff monitoring, animal and farm monitoring and service improvement for underprivileged in the society including the blind, deaf and physically impaired persons [3].

Current smart phones components include built-in sensors and standard Application Programming Interfaces (APIs) that enable the devices to not only measure but also collect data. Some examples include using the inbuilt accelerometer to measure physical activities, using Bluetooth detection to measure crowd density, using the GPS sensor to capture mobility patterns, using the camera to capture images and videos and measuring the Wi-Fi signal to measure the time spent indoor versus outdoor [17]. Thanks to the advancement of technologies, the collected data can be used to develop more intelligent applications through the integration of machine learning.

Different machine learning based applications have been proposed by different authors. For example: In a paper by Sarker [4] we see data models built using machine learning techniques. Data based on mobile devices for data science is collected from various sources and used in building data-driven models using machine learning techniques is proposed. The solution is designed for the purpose of making dynamic decisions intelligently in various day-to-day situations of the user. Other examples include: A machine learning-based mobile app for User Authentication is presented in [5], a Mobile Applications for Diabetes Self-Care and Approach to Machine Learning is proposed in [6], a Machine Learning-based Descriptive Statistical Analysis on Google Play Store Mobile Applications is presented in [7], in [8] Deep Learning towards Mobile Applications is evaluated, and [9] shows an Evaluation of Machine Learning–Based Automated Personalized Daily Step Goals Delivered Through a Mobile Phone App.

However, deep learning as a concept of machine learning dictates the use of high performance devices. Due to the high performance requirement, there is a huge computation capability to deal with complexities of training and inference methodologies built on large dataset. What this means is that cloud servers are able to meet this steep requirement by providing computational capabilities that are able to satisfy the computation thirst. Standalone solutions which require the user to prepare their laptops or desktops are deemed ineffective which has driven more non-traditional alternative solutions in recent years to effectively execute the AI computation tasks. For example, "Google provides the tensor processing unit (TPU) solution as the specialized computing unit for AI processing tasks. NVIDIA also innovates new GPU server architecture to favour AI characteristic" [12; wih references]. A cloud environ has is a proven platform to serve some AI applications. Nonetheless, the use of cloud technology has found limitations that might prevent the adoption on all AI applications. Some challenges with cloud-based architectures include high latencies, privacy issues, increased costs of connectivity and limited connectivity in some regions especially in developing countries. Due to the matters arising from the limitations of cloud applications, there is a requirement that AI computation must be on the edge devices (Edge AI).

This study therefore proposes the use of Edge AI to enable more intelligent mobile applications that do not rely on connectivity. The use of such an architecture will lead to the following advantages:

- Reduce costs of connectivity
- Applications will continue functioning even if connectivity is lost
- There will be limited sharing of data enhancing security and privacy
- Reduced latency making such a solution appropriate for use cases that need real-time inference

As a proof of concept an offline braille interpreter is presented in this paper. An open-source data set was implemented to train the models and a tinyML model generated for deployment on a mobile phone. The results show the capability of using edge AI to enhance intelligent offline applications to be deployed in mobile phones.

The rest of the paper is organized as follows; in the next section the concept of Edge AI is presented in detail. This is followed by a section outlining the proof on concept from data collection, training, evaluation to deployment. The results are then presented and discussed and lastly a conclusion drawn.

2. Edge AI

Artificial intelligence (AI) can be referred to as intelligence acquired by machines making them try and replicate human reasoning. AI is today applied in many applications some of which included: mobile devices, robotics, smart agriculture, smart transport, smart energy, healthcare service, education and many more. Even though there has been a growing advancement in area of AI, there exists a potential of developing more intelligent applications. With the growing popularity of Internet of Things (IoT) there is a necessity for low latency and low energy on device processing to limit dependence on cloud processing hence the merging concept of Edge AI [11] in which a ML model is trained on the cloud and deployed for inferencing on an edge device making it possible to enjoy ML intelligence offline.

Figure 1 Illustrates a comparison between a cloud centric and edge centric AI models. With the Edge AI the ML intelligence is moved to the data source unlike in the cloud centric architecture where the data is transported to the cloud. With Edge AI processing and computation is moved away from the cloud to the device unlike the cloud-based AI in which data has to be moved from the device to the cloud to benefit from massive computation. With this approach computation take place on the device leading to low latencies, reduced cost of energy and connectivity and privacy enhancement.

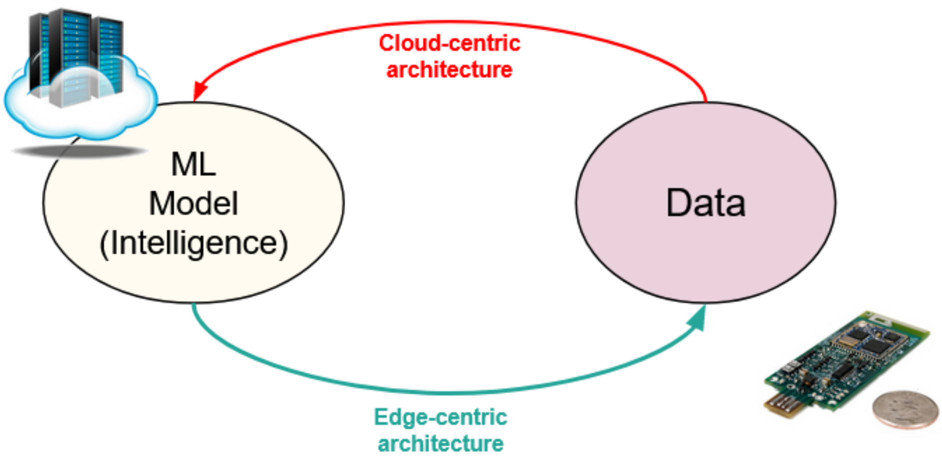

Figure 1: Edge AI Vs Cloud AI Architecture

In relation to device constraints in commonly used smart phones. ML can either be classified as serving ML to the smart phone or processing ML at the edge within the smart phone. In the serving ML scenario, the ML algorithm is deployed in the cloud and the device has to send data to the cloud to make inferences [12]. In the processing ML case, the ML model is deployed locally, and the device can directly inference on sensor data without the need for connectivity and only selected data can be sent to the cloud from time to time.

2.1 – Edge AI Process

Similar to any ML process, the edge AI process [13] presented in Figure 2 begins with a dataset for training. Data can either be collected using the sensors on a mobile phone or open-source data sets can be used as source of training data. The next phase involves training the dataset with an ML framework that can produce a model specifically optimized for embedded processors known as the TinyML model. The model that is gotten as a result, is then tested and packaged as a WebAssembly library. This packages the learning blocks, signal processing blocks and configuration as a single package. This package was included in web pages or as part Node.js application in user mobile devices. This allows the running of the prediction model locally without the need for compilation.

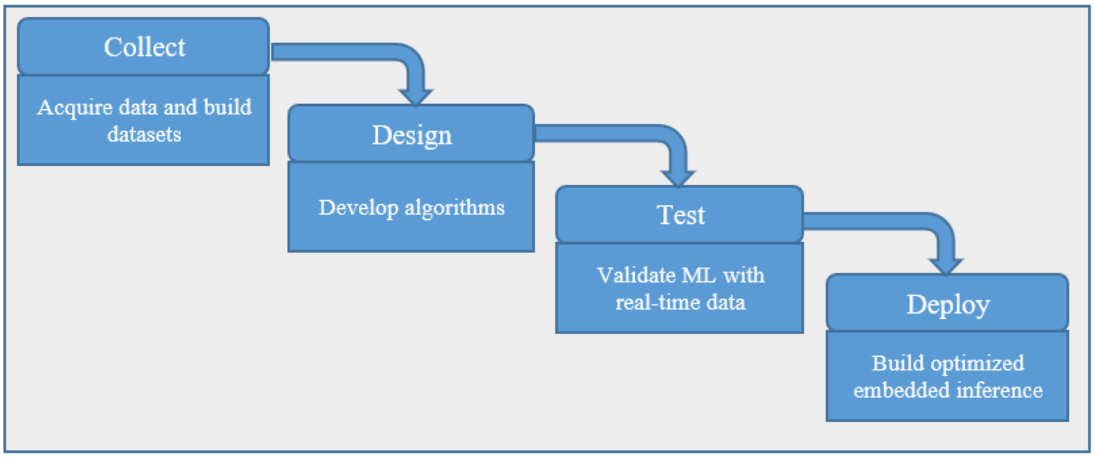

Figure 2: Edge AI process

3. Proof of concept

As a proof of concept an offline Edge AI braille interpreter is presented. Such a solution was selected due to the need of the solution in Rwanda and other parts of the globe.

3.1 – Why a Braille Interpreter?

According the World Health Organization in [14], for every 100 people in Rwanda, one of them is visually impaired. This estimates the total number of visual impaired people in the country to around 400,000. In Rwanda for example, only two schools in the country specialize in imparting knowledge to visually impaired students with a current education method based on converting physical books into Braille documents. It is further noted that each single page of English written text generates a ten pages Braille document. Furthermore, the lack of Braille based educational resources and technological solutions have made the learning process lengthy and complicated for the visually impaired in developing countries due to the fact that most of the people cannot afford for the costly Braille related technological tools for the visually impaired [15]. An offline mobile phone-based braille interpreter will not be very valuable and useful for students or other people without impaired vision to help those with impaired vision, if they would need to assist them. There is thus a need for a machine learning model that can be able to work offline given the connectivity challenges in Africa to make this a reality.

3.2 – Existing project

There have been attempts to develop application and solutions to help the visually impaired access more resources. To begin with, a mobile phone based Braille Tutor System, for Android platform is designed to provide an easy Braille learning technology for the visually impaired [15]. Even though, the objective of the project is to create a low cost, economical presentation device and Braille tutor system based on Android for the blind, due to connectivity challenges such a solution may not be accessible to a larger population. In [16] a communication device model for conversion of alphanumeric English text to its corresponding Braille format that can be read by a Deaf-Blind person is proposed. However, such a solution is not able to convert text from braille to English and will not help solve the cost challenges, hence the need for an offline based solution that can convert text from braille to English.

3.3 – Edge AI pipeline

The proposed solution followed the Edge AI pipeline as shown in Figure 3.

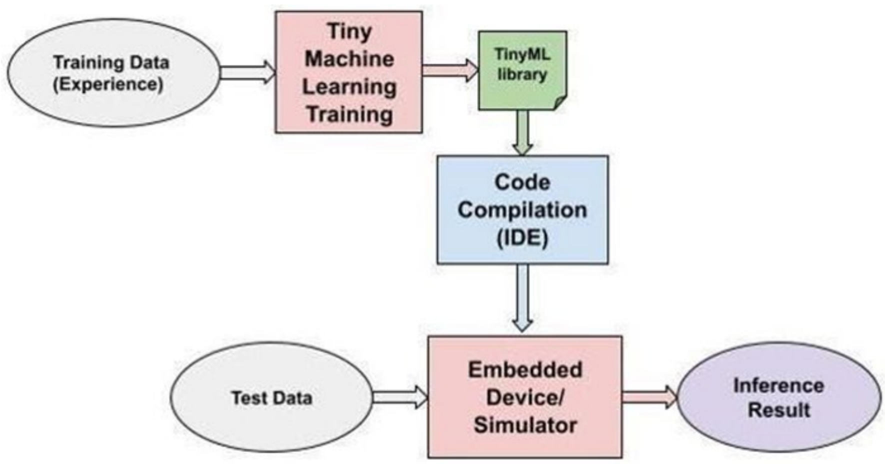

Figure 3: Edge AI pipeline

The edge AI process begins with using a dataset consisting of multiple sets of the Braille alphabet, numbers, and symbols. The aim is to train an AI that recognizes images of individual Braille characters and translate them into English characters. The result is ideally a concatenated image of a sentence/line of Braille that has been processed by a segment each Braille character out individually fed into our pipeline for an English sentence or word.

3.4 – The Data

The open dataset from GitHub, part of an organization called aeye-alliance was collected by a group of four undergraduate female students in computer science who were part of the AI4SocialGood Lab 2018 at McGill University. The data is acquired from rare book collections and the internet. We constructed our own dataset consisting of multiple sets of the Braille alphabet, numbers, and symbols. We then trained an AI that will recognize images of individual Braille characters and translate them into English characters (Figure 4). Using a specific ratio and cropping function, we are able to take an image of a sentence/line of Braille and segment each Braille character out individually. We feed each of these characters into our model and then concatenate the output characters together into an English sentence or word. Organized into 26 folders of 500 images of how each letter looks like in Braille, symbols like colon, question marks, full stop and space.

Figure 4: Sample dataset of Braille images

3.5 – Training Steps

Edge impulse, an open-source embedded ML platform was used for training. We first upload a dataset of 500 images for each of the 26 classes representing the alphabet to the cloud platform forming a total of 13,179 samples. In a second step, features were extracted from the uploaded data before training. This is done to anticipate the fact that during the inference process, feature extraction on raw data by a deep learning model would require more processing power than available in embedded systems. Figure 5 show a plot of the extracted features.

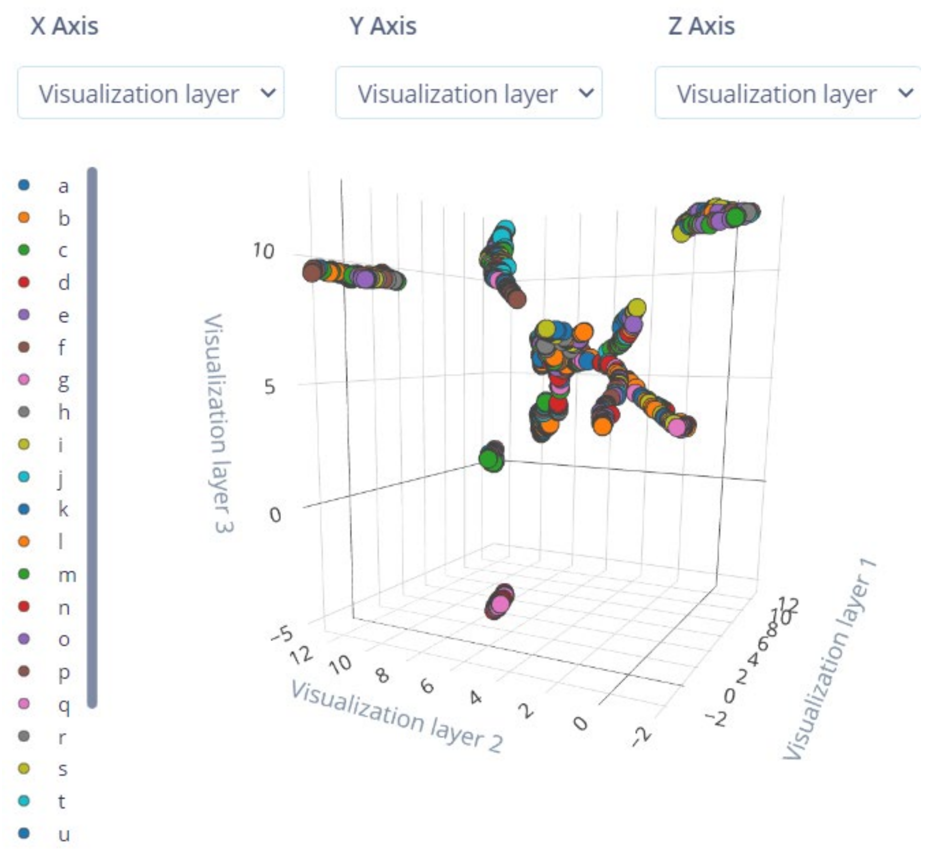

Figure 5: Extracted features

The images formed the input to the neural network classifier with 26 classes forming the outputs with a classification as to which letter has been identified by the model. We process the images by color image, rather than in image grayscale, and then turns the data into a features array. Further in the processing phase we perform the following operations:

- Resize all the data.
- Create a 3D visualization of your complete dataset shown in Figure 5.
- Training parameters and output

As configuration, the training parameters are shown in Figure 6.

Figure 6: Training parameters

Edge impulse provides a 'Transfer Learning' learning block, which takes all the images in and learns to distinguish between the 26 classes. To make this easier and faster we are using transfer learning because building a computer vision model from scratch inclusive of training such models can take days on a GPU. Transfer learning allows, retraining the upper layers of a neural network, leading to less time required for training to achieve a suitable model.

For both training runs, different numbers of training epochs were tested and obtained a good performance already at 10 epochs, with the learning rate set at 0.0005 and the validation set was 20% Fig. 7 shows the confusion matrix for the validation set.

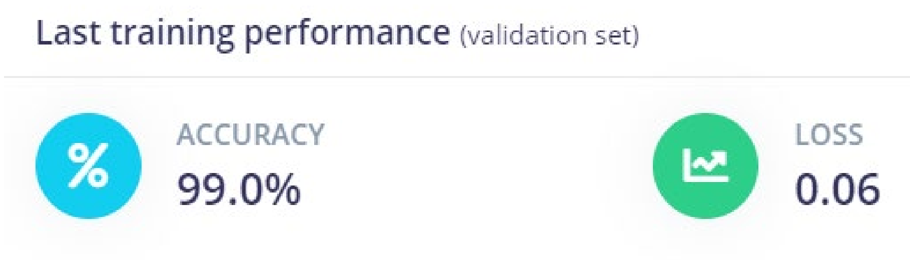

Figure 7: Confusion matrix for the model on the validation dataset.

3.6 – Generation of TinyML library

The model was also deployed as a WebAssembly library. This packaged the learning blocks, signal processing blocks and configuration as a single package. This package was included in web pages or as part Node.js application in user devices. This allowed the running of the prediction model locally without the need for compilation.

4. Results and Discussion

After validating the effectiveness of using Edge AI in enabling intelligent mobile applications that are not dependent on connectivity. This section presents and analyze key findings.

4.1 – Test Results

The model was deployed as a WebAssembly library as a single package which can be included in web pages. The impulse ran locally for an experiment phase, without any compilation. The image in figure 7 shows letter "a" on edge impulse live classification. When the raw features are captured from the live cloud studio and taken to a local console on the command prompt, we are able to prove that we get the same classification on the cloud as well as on a standalone device deployed using web assembly technologies as shown in Figure 8 and 9. Further a Text-To-Speech (TTS) for node.js was implemented. This enables one to send text from node.js to your speakers. The speaker output is able to clearly sound a letter or word using this library.

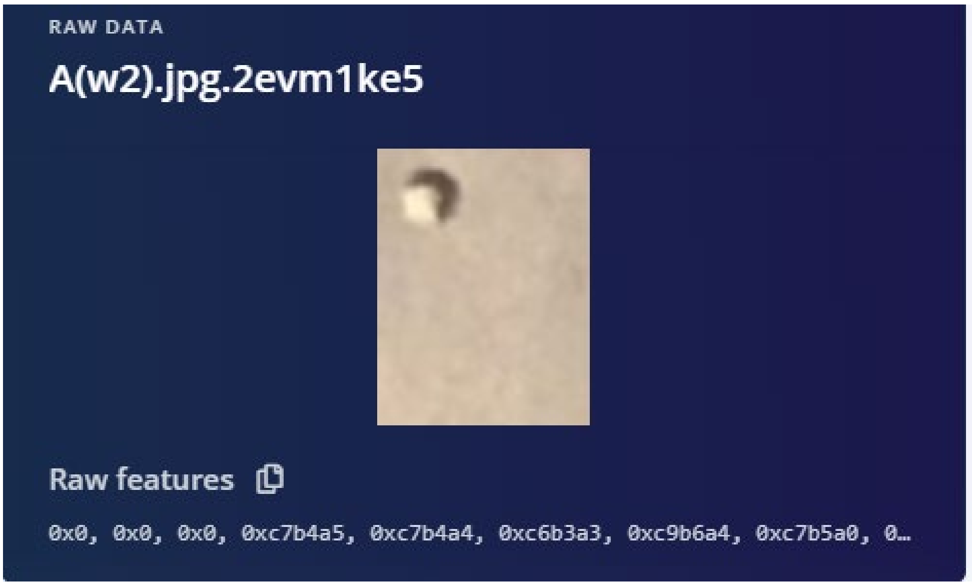

Figure 8: Live classification

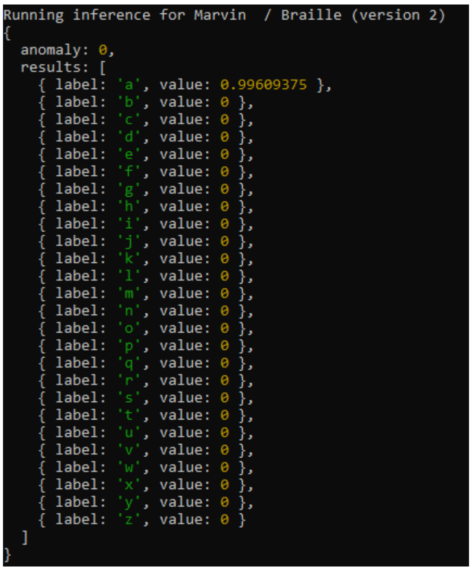

Figure 9: Image of console output classifying letter A correctly

4.2 – Inference Accuracies

Test data was applied on the model in the cloud platform and the same also used to test on the mobile application. The system was able to classify the images with 100% accuracy as was done in the cloud environment. This show that the conversion of a model to a lightweight model for deployment on mobile phones do not affect the model accuracies.

4.3 – Edge Performance Estimates

The edge performance estimates for the model on the edge device was 33.4K peak RAM and 57.3K flash usage as given in Figure 10. This show the model is tiny enough to run in resource constrained devices.

Figure 10: On device performance

4.4 – Effect of data on accuracies

The number of images for each class was reduced so as to determine the effect on accuracies. The results showed that when images were reduced the accuracies also reduce supporting the findings by other related studies.

5. Conclusion

This study presents the potential of using Edge AI for intelligent offline mobile applications. Edge AI brings with it advantages including low latency, fast response time, reduced costs and enhance privacy. With the wide use of smartphones, this proposal suggest that inclusivity is attainable without the need of additional materials to complement your phone. Further it reduces the need for paper work as the digital contents can be acquired on a need to need basis, at any time and conveniently.

This innovation proved that we do not need extraordinary phones with very high prices in order to deploy our model. Further considering the network inconsistency in the developing world, having a solution that can perform without the need to connect to the internet fits the context of an environment with need for edge processing via tinyML

The proposed offline braille would, we argue, lead to increased literacy rates with improved access to resources by the visually impaired. Non-visually impaired people who cannot read available braille resources will be able to easily communicate with the visually impaired. They will be able to help them in their studies by using the proposed devices to convert text that they can understand. In addition, the blind will have access to the materials via audio messages from the device. This will go a long way towards enhancing the communication between people with varying functionalities in Africa and beyond.

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The Use of Mobile Communication for Cognitive Development: A Case Study of Dyslexia in Nigeria

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ABSTRACT The main aim of this paper is to assess and understand the role of mobile applications in the cognitive development of individuals with learning disabilities-dyslexia. The study is focused on the effectiveness of the mobile application in creating the well-being of cognitively disabled individuals. This study further explored various mobile phone applications and their effectiveness based on previous studies on cognitive disability in Nigeria. This study also contributes to transformative service research by assessing well-being. The results of this study can be used in Sub-Saharan Africa too.

1. Introduction

The COVID-19 crisis has highlighted the urgent need to rethink the human ecosystem on the well-being of the individuals and zoomed-in on how we live together and more specifically on how we communicate. Before the COVID-19 pandemic, the economic and social service systems were accelerated based on the trends of the tradtional practices within the immediate environment and systems. The impact of this complex change caused an isolation of individuals from the traditional environment and caused bigger challenge for individuals with disabilities, especially the cognitively disabled ones. This complex change in the social service systems in sub-Saharan Africa where individuals with disabilities receiving less care and attention has a total adversity in their wellbeing. In sub-Saharan Africa disabled individuals receive less care and attention as is obvious that the cost of caring and supporting people with disability is high. The impact to Cognitively Disabled Persons is considerably high comparing to other disabilities in this situation as the adaptability is limited.

Cognitive Disability is characterized by substantial limitations in cognitive functioning and adaptive behaviour**.** Cognitive skills are the core or fundamental skills a person uses to read, learn, remember, pay attention, think and reason. These skills are very crucial in day-to-day processing of new information. They work together to ensure that incoming information is properly received, retained and retrieved on demand. Weakness in any of these cognitive skills can impact learning and working adversely. Most of the struggles students go through in their academic endeavours, for instance, are as a result of weakness in one or more of these cognitive skills and students living with dyslexia show deficit in a number of cognitive skills (Nadler &

Archibald, 2013). People with cognitive disability ought to have reasonable access to learning opportunities that assist them in gaining vital knowledge and skills. The unavailability of these opportunities could possibly lead to poverty; they may be unable to access rudimentary products and services such as telephones, television and the Internet (Larco, Enríquez & Luján-Mora, 2019). Inadequate access to technology has led to a digital divide. However, information and communication technology can help people with intellectual disability in their interaction with the external environment. In this perspective, information technology is having a promising effect in easing difficulties and assisting individuals with disabilities.

People with Dyslexia (difficulty with words) have difficulty acquiring the necessary skills for the effective reading, spelling writing and pronunciation of words. These difficulties are persistent even when they have the necessary cognitive abilities and exposure to adequate instructions (IDA, 2008). This disorder is a complex neurologically based condition which may last a lifetime depending on its type and severity, making the people with dyslexia experience lack of academic progress, lowered self-esteem, depression and anxiety (Adubasim & Nganji, 2017).

According to the International Dyslexia Association (2000), overcoming dyslexia, and other learning difficulties, can be achieved through multisensory re-education, which includes the application of visual, auditory, and kinaesthetic-tactile pathways simultaneously in order to enhance memory and written language learning. Games provide an individualized teaching and learning environment, which may contribute to the development of memory, visual perception, auditory ability, language, reasoning, time and space orientation, and motor coordination (Ball & McCormack, 2013). People with Cognitive Disability ought to have reasonable access to learning opportunities that assist them gain vital knowledge and skills. The unavailability of these opportunities could potentially impact the well-being of the individual and the society in general.

The study is focuses on the effectiveness of the mobile phone application in creating wellbeing for the individuals with limited access to technology as well as assesses the effect of technology in transforming the wellbeing of people with Cognitive Disability. Therefore, to clarify the focus of this study and the main aim of this paper, we are describing the Brainfeed Alternative Intervention Programme and the role of mobile phones applications in the cognitive development of individuals with learning disabilities, especially dyslexia.

1.1 – Brainfeed Alternative Intervention Programme

Information and communication technology can help people with Cognitive Disability in their interaction with others and in the way they co-create value. Brainfeed is a programme that is made up of various mobile applications that enhances cognitive skills. The programme is aimed at assessing the challenges and opportunities in transforming the available techniques and solutions to assist individuals with cognitive skills deficits and their wellbeing. In other words, Brainfeed aims to develop a mobile-based solution grounded on different exercises. The Brainfeed Alternative Intervention Programme is a combination of exercises that challenge attention, concentration, logic and reasoning, memory, speed and accuracy. These include flash exercises, rapid automatic naming exercises, word and face memory exercises, speedy recall and reaction exercises, Schulte table exercises, speed math exercises, mental flex exercises, etc. The exercises that target working memory include Flash; Recall, Path Memory; Changing Focus; Schulte table and Visual memory racer (John-Adubasim & Ugwu, 2018):

Schultz Table: This is a brain feeding programme that is composed of 25 boxes with serial numbers or letters placed in the boxes randomly. The time it takes for a respondent to completely select boxes with numbers is computed and used to assess the processing speed of respondents.

Flash: In flash, numbers are shown and withdrawn. Thereafter, the respondents are required to indicate where the number was shown. After completing a series of 10 of these exercises, respondents are scored on their performance.

Recall: Series of numbers are shown in boxes and are later hidden. Thereafter a prompt is provided for the respondents to indicate where the numbers were shown.

Path Memory: Figures are arranged across a path. This is later withdrawn and students are asked to draw the pattern shown earlier.

Changing Focus: Respondents were shown shapes in box with specific colours, and are prompted to match either the colours or the shapes.

Visual memory racer: Respondents are shown nine images in boxes and another page is provided where they are expected to identify the images as shown in the previous pages.

For more information on the Brainfeed programme, see https://www.brainfeedfoundation.org/.

1.2 – Mobile Application and Dyslexia

The increase in information and communication technology has a positive impact in many ways. With the increase in information and communication technology, mobile applications have gradually become an essential part of daily life in this emerging digital world (Larco, Enríquez, & Luján-Mora, 2019).

The mobile app economy has grown exponentially, motivated by a massive community of software developers. The rapid change and increased need to connect the technology to co-create value in a transformative way is also linked to the human wellbeing. With the turn of event the world is increasingly embracing mobile technology as part of the daily life and as a result the devices become more influential, extremely functional and low-priced, thus increasing their prospect as a tool to support learning within the spheres of the affluent. In view of this context mobile devices may become essential as a learning aid for students with special educational needs and for students precisely with dyslexia in.

Games provide an individualized teaching and learning environment, which may aid in the development of memory, visual perception, auditory ability, language, reasoning, time and space orientation, and motor coordination. In this setting, the games can be potent teaching tools in order to increase the knowledge of students and therefore improve their self-esteem, if used with pre-defined objectives. Ball and McCormack (2013) claim that improvements in computers and assistive technology offer notable and vital support to students with dyslexia.

Recently, mobile projects focused in dyslexic re-education have emerged. Examples are Graphogame (www.graphogame.org) and Dyseggxia (www.dyseggxia.com). Graphogame, designed for personal computers and with a demo version attuned for Android in January 2015, is a game that supports children learning to read in their local language with the assistance of technology constructed with the knowhow of acknowledged specialists of reading acquisition.

1.3 – The aim of this paper

This paper presents a case study of Cognitive Disability challenges of people with dyslexia and the role of mobile communication in practice based on (i) the cognitive development and information communication technology, and (ii) transformative service research perspectives. This paper is going to make an original contribution to the discussions of mobile communication for development from the cognitive development and learning disabilities perspective. This study also contributes to the Transformative Service Research by assessing the way value created or co-created and its impact on the well-being of the individuals. Furthermore, the results of this study on the effectiveness of mobile phones to enhancement of cognitive development of people with dyslexia in Nigeria can be used in the rest of Sub-Saharan Africa too.

2. Theoretical framework

2.1 – Cognitive Development and Information Communication Technology Structural Cognitive Modifiability Theory (SCM)

Sternberg's Triarchic theory which defines intelligent behaviour as adapting to your environment, changing your environment or selecting a better environment revolving around analytical, practical and creative aspects of the mind, provides very useful basis for analysing both gifted and struggling learners' levels of achievement. Most remarkably, it suggests that deficit in certain aspects of cognitive ability may affect the general perception of intelligence of the person. Thus, from this awareness, the fusion of a new concept of remediation which becomes achievable if the deficiency can be secluded and repaired began to emerge. On this premise of achievable remediation as a result of targeted intervention Reuven Feurstein proposed the theory of modifiability of cognition within a person (Pfister, 2012). The cognitive functioning of a person can be modified and improved through environmental enhancement, according to Reuven. This is based on the fundamental assumption that through adequate mediated learning experience every human being is capable of modifying his or her cognitive structure regardless of the severity of the challenge and whether it is mental, physical or emotional. That is to say that the human cognitive faculty is not fixed but flexible (Atkins, Sprenger, Colflesh, Briner, Buchanan, Chavis, & Doherty, 2014). Cognitive Modifiability refers to structural changes brought about by a deliberated programme of intervention.

This theory posits that teaching thinking goes beyond using of tools and skills and involves addressing the complete cognitive structure. Thus, it believes in the plasticity and modifiability of cognition and proposes that by changing the total cognitive structure rather than chosen dimensions of behaviour a more lasting and stable modifiability can be achieved. Feuerstein stressed the necessity to understand what is going on in the mind of the learner by finding the specific Deficient Cognitive Functions. These are unplanned impulsive and unsystematic exploratory behaviour because of lack of mediated learning experience (Pfister, 2012). The concept of modifiability in the context of Structural Cognitive Modifiability theory means that the changes that occur are not a disjointed episodic result of exposure to experiences but rather a type of change that affects the basic formation of behaviour. This challenges the belief that unpleasant early experiences result in permanent and irreversible damage.

It signifies that there is solution to challenges that are related to cognitive functioning, because mind and intelligence are not static but flexible and can change under the right conditions. This leaves cognitive psychologist with the burden of working out modalities of how this can be effectively done.

As pointed out in John-Adubasim and Ugwu (2018), it is on this premise that recent research into cognitive enhancing therapy and programmes have been carried out and many have emerged and many more are on the way. Thus, these theories and findings have paved way for development of various computer- and mobile phone-based programmes and exercises specifically designed to target core brain areas for cognitive training. Evidence from various research showed that most of these training programmes have improved processing-speed, attention and working-memory in people with specific learning disability, ADHD, Aphasia and elderly respectively (Bruce, Edmundson, Aviet and Willison, 2010; Butnik, 2013; Diamond and Ling 2015; Howieson, 2015).

2.2 – Transformative Service Research (TSR)

In the field of service research, transformative service research (TSR) – which lies at the intersection of service research and transformative consumer research and focuses on well-being outcomes related to service and services (Anderson et al., 2012; Ostrom, et. al, 2014) – is opening the door for well-being not just at an individual level but also from a societal perspective by delivering service in a sustainable manner (Ostrom et al., 2010), and furthermore in a manner that can be aligned with prosperity. Anderson et al. (2012) have also identified wellbeing of individuals as one of many possibilities on the future TSR agenda. Although it is worthwhile here to highlight the link between TSR and wellbeing of individuals as part of sustainability and Sustainable Developmental Goals (SDGs) (United Nations, 2015) too. This paper largely focuses on assessing the role of transformation to address wellbeing and societal challenges and can therefore be considered an extension of research into mobile development. This paper also considers the service research priorities identified by Ostrom and her co-authors (Ostrom et al., 2015), through which service is stimulated by understanding it in the context of global practices, which the SDGs are one.

The United Nations point 25 of the 2030 Agenda for Sustainable Development advocates for “leave no one behind”, by obliging to the provision of inclusive and equitable quality education at all levels. All persons, irrespective of sex, age, race or ethnicity, and persons with disabilities, migrants, indigenous peoples, children and youth, especially those in susceptible situations, should have access to life-long learning opportunities that help them to acquire the knowledge and skills needed to exploit opportunities and to participate fully in society (United Nations, 2015). These provisions notwithstanding, not all students have equal access to Information and communication technology (ICT). The importance of ICT for people with cognitive disabilities cannot be overemphasized.

3. Analysis, Discussion of results and related research

3.1 – Analysis of the results

In a study using Brainfeed Alternative intervention programme for 60 students with working memory deficit diagnosed with Dyslexia in Port Harcourt metropolis Rivers State, Nigeria. The study evaluated the effectiveness of Brainfeed Alternative Intervention Programme administered 30 minutes, 3-5 days a week for 3 months on Improving Working Memory of Students Living with Dyslexia. This study was guided by five research questions (with hypotheses testing). There were two experimental groups receiving treatment and two control groups. A quasi-experimental design with Solomon Four-Group Design was used in the study, that is, a combination of pretest–posttest design and posttest-only design “to take into account the influence of pretesting on subsequent posttest results” (Daily, 2018). For the two pretest-postest groups (one experimental group and one control group) the same test was applied twice. However, the study is not to test the extent of interference of pretest on the sample but the actual effect of treatment on the sample. The research questions were answered using mean, standard deviation of the pretest and posttest scores, while dependent t-test, one way and two way analysis of covariance (ANCOVA) were used to analyse the null hypothesis (John-Adubasim & Ugwu 2018).

A summary of the results in John-Adubasim and Ugwu (2018) per research question follows.

Research Question One: What is the effectiveness of Brainfeed programme on the improvement of working memory of students living with dyslexia in the experimental group who received pretest and post-test?

At pre-test the students had a mean score of 83.83 (Sd = 9.56), and at post-test phase had a mean of 102.13 (Sd = 7.70). This resulted in a mean difference of 18.60, which indicates that Brainfeed intervention programme contributed in improving the working memory of students living with dyslexia. When these values were subjected to a dependent sample t-test analysis, a t-value of 5.75 was obtained at 14 degrees of freedom and a p-value of 0.0005 which was statistically significant at 0.05 level of significance. The Cohen’s d value obtained was 2.13 which showed a large effect size. This result therefore shows that Brainfeed intervention programme leads to a statistically significant improvement in the working memory of students living with dyslexia

Research Question Two: What is the effectiveness of Brainfeed programme on the improvement of working memory of students living with dyslexia in the experimental group who received only post-test compared to those who received pretest and post-test?

Students in the experimental group where they received both pre-test and posttest had a mean working memory score of 102.13 (Sd = 7.70), students in the experimental group who received only post-test had a mean working memory speed of 96.40 (Sd = 6.84), which yielded a mean difference of 5.73. This indicates that the pretest relatively contributed in the improvement of processing speed among students living with dyslexia. When these values were subjected to an independent sample t-test analysis, a t-value of 2.15 was obtained at 13 degrees of freedom with a corresponding p-value of 0.04, and an effect size of 0.79. This result indicates that students in the experimental who received pretest before treatment, had a significant improvement in working memory than those in the other experimental group who were not tested before the Brainfeed intervention.

Research Question Three: What is the working memory of students living with dyslexia in the control group who were assessed in pre-test and post-test stages?

Students in the control group 1 had a pretest working memory score of 79.60 (Sd = 10.09) and a post-test mean score of 79.73 (sd. = 9.70). This showed a mean difference of -0.133, which showed a small degree of improvement in the working memory. A dependent sample t-test analysis gave a t-value of 0.381 was obtained at 14 degrees of freedom and a p-value of 0.709 which was statistically not significant at 0.05 level of significance. Cohen’s d value was 0.01 which showed a small effect size. This result therefore shows that there was *no* significant improvement in the working memory of students living with dyslexia who were *not* treated with Brainfeed intervention programme.

Research Question Four: What is the working memory of students living with dyslexia in the experimental and control groups who received only post-test?

Those in the experimental groups had a mean score of 96.40 (sd = 6.84) while those in the control group had a mean value of 75.26 (Sd. = 13.77), which yielded a mean difference of 21.13, This result showed that those who received treatment in the experimental group had an improvement in working memory that was greater than those in the control groups who did not receive any treatment. An independent sample t-test analysis resulted in a t-value of 5.232 was obtained at 28 degrees of freedom and a p-value of 0.000 which suggests that there was a significant improvement in the working memory of students living with dyslexia who received only posttest after treatment compared to those not treated but who received posttest.

Research Question Five: What is the effect of Brainfeed intervention programme on the cognitive skill of working memory of students living with dyslexia on the basis of their groups?

Students living with dyslexia in experimental pretest-posttest group had a mean working memory score of 102.13 (Sd = 7.71). For those in experimental posttest-only group who were exposed to treatment and assessed after had a mean working memory of 96.40 (sd = 6.84). For those in the control group with pretest and posttest had a mean working memory of 79.73 (Sd = 9.71), while those in the control group who were exposed to only posttest had a mean working memory score of 75.27 (Sd. = 13.77). These values show that students living with dyslexia in the experimental groups had higher mean values of working memory than those in either of the two control groups.

3.2 – Discussion of result

The major result from the study shows that for working memory, student who received both the pretest and the post-test performed significantly better than those who received treatment but were only post-tested. Most importantly, the result shows also that those students who received treatment either in the experimental pretest-posttest group or in the experimental posttest-only group performed significantly better than those who did not receive any treatment. These findings are in consonance with related studies.

The result from this study is similar to that obtained by Pfister (2012) who found out that among 1,277 adolescents, cognitive rehabilitation therapy significantly improved memory. The sample in the study showed significant improvement in working memory on the basis of their performance in the Woodcock Johnson Test III before and after treatment was administered. Despite the similarity in the finding of this study to that of Pfister (2012), significant difference exists in that the samples used were different from that of the present study. Furthermore, the intervention programme used differs in that Pfister used cognitive restructuring, while this study used technological based Brainfeed intervention programme.

Results from similar study obtained by Andersson and Wagovich (2010) who showed that among students with learning difficulties, cognitive intervention strategies often leads to improvement in their working memory of the students. This finding is in consonance with that of Shipstead et al (2012) who discovered that cogmed working memory training significantly improved working memory of students with learning challenges.

Furthermore, in a study that assessed iOS apps quality for people with intellectual disability using Mobile App Rating Scale. Although there are now just a few randomized controlled studies on the use of smartphone apps for the cognitive training of the elderly (Shin et al., 2017), if compared with the smartphone app focused on physical training, the findings indicate that smartphone apps have a promising ability for the enhancement of cognitive competences of older people, precisely for the improvement of their working memory and reasoning skills (Klimova, 2016). In addition, the findings imply that cognitive training via smartphone apps is practicable. For example, Korean study by Oh et al. (2017) and Shin et al. (2017) carried out with 53 individuals aged between 50 and 68 years evaluated the effects of smartphone-base cognitive training app targeted at memory. The results of this study showed that the total working memory (WM) quotient had greatly increased [t(17) D 6.27, $p < 0.001$], as well as auditory-verbal WM score [t(17) D 4.45, $p < 0.001$] after applying the smartphone app for 15-20 min a day for 8 weeks. This was also confirmed by Borella et al. (2013), who argue that there is still room for the elderly to enhance their working memory skills since the results of their study indicate that working memory training programmes generate persistent benefits, particularly in the verbal working memory tasks. Affirming that Smartphones can serve as an external memory support.

Nonetheless, the Norwegian study by Bless et al. (2014) described the positive effects of smartphone app on self-supervised training of auditory attention in 28 older individuals. The results of 3-week training indicated an improvement in attention performance, which was accompanied by corresponding change in brain activation.

4. Conclusion

To conclude, the main aim of this paper is to make an impact to the cognitive development of individuals with learning disabilities through mobile phone applications. In this study the effectiveness of the mobile phone application in creating wellbeing to the individuals with limited access to technology thorough value co-creation is also assessed. It is our view that Transformative Service thinking is part of the implementation process in the well-being of the individuals. To repeat, not all students have equal access to Information and communication technology (ICT). The importance of ICT for people with cognitive disabilities cannot be overemphasized, but it must be affordable ICT.

While we will acknowledge the work of the existing platforms and projects, the Brainfeed programme also provides an opportunity to reaffirm mobile application development. In the new mobile application blueprint for Cognitive Disability assimilation, Transformative Service Research provides concepts and frameworks to support the value co-creation process. Moreover, the results of this study on the effectiveness of mobile phones applications to the enhancement of Cognitive Development of people with dyslexia in Nigeria can be used in the Sub-Saharan Africa.

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Service-learning & Appropriate Technology: The Seed of a Rwandan Success Story

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ABSTRACT We discuss combining the ideas of Appropriate Technology and Service Learning in university-level computing education, with a particular interest in mobile technologies, and sketch some current lines of research in this area. We present a concrete example where the first prototype of an application developed and deployed by a Rwandan public-sector organisation was built according to this approach in the context of an MSc thesis. In over a decade of use, it has provided an invaluable service to millions of Rwandans.

1. Introduction

Recognising the important role of ICTs in the Agenda 2030, accreditation bodies such as ABET and organisations that provide curricula recommendations such as the ACM/IEEE stress the importance of integrating ethical-civic competences and sustainability in undergraduate curricula. We advocate the use of the service-learning (SL) pedagogical methodology as an eminently suitable vehicle for the acquisition of these transversal competences in both undergraduate- and postgraduate-level engineering studies, due to its active, constructivist and experiential nature which greatly facilitates raising awareness in the students of the impact, and of the potential for social transformation, of technology development and deployment. We further argue that SL objectives in engineering studies are complemented and enhanced if the development and deployment used in these studies follows the principles of appropriate technology (AT).

In tertiary computing education, the curricula areas which most lend themselves to the use of SL pedagogy and AT principles are undergraduate degree projects and master's degree theses, due to the number of student hours they entail and to the fact that they are subject to relatively few curricula restrictions. We report on a successful use of AT-based SL in which a prototype application, which was originally designed and implemented in the context of an MSc thesis and then further developed and deployed by a Rwandan public-sector organisation, resulting in an application which have had a significant impact on Rwandan society. Since a version of this application has now been deployed for more than a decade, we can draw some conclusions about the sustainability of the technology and about the long-term impact that AT-based SL can have on the community partner.

The rest of this article is structured as follows: in Section 2, we provide definitions of the concepts that are crucial to this article, SL and AT, briefly discussing the history of AT, its relation to sustainable development and the use of AT in the field of ICT. In Section 3, we discuss technologies that are well-suited to forming the basis of A-ICT projects. In Section 4, we present our work on promoting A-ICT based SL, in particular, using these technologies. In Section 5, we present the highly successful Rwandan public-sector application which began life as a SL-oriented student thesis in AT and in Section 6, we draw our conclusions.

2. Service Learning and Appropriate Technology

2.1 – Service Learning

SL is defined by Barbara Jacoby as "a form of experiential education in which students engage in activities that address human and community needs, together with structured opportunities for reflection designed to achieve desired learning outcomes" [1, pp.1-2]. Jacoby adds that "some definitions clearly state that service-learning must be part of the formal academic curriculum". *Community engagement* is perhaps a more commonly used term in the African context [2]; though definitions of both terms vary, generally speaking, service-learning has a more precise meaning. In particular, most service-learning experts stress the distinction, on the one hand, between service learning and volunteerism/community service, where Jacoby [1, pp. 2-3] indicates that the former has "no intentional link to reflection or learning" while the latter "may lack academic credibility" and, on the other hand, between service learning and internships/fieldwork, which Jacoby affirms do not necessarily address human and community needs due to a focus on learning.

SL, the concept and the term, is already widely implemented in universities in the American and Asian continents [3]. Interest in Europe is growing, particularly since the Bologna process and specifically in the Spanish university sector [4], where one of the authors of the present article is based. It is important to point out here that the current worldwide interest in university-level service-learning extends to engineering faculties [5]. International service learning refers to service-learning projects with an international dimension, usually involving students from universities in high-income countries (HICs) travelling to low or middle-income countries (LMICs) to carry out service-learning projects.

The university sector is often said to be insufficiently engaged with the real needs of society; academics should "come down from their ivory tower" in the popular image. Without diminishing the importance of collaboration between the university and private sectors, the ivory-tower narrative tends to view the private sector as sole spokesperson for society's needs in any university-society dialogue. However, building a more complete view of these needs in the short, medium, and long term, would also involve listening to the voice of other civil society actors (who, incidentally, should also be able to contribute to defining the strategic lines of research of the public sector!). Given that SL community partners are generally public-sector or third-sector organisations, by providing a framework for collaboration with these actors, SL also provides a means for their voice to be heard in the university sector. In fact, SL also provides the multi-stakeholder framework and collaborative networks suitable for carrying out R&D in AT, and for the promotion of social entrepreneurship based on AT.

2.2 – Appropriate Technology

The concept of AT is particularly relevant to sustainable uses of technology. In its original meaning as coined by Schumacher in 1973 [6], the term refers to technology that responds to basic social and ecological needs, while being low-cost, small-scale, decentralized, with low environmental impact, drawing on community and local knowledge, and facilitating the participation of users in its conception and implementation, thereby contributing to the empowerment of local social organizations. It is a technology focused on specific problems and contexts, based on the knowledge of the culture, resources, needs and values of the target communities, with the aim of maximizing the possibilities of adoption and sustainability. It seeks to avoid the assumption that technological development in more marginalised communities can be achieved by simply providing more universal access to technological solutions designed for high-income populations. Not all projects that can be classified as AT will exhibit all of the above attributes and, moreover, in some fields, the original AT definition may need updating and the AT meaning of some of these attributes clarifying; for example, the attribute "small-scale" in the field of ICT. Notwithstanding these caveats, Schumacher was a pioneer in introducing ideas of sustainable development, today so ubiquitous on international agendas, long before the foundational 1987 Brundtland Commision [48] definition of this concept.

2.3 – Which technology for sustainable development?

Technology is often presented as a universal panacea: it is not necessary to question the causes of crises since every problem, even global warming, will have a technological solution. While it is recognised that technology can play a central role in the Agenda 2030, one needs to be wary of excessive techno-optimism and techno-centrism, oftentimes accompanied by a hidden or not-so-hidden commercial motive. Not all technology is beneficial or in keeping with the spirit of the Agenda 2030, and some can turn out to be a wolf in sheep's clothing. For example, when the idea of biofuels was first widely promoted, it was not obvious that it could displace food crops in parts of the world suffering from hunger; as a World Bank report stated, "the grain required to fill the tank of a sport utility vehicle with ethanol [...] could feed one person for a year" [7, p. 71].

How to avoid negative technological impacts? Pursuing the biblical analogy, though it may well be true that "by their fruits shall ye know them", in the case of technological development, by the time the fruits arrive, it is generally too late to do much about it if they are poisonous. The adage "prevention is better than cure" is a more appropriate one for this situation and, along these lines, Appropriate Technology constitutes an attempt to ensure positive impacts, and reduce the chance of negative impacts, of technological development.

2.4 – Appropriate Technology for sustainable development

The concept of AT arose in opposition to the idea that the path of industrialisation followed by Europe and North America could be reproduced and accelerated in other parts of the world, that all that was needed was the direct transfer of the means of industrial production to different geographical and social contexts, this being the prevailing wisdom until the late 60s. The origins of the fair-trade movement were contemporary and arose from similar considerations. Awareness of the need for a new type of technology, intentionally designed to conserve natural resources and promote social equity was an important movement that triggered major shifts in focus in development programmes.

As stated in [8], though the 70s witnessed a boom in AT in LMICs, in the 80s the AT movement was partially discredited, due to the well-publicised failure of some AT initiatives but also due to it being out of tune with the neoliberal zeitgeist and "Reagonomics", which was not exactly characterised by its emphasis on sustainability issues. AT was also criticised for not practising what it preached, often remaining within the framework of technology transfer from "developed" to "developing" countries.

The concern for sustainability in the last decade has led to a resurgence of interest in AT [8], accompanied by the emergence of related approaches such as frugal technology [9], and that inspired by indigenous/autochthonous knowledge [10], [11]. The former emphasizes minimizing the cost and use of resources while the latter aims to use knowledge from indigenous societies independent of, and often prior to, the advent of modern scientific knowledge systems.

The new incarnation of AT seeks to learn from previous failures, taking advantage of the knowledge accumulated in recent decades in development studies, in particular, regarding the monitoring of the impact of AT projects and consideration of the cultural, social and political processes in the deployment environment. Defining objectives and assessing impact can now be guided by the UN Sustainable Development Goals (SDGs) and the Human-Rights Based Approach promoted by UN development agencies [12]. Projects now also pay more attention to crucial but previously neglected aspects such as the creation of job opportunities. Finally, AT is no longer conceived for LMICs but for marginalized communities anywhere.

2.5 – Appropriate ICT

The new incarnation of Appropriate ICT (A-ICT) can find inspiration in many of the projects of the ICT4D field, which has progressed tremendously since its inception at the end of the last century. Today it has virtual communities (e.g. ICTworks), conferences (e.g. M4D, ICT4D) and journals, (e.g. Information Technology for Development). Noteworthy developments in recent years are the increasing focus on the SDGs and the definition of a set of "principles for digital development" by some ICT4D practitioners [13]. On the other hand, critiques of ICT4D, such as that of [14], are another important source of knowledge for AT. Indigenous Technologies could also have some role in A-ICT; while the technological basis of an ICT project clearly cannot be indigenous – one will search in vain for an indigenous Hertzian communications technology, for example – ICTs can serve as a support to automate and computerize indigenous processes, and to formalize and preserve indigenous knowledge, see [11].

3. Technological basis of A-ICT projects

Clearly, some technologies are more suitable as the basis for AT projects than others. We contend that in the ICT field, new disruptive technologies could provide an excellent basis for the development of A-ICT projects. Here, we look at the case of two such technologies: Artificial Intelligence (AI) and decentralized computing (DC).

3.1 – Artificial Intelligence as a basis for A-ICT projects

The authors of [16] discuss the growing interest in exploring the role of AI in the Agenda 2030 by entities such as UN Global Pulse, UNICEF's Global Innovation Centre and even the World Economic Forum or The International Telecommunication Union. [15] also suggest a set of principles, paradigms, and methodological and technical tools for the development of AI4Eq (Artificial Intelligence for Equity).

Numerous examples of successful applications of AI in the prevention, prediction, monitoring and evaluation of environmental and humanitarian crises (famines, ecological disasters, epidemics, conflicts), in the identification of vulnerable groups (discrimination of different kinds, deprivation of basic services etc.), in the planning of social protection services and emergency aid, or in support of participatory democracy processes have been reported; see [16]. However, Big Data for humanitarian purposes also presents particular challenges, especially related to privacy. Privacy is particularly important in contexts in which privacy problems can become personal security problems, e.g. the rush to deploy a digital identity backed by biometrics in Afghanistan could now facilitate repression by the Taliban [17-18].

As another example, [19] discusses how the cheapening of drone technology has led to an explosion in the use of aerial imagery in agriculture around the world, and consequently in the use of AI imaging techniques in agriculture, even in conditions of scarce resources.

3.2 – Decentralised Computing as a basis for A-ICT projects

At the beginning of the 21st century, interest arose in decentralized peer-to-peer (P2P) technology leading, among other advances, to distributed hash tables (DHT), unstructured P2P systems with Gnutella-type hierarchy and the successful File Exchange System BitTorrent. A little more than a decade later, DLT/blockchain technology, smart contracts, decentralized autonomous organizations and the so-called decentralised web emerged.

What makes DC interesting as the basis of A-ICT is that, in principle, it allows a community to pool its computing resources to create a system that doesn't need any central server or central authority to function. Administration and maintenance are integrated into the application itself and, therefore, automatically distributed among the devices of all participating users. This aspect makes it possible, in particular, to use computer applications that are non-profit but sustainable over time. In the case of centralised, non-profit computing applications, the work of administration and maintenance falls to volunteers, usually the founding users, whose initial enthusiasm tends to wane over time. If, as is often the case, other users are unwilling or unable to take over these tasks, the usual result is the abandoning of the project. This phenomenon has often been observed, e.g., in time-banking applications.

A prominent objection to the use of DC concerns “freeloaders” and the so-called “tragedy of the commons”[1]. However, the study of long-lived, commonly-owned real systems has revealed the main flaw in this argument, and its biased reading of history: it does not distinguish between restricted access common to a group of users and open access. Ostrom, winner of the 2009 economics Nobel Prize for her work in this line [20], characterised the tendency to misapply theoretical arguments of this type with the adage “an organization of resources that works in practice can work in theory”.

[1] Though the idea is much older and was prevalent at the time of the enclosure act in 19th century Britain, this title of an article by Garrett Hardin is used to name the idea that each user of a common resource will act in function of his or her own interest until the resource is exhausted and that, as a consequence, systems of ownership other than purely private property (or involving government intervention) are doomed to failure.

The critique of the 'tragedy of the commons' thesis does not mean that a decentralized system does not have to contemplate “freeloaders”. However, in the decentralized virtual world, there would appear to be a spectrum between common access and open access, and the computing attributes that characterise the position on this spectrum need to be clarified. Elucidating these issues could be decisive in determining whether a project tends to increase or decrease inequalities, i.e. whether or not it is consistent with an AT approach.

In recent years, the brightest star in the DC firmament has been DLT/blockchain technology. Its potential as appropriate technology or, at least, as socially useful technology, has recently been the subject of much attention, see e.g. [21-24], including in EU bodies [25-26] and within international organizations, e.g. UNICEF Office of Innovation [27], WFP Innovation Accelerator [28], UN Innovation Network [29], FAO [30], Start Network [31], World Bank [32], GSMA [33]. Though it is still early days for judging whether this potential will be fulfilled, it is advisable to be wary of the tendency towards techno-optimism that is common with new technologies.

3.3 – Caveat regarding excessive techno-optimism, the example of DLT/blockchain

Whether there has been an excess of techno-optimism regarding DLT/blockchain technologies, which could be said to be still in the “peak of inflated expectations” of the well-known Gartner Hype Cycle, is discussed in [34]. Their use in situations where other solutions would have been more adequate has stimulated the criticism that they are “a solution in search of a problem”.

According to [35], there is a rush to legislate about DLT/blockchain, e.g. in the US state of Arizona, without a consensus on the meaning of the basic terms. Walch argues in [36] that even the term decentralised, as used in “blockchain discourse”, is not sufficiently well-defined to have the legal implications that some are considering giving it.

There are even free-market zealots that preach the replacement of nation-states with ‘decentralised borderless voluntary nations’ that compete for citizens by offering of a range of opt-in government services, see [37], without there being any study of the effect that such a system would have on the well-being, equity, equality of opportunities etc. of these “sovereign citizens”. As stated by [38], the ‘empowerment’ of this view “does not stem from building community ties… it is imagined to come from retreating from trust and taking refuge in a defensive individualism mediated via mathematical contractual law.”

A large stumbling block in the sustainability of DLT/blockchain is the huge and growing ecological footprint left by the use of the consensus algorithm based on proof-of work (PoW), popularly known as mining, of the traditional blockchain. Energy consumption of bitcoin mining is currently close to that of Sweden [39] and it produces enormous quantities of electronic waste [40]. Blockchain advocates allege that blockchain uses mostly green energy, which is false, or that blockchain is well-placed to take advantage of the sporadic nature of green energy production and that conventional banking also uses large amounts of energy, which are mostly disingenuous arguments. Alternatives to PoW exist, in particular the next-most-popular candidate, proof-of-stake (PoS), but they are more complex and much less tested (and therefore, less secure), which explains the delay of Ethereum, the second biggest blockchain after bitcoin, in transitioning from PoW to PoS [41]. Moreover, the effect of PoS on wealth-distribution and, more generally speaking, on equity is largely unknown.

Finally, there are questions about the nature of the blockchain ecosystem. Firstly, is there any point in using this technology in private blockchains as many are doing? Secondly, it would appear that most blockchain-based distributed applications interact with the main blockchains via a handful of proprietary APIs (Infura, Alchemy, OpenSea…) so does it matter that the whole system, blockchain + broker is neither decentralised nor trustless?

4. Promoting A-ICT based SL

To promote A-ICT based SL, we have worked in three complementary directions:

1. The supervision of Bachelor's-degree final projects and MSc theses on emerging technologies that have great potential as a basis for A-ICTs and future A-ICT based SL projects.
2. The supervision of Bachelor's-degree final projects and MSc theses, and the organization of programming lab assignments, on using well-established technologies to develop A-ICT SL projects.
3. The development and implementation of an application to support the use of SL in universities, in particular international "virtual" SL and AT-based SL.

Below, we report on examples of work in the first two directions; more information regarding our work in the third direction can be found in [42].

4.1 – Exploring emerging technologies with a view to use in future AT-based SL

To illustrate the first direction, we briefly present work we are carrying out on the potential of the DC technology mobile ad-hoc networks/opportunistic networks as a basis for A-ICT projects (we do not present work we are also undertaking on the potential of P2P technology or AI as a basis for A-ICT projects). This work has benefitted from a Shuttleworth Foundation Flash Grant.

We are developing an application for the Wifi broadcast of an audio and video stream generated by a common mobile device though an ad-hoc network composed of other common mobile devices with two main usage scenarios in mind:

1. Alleviating humanitarian emergencies, in situations in which the network infrastructure is not operational due to a natural or man-made disaster. The objective is to transmit video and audio streams through the ad-hoc network until they reach a device with Internet access, with a view to providing information to the world outside of the disaster area of the situation within it. Apart from the case of disasters, the application configured for the humanitarian situation could also be used in areas where the network is not out-of-service but where mobile coverage is very poor, as long as the area is not too isolated since the transmission relies on other mobile devices being in Wifi range, for example, a mountaineering accident.
2. Bearing witness, in situations in which the network infrastructure is not operational due to being deliberately put out of service by an oppressive regime, or in which communications passing via the network infrastructure are censored and/or could constitute a security risk for the parties involved in them. The objective is to transmit video and audio streams that provide evidence of human-rights abuses through the ad-hoc network until they reach a device outside the high-risk area that can act as temporary custodian of the evidence, or until they reach a device with safe Internet access so they can be sent to a permanent custodian of the evidence, e.g. via Tor and Secure Drop [43].

Notice that the privacy and security requirements of the two usage scenarios are not the same. Regarding privacy, in the first scenario, human faces should likely be blurred, though it is debatable whether this should be done at source, since video streams coming out of a cut-off area affected by a disaster may find legitimate use in locating particular individuals or in providing testimony that the security or health of particular individuals is not under threat. In the second scenario, metadata that would enable the source to be easily traced must be removed from the stream, while the other metadata, such as global positioning information and time of emission, needs to be protected from tampering. Regarding security, in the first scenario security problems are unlikely, while in the second scenario the application is likely to come under a wide range of attacks. The application configured for either scenario is also vulnerable to malevolent use in situations for which it was not conceived so the possibility of taking countermeasures needs to be looked into.

As far as routing is concerned, again, the requirements of the two usage scenarios are not the same: in the first scenario the network is likely to be sparse, while in the second scenario it is likely to be dense. Different strategies for broadcast routing in MANets are discussed in [44].

4.2 – Using well-established technologies for current AT-based SL projects

To illustrate the second direction, we discuss the supervision of MSc theses in AT at the Carlos III University of Madrid.

Erasmus Mundus 2009-2013 was a cooperation programme in higher education between the European Union (EU) and the rest of the world. The document that established the program speaks of "ensuring coherence and complementarity with development policy" as well as "with external cooperation programs," among other "relevant community instruments and actions." In addition, it included among its objectives "the sustainable development of third countries in the field of higher education". One of its actions was to offer joint MSc programmes from EU universities to students from countries outside the EU, including a generous scholarship scheme. The Erasmus Mundus *MSc in Network and e-Business Centred Computing* (NeBCC) was an inter-university MSc offered jointly by the University of Reading, UK, the Aristotle University of Thessaloniki, Greece, the Carlos III University of Madrid, Spain and Trinity College Dublin, Ireland. In the first half of the NeBCC MSc program, the students attended lectures for one term in each of the first three universities while the second half involved the students carrying out an MSc thesis in one of the four universities.

Since the majority of NeBCC MSc students came from LMICs, the NeBCC MSc thesis provided a propitious context for developing AT projects designed to respond to the needs of communities in the home countries of the students, who could act as local experts and intermediaries with those communities. With this in mind, Simon Pickin supervised the following NeBCC MSc theses: in 2008, "The concept of appropriate technology in the context of web applications"; in 2009, "Developing a web-based e-government application for the government of Ethiopia" and "Mobiles for data collection in rural areas: an appropriate technology study" (oriented to the Honduran context); and in 2011, "Developing a web application for supporting digital inclusion in Brazil" and "Information technology planning and design framework for e-Government of Nepal". Although the academic results and the assessment of the experience by the students were very satisfactory, in most cases the deployments suffered from a lack of follow-up. However, this was not the case for the first of these MSc theses. We present the application developed in this thesis in the following section.

5. Publication of school exam results in Rwanda

5.1 – Context in which the system was first developed

Simon Munyaneza worked on his MSc thesis entitled "The concept of appropriate technology in the context of web applications" supervised by Simon Pickin, then a lecturer at the Carlos III University, in 2008. In the context of this thesis work, Simon Munyaneza chose to develop a prototype web application for the publication of school exam results in Rwanda. As a long-term resident of Rwanda and as head of the IT department of the Rwanda National Examinations Council (RNEC), he was well-positioned to understand the needs of the target community as well as to have knowledge both of the infrastructure available to develop and deploy the system and of that available to the target community for accessing it once deployed. On finishing the NeBCC MSc degree he returned to his post at the RNEC and ensured the continuation of the work on the exam-results application that he had begun in his MSc thesis. The application was brought into service nationally in Rwanda in 2009 and a version is still in service at the date of publication of this article.

5.2 – Background

The Rwandan education system is divided into basic education and tertiary education, and within basic education, primary and secondary. The monitoring and evaluation of basic education was formerly carried out by the RNEC, though this organisation was later merged with other bodies to become the Rwanda Education Board (REB), the REB being restructured again in 2020 into the REB and the National Examinations and Schools Inspection Authority (NESA). NESA was established under the Ministry of Education with a remit to monitor the implementation of Norms and Standards through school inspections and to administrate the comprehensive assessments from level one to level five in TVET and Basic Education in line with Competence Based Curriculum / Training, see [45] for more details

The development of the system to publish school exam results presented here took place in the context of a country-wide Internet access and mobile-phone coverage 20-Year National Plan blueprint named 'Vision 2020' and in line with e-government innovations spearheaded by the government to develop Rwanda into a knowledge based economy.

Administering the school exams of the entire country is an enormous task that is time critical, in particular, the results of the assessment have to be disseminated to the examinees in time to enable them to organise their progression to the next level of education. The examinations body therefore needed a solution enabling the exam results to be delivered to the candidates as early as possible.

In the latter half of the 2008 and the beginning of 2009, the RNEC, based on the knowledge gained by the then head of the IT department on the NeBCC MSc degree, developed a system to publish school exam results. The AT characteristics of this system are that it responds to a basic social need, seeks to provide a service to all sectors of society and requires only basic low-cost, widely available infrastructure.

5.3 – Development

The number of Rwandans with a mobile phone subscription increased 30-fold in the decade from 2005, the number of households with at least one mobile phone approaching 1 in 2 at around the date that the system was first deployed [46]. The mobile penetration rate, and the rate forecast for the following years, was considered sufficient to use mobile devices as the main interface for accessing the exam results system, taking into account that, at least at the time of the first deployment, the smart phone penetration rate was low. Though the solution was initially developed only for primary and secondary education, due to its success, it was later extended to also serve technical and vocational education and teacher-training colleges.

The RNEC developed a solution with two modules:

1. *The web-based module*: Using this module, the candidates submits his or her registration number and chooses the level or grade through a web link on the website of the examinations body whereupon the results are displayed. The display can also be exported to PDF and printed for presentation to secondary schools or universities. The system uses basic, browser-neutral technology and works, in particular, on mobile devices. See [47] for the current version of the web interface.
2. *The message-based module*: The majority of the Rwandan population did not have a laptop or smart phone to access the web application, but as mentioned above many did have a basic mobile phone. To include such users, a text-message interface was built using the session-based protocol USSD, via USSD code 489 (now 4891), for the initial interaction in which the student enters his or her registration number and school year and the data is validated, and an SMS message to return the result. Even the smallest mobile phones can access the results via text messages using this method.

5.4 – Impact

Prior to the development of the exam results publication system, when the examinations - marking and grading were completed, all head teachers and principals of colleges had to travel from all over the country to the head office of the examinations body to collect the lists of examination results, after which the students would travel to the schools to pick up their results.

This process was very time-consuming and expensive both for students and for head teachers and principals. Some students would travel right across the country, from one end to the other, just to pick up the results slip, which they are now able to print from any computer with Internet access or obtain using the appropriate USSD code on their phones.

This solution has been further developed to even include placement of students in the schools and colleges after exams. One week after the publication of the examination results, the students can visit the portal, or obtain the information via USSD text messages, to see the school in which they have been placed to continue their studies.

Once the system was deployed, there were no more lines of students queueing at the schools or lines of teaching staff queueing at the head office of the examinations board. Within a few minutes of the exam results being made public, every student can access their results. In the first two years of its deployment, the examinations portal was visited over 700,000 times. The usage statistics for 2021 are: primary school leavers 254,678, lower secondary school candidates 122,320, completion of secondary school exams 52,145. All these candidates accessed the platform at least twice: first, to check their results and second, to check the school in which they have been placed to continue their studies.

5.5 – Privacy Considerations

Awareness of the need for privacy of exam results is relatively recent and can still, in fact, be polemical[2]. The system greatly improved the privacy of exam results as compared to the previous method of sending long lists of exam results to schools which exposed the performance of every student to their fellow students.

In this case, the student is required to choose the level and then enter the candidate number which is usually known by the candidate only, whereupon the results are displayed with a minimum of personal details and a summary of the marks/grades awarded in each subject.

6. Conclusions

The study and use of Appropriate Technology (AT), i.e. technology at the service of basic needs, supported by local, sustainable knowledge, which grants autonomy and empowers the target communities, can help to ensure that technological development contributes towards achieving the SDGs rather than being a hindrance to their achievement.

Service Learning (SL) is a means of integrating ethical-civic competences and sustainability in undergraduate and postgraduate curricula through an active and experiential pedagogic approach, thereby helping to make future engineering professionals aware of their social responsibility, its efficacy being enhanced if based on AT. The university—civil society collaboration that it involves is also of some importance in itself.

To illustrate the utility of AT-based SL, we have presented a highly successful Rwandan public-sector application for publishing school exam results online and via mobile phone text messages. Rwanda was a pioneer among African countries in this regard. The initial prototype was built in the context of an SL-oriented MSc thesis in AT carried out at the Carlos III University of Madrid by one of the authors of the present article and supervised by the other. This system has been one of the greatest success stories in the impact of mobile and web-based technologies on the development of Rwanda. It has had a positive impact on nearly all families and schools in the country both financially, since no more transport costs are incurred, and in terms of time saved. In over a decade of use, it has provided an invaluable service to millions of Rwandans.

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Students' Mobile Security Awareness: Insights from a University in the Eastern Cape

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ABSTRACT Very few studies have reported on mobile security awareness in rural universities. The study assessed the students' knowledge of mobile security best practices at a rural university in the Eastern Cape (EC) province of South Africa, to serve as a basis for future interventions to improve mobile security and protect the university network. A quantitative approach was adopted. Data collected from 150 respondents were analysed using SPSS. Most users were found to engage in risky behaviour that possibly exposes them to mobile security threats. A model was proposed to improve awareness amongst EC rural university students.

1. Introduction

Mobile device penetration among consumers across the globe is ubiquitous [1]. The smartphone is the mobile device of choice in many countries as they provide more features and have become relatively affordable to many consumers even in rural settings [1]. Statistics indicate that mobile devices usage supports consumers' lifestyle and are tools consumers can no longer go without [2] [3]. With the accelerated usage of mobile devices across a different grouping of users, mobile security awareness has become a major concern in privacy, data and information security [4] [5]. This accelerated usage has largely been propelled by the vast availability of low-cost smartphone devices in the market as a way of catering to all user groups. The other factor currently driving usage uptake is the COVID-19 pandemic which has significantly forced a virtual environment to be adopted at an unprecedented rate. There are however concerns relating to the usage of mobile devices in terms of security and as such many users have fallen victims to the threats and malicious intent by many intruders who seek to achieve their malicious goals. Many studies have studied the usage and the impact of mobile devices in supporting our lifestyle on one hand and others have focused on the security aspects that surround the use of mobile devices [6][7][8]. Indeed, mobile devices are attack points for cyber-criminals and are the target of physical theft in many instances. Mobile devices carry in some instances a user personal content as well as work- or business-related contents that might be very valuable to the owner. Studies in the mobile security arena have looked at students' in various universities across the globe security knowledge and practices but very few have focused on mobile security awareness and practices among rural university students in African context [9]. The same challenge of very few researches on mobile security awareness and practices in rural university students affect the higher eduction environment in South Africa. The majority of students enrolled at South African universities currently rely heavily on smartphones for their educational activities [10], [11]. As these students use the mobile devices at home or at the university, most of them are largely unaware of the ever-impending threats on their mobile security. Many students have fallen victims of fraud, theft and invasion of their privacy as well as malicious destruction of their data or theft of it thereof [12]. By extension universities continue to be exposed to the existential threats to network as most users are unaware of the threats that exist in the mobile security space. These security concerns in relation to university students become more pronounced when looking at a rural university in the Eastern Cape (EC) province of South Africa as most of their enrolled students are largely from a rural background with little to no knowledge of ICT. This community of mobile users is characterized by little awareness due to lack of access to security awareness interventions in their communities. Furthermore, mobile security is an overlooked aspect in many African universities receiving little or no mention from user training and behaviour perspective.

In this exploratory study, the aim is to assess using a questionnaire the students' knowledge of mobile security best practices in their usage of mobile devices at a rural EC university, as well as, propose a mobile security awareness model that can be adopted to increase mobile security awareness. The proposed mobile security awareness model could serve as a basis for future interventions to improve mobile security as well as protect the university network.

1.1 Research problem

Mobile devices are the most used computing devices among students in higher education [13]. They are used to meet various student needs including entertainment, socialization, education and other needs. From an educational point of view; students use their mobile phones to take notes, access learning management systems (LMS), participate in discussion forums, attempt online quizzes and engage in peer learning in social media-based study groups. However, students do not pay much attention to the security of their mobile devices [14]. Little effort is made in higher education environments to emphasize secure mobile practices among students and staff members [15]. The ideal university environment should have mobile security policies, procedures and controls, train users and create awareness of secure mobile practices among its stakeholders including students. On an individual level, students and staff must learn and pay attention to security and stick to safe behaviours. The study is guided by the following research questions:

1. What are EC rural university students' understanding of mobile security?
2. What protective mechanisms against Mobile Apps security threats are students at EC rural universities aware of?

The rest of the paper is structured as follows: Section 2 reviews the literature, Section 3 gives the research methodology adopted, Section 4 presents the results, Section 5 discusses the findings and finally, section 6 concludes the paper.

2. Literature Review

With the high availability of low-cost smartphone devices, the COVID-19 pandemic, and a rise in the bring your own device (BYOD) policies in organizations, mobile devices have become commonplace in business and university setups. This calls to attention the importance of mobile security measures to protect both the user and the organization from targeted malicious attacks that would seek to take advantage of the vulnerabilities offered by the use of mobile devices within the organization's network. Mobile security also referred to as mobile device security has been defined by numerous organizations. IBM defines mobile device security as "being free from danger or risk of asset and data loss using mobile computers and communication hardware" [16]. Cisco defines mobile security as "the full protection of data on portable devices and the network connected to the devices" [17]. Mobile security is defined as the protection of smartphones, tablets, laptops and other portable computing devices, and the networks they connect to, from threats and vulnerabilities associated with wireless computing [18]. The common factor in all the definitions is that mobile security is focused on the protection of mobile devices against cybersecurity threats. It has been noted in the literature that a significant number of organizational mobile security breaches are a result of the exploitation of human elements also termed "social engineering" [19]. This vulnerability stems from the vast amount of personal data that is stored on users' personal mobile devices that can be used to read into the identity of an individual. Social engineering is the bane of mobile security and has to be curbed through mobile security awareness which is often lacking in rural communities that eventually feed into the rural university populace. Therefore, rural university students' mobile security awareness has become an essential feature of protection against mobile security attacks.

With the proliferation of mobile device usage in business at its all-time high, the need for mobile security becomes indispensable [20]. The growth of the Internet of Things (IoT) together with the boom of the mobile device industry brings with it unique mobile security challenges. Securing mobile devices itself is very complex because of the numerous potential attack vectors that exist [21]. The mobile devices can be attacked from different levels with malicious attacks being targeted at either application that users install on their mobile devices, the network that the mobile devices are connected to, the operating systems which the devices run, or theft/loss of the actual mobile device. This is worth noting because mobile device users should be aware of the different threat entry levels for them to implement any threat mitigation techniques. At the application level numerous threats exist; Mobile malware, ransomware, jailbreaking and rooting techniques from excessive app permissions, etc [22]. Mobile malware in the form of malicious apps or spyware can cause unfathomable damage to business reputation and remain undetected whilst it gains illegal access to a client, computer, or server network. Ransomware can even be used to hold an enterprises' business data or files at ransom until a fee is paid. Jailbreaking and rooting techniques enable an attacker to carry out an even broader range of attacks owing to the excessive app permissions granted. At the network level threats such as man-in-the-middle attacks, phishing, Botnet, denial of service and distributed denial of service attacks, computer viruses, SQL injection attacks, etc. are frequently used by cyber attackers [23] [24]. At the operating system level, mobile threats such as jailbreaking/rooting techniques due to vulnerabilities that may arise from unpatched operating systems have been noted. Operating systems have been known to have vulnerabilities that can be exploited by malicious threats [25]. The global smartphone market indicates that most of the smartphones in existence run the Android operating system [25]. Apple's iOS is by no means an exception, although it has encountered significantly lower cyberattacks in comparison to the Android OS. It has been noted in the literature that despite mobile device users' lack of awareness and knowledge of the security mechanisms platform owners take to ensure the security of the applications available in their application store, most users trust platform owners and believe the applications they download from the repositories are secure [26] [27]. Cyber attackers take full advantage of this misguided trust and use these repositories to spread malicious software which they use as entry points for their targeted attacks.

The multitude of potential attack vectors when considering mobile security makes it difficult to combat all threats. It is worse for universities that have embraced the BYOD policies as they give possibly unsecured devices access to their network servers, sensitive databases, etc. exposing the university to cyberattacks. A study conducted by Verizon in 2019 highlighted the criticality of mobile security after finding that 33% of the 670 security professionals they surveyed reported suffering a compromise involving a mobile device, 64% reported suffering downtime from mobile device security compromises and 47% claimed remediation was "difficult and expensive" [28]. Fast forward to the year 2022 an estimated number of 18 million IoT devices will be connected [29]. This is 6.7 million more connected IoT devices than in the year 2021 [30]. With such growth, technology improvements and high-performance power computing, cybercriminals get more ammunition for their craft subsequently resulting in a drastic increase in the types and numbers of cyberattacks. To counter these threats, users need to implement cyberattack prevention mechanisms which include but are not limited to enterprise mobile management platforms, endpoint security solutions, virtual private networks, secure web gateways, email security, cloud access security brokers [31] [32]. However, to implement any of these solutions, users need to understand the mobile security risks they are exposed to and be willing to follow mobile security best practices [33]. Therefore, mobile security awareness becomes critical. To date, not so much research has been done in the university mobile security awareness space, more especially with a focus on rural universities and their student populace. Most of the studies conducted have focused on improving the effectiveness of the messaging in cybersecurity awareness campaigns [34] [35]. Although research into how to improve the effectiveness of cybersecurity awareness campaigns has increased, there still is a lack of research into models for improving mobile security awareness in rural universities. This research study seeks to fill that gap by proposing a mobile security awareness model that can be adopted by a rural university.

It has been argued that security awareness in the desktop and personal computer (PC) domain is higher than security awareness in the mobile domain [36]. The argument stems from the belief that the skills required for mobile security safety are different from the ones in the desktop and PC domain hence the researchers in [37] proposed and defined a taxonomy of mobile users' security awareness. Their study was influential considering it built its taxonomy based on a foundation of key focus areas such as applications, browsing and communication, communication channels and the device itself. This foundation is generic enough to touch on the majority of potential cyber threats. Therefore, the proposed taxonomy which is prescriptive in nature together with the descriptive element which represents the users' knowledge regarding security as highlighted in [38] influenced the development of the questionnaire that was distributed to the rural university students for purposes of the present research study. Researchers in [39] conducted a study to understand the information security behaviour of the students of the University of Dhaka, Bangladesh in their use of smartphones. The study revealed that students of the University of Dhaka moderately follow mobile security best practices. Although it discusses the university students' behaviour towards smartphone usage, the study in [39] does not propose mechanisms to improve awareness of mobile security awareness for the university student populace. A study in [40] proposed a learning continuum model for information security, starting from awareness through training to education with a focus on enhancing the knowledge of end-users. Borrowing from their building blocks ((IT security policy, user responsibilities, and processes for monitoring and reviewing), this research proposes a model for mobile security risk awareness which is described in the discussion section of this paper.

3. Methodology

The research study adopted a quantitative research design. The data was collected using a closed-ended questionnaire to understand the level of mobile security awareness at a university in rural areas of South Africa. Data was collected from one campus of a rural university from all the facilities and levels of the university to understand the phenomenon holistically. The final and approved questionnaire was administered online since it is one of the ways to reach a large audience in the shortest possible time and with fewer resources. The study used an uncontrolled quota sampling technique to collect data that represented all the levels within the university. Uncontrolled quota sampling was used because it does not have limitations, and sampling is according to the convenience of the researchers [41]. The researchers distributed a link to the questionnaire to students via formal university social media groups and emails.

The validation of the content of the questionnaire was done by all the researchers. The researchers reviewed the questionnaire independently and came together to consolidate the content. The questionnaire was then edited for grammatical and logical errors before a pilot run. A pilot survey was conducted using 10 students across different levels. The reliability test for the questionnaire based on the Cronbach's Alpha was 0.733 which is within the acceptable range.

The questionnaire survey was completed by 150 respondents from across all the levels of a selected campus of a rural university. Data generated were analysed using SPSS software version 27. The study used descriptive statistics.

4. Findings

In this research study, the collected data were analysed using SPSS Version 27 and the results were presented in form of charts and simple distribution tables as well as descriptive statistics.

Table 1 presents the demographics of respondents. The majority of respondents (89%) are within the age range of 18 to 29 years. Few respondents (11%) were 30 years and above. Age was not a criterion for participation in the research. In terms of gender, the majority of respondents (59%) were females while males were 41%. The gender distribution of respondents was fairly distributed. Finally, the respondents were fairly distributed across all levels. The postgraduate level had the highest number of respondents (27%) while the first year level had the least number of respondents (13%).

Table 1: Demographic Information of Respondents

Age	**Frequency**
18-21	27%
22-25	41%
26-29	21%
30 and above	11%
Gender	
Female	59%
Male	41%
Level of Study	
1st Year	13%
2nd Year	17%
3rd Year	25%
4th Year	17%
Postgrad	27%

Figure 1 shows the results regarding the devices owned by respondents. Respondents had the option of choosing more than 1 device. The majority of the respondents (98%) owned smartphones followed by laptops with 69%.

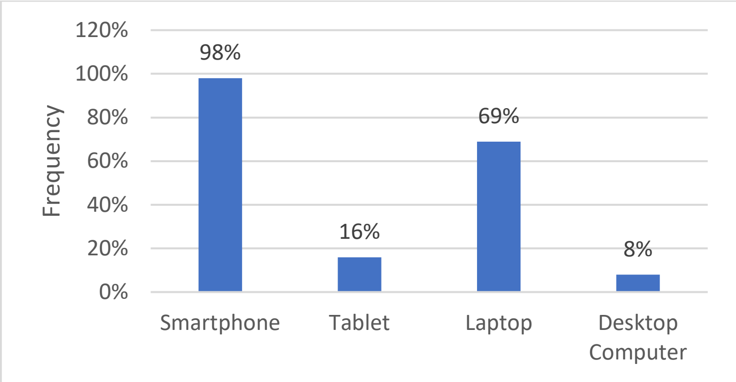

Figure 1: Devices Owned by Respondents

Figure 2 shows the operating systems for respondents' devices. The majority of the respondents (85%) were using the android operating system on their devices while only 1% were using the Blackberry operating system.

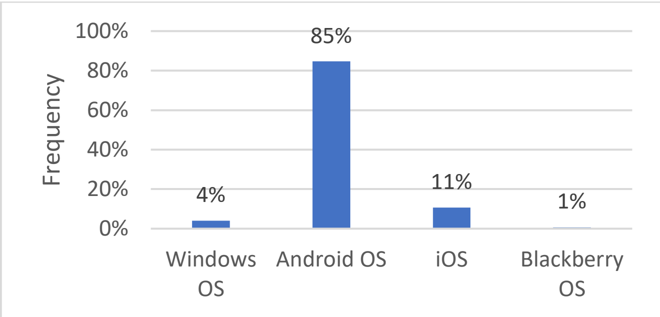

Figure 2: Operating System used by Respondents

Figure 3 shows the type of Internet connection used by respondents. The results show that 40% of the respondents used both private and public Internet connections. There were 33% of the respondents that were using a private Internet connection while 25% were using a public Internet connection. The results show that a significant percentage of respondents were using a public connection for accessing the Internet.

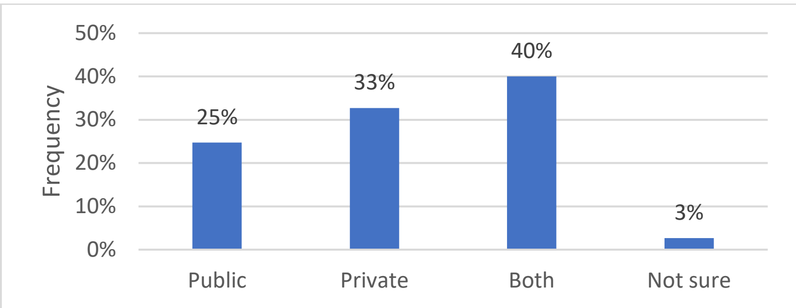

Figure 3: Proposed Mobile Security Risk Awareness Model

The respondents were asked to indicate how often they perform the given statements using a 4 point Likert scale with never =1, rarely =2, sometimes =3 and always =4. These questions were used to check the level of understanding of respondents concerning mobile security issues. The results in Table 2 show that respondents often (2.64) connect to any network available to them and also download and install 3rd party applications (2.64) without considering the security of their devices. At least respondents often check permission to the application when installing (2.92), turn off Bluetooth (3.29) and location services (2.61) when not in use. There are elements of respondents sometimes accessing their confidential data on public networks (2.26), transacting on sensitive applications on any network (2.05), downloading and installing applications from unknown sources (2.40), accessing accounts on other people's devices (1.89) and checking the cookies when visiting websites (2.36).

Table 2: Means, Standard Deviations and Qualitative Description Regarding Mobile Security Issues

Statement	Mean	Std. Deviation	Qualitative Description
I connect my device to any network available	2.64	.936	Often
I access my confidential data on a public network without any fear	2.26	1.006	Sometimes
I transact on sensitive applications such as banking apps on any network	2.05	1.051	Sometimes
I download and install 3rd party application(s)	2.64	.922	Often
I download and install applications from unknown sources	2.40	.990	Sometimes
I check permission or access authorization to the application when installing	2.92	.938	Often
I access my personal electronic accounts on other people's devices	1.89	.856	Sometimes
I turn off Bluetooth when not in use	3.29	.944	Often
I turn off location services when not in use	2.61	1.073	Often
I check cookies when I am visiting a particular website	2.36	1.025	Sometimes

Legend: 1.00–1.49 (never), 1.50–2.49 (sometimes), 2.50–3.49 (often), 3.50–4.00 (always)

A 4-point Likert scale was used to understand the level of understanding of respondents concerning security threat awareness and prevention with definitely no =1, probably no =2, probably yes =3 and definitely yes =4. The results in Table 3 show that respondents probably know about the antivirus on their devices (2.62), threats on their smartphones (2.70), and 2-factor authentication (2.51). The respondents further showed that they probably update their operating systems (3.29), update their installed applications (3.34), install and maintain antiviruses on their smartphones (2.51), backup their data (3.17) and delete all data before disposing of their devices (2.72). The respondents probably do not (2.03) know where to report the suspected incidents or security breaches. However, respondents probably believed that the university had no clear security policies on how to deal with a suspected security breach.

Table 3:Means, Standard Deviations and Qualitative Description Regarding Security Threat Awareness and Prevention

Statement	Mean	Std. Deviation	Qualitative Description
I know the antivirus on my device	2.62	1.133	Probably yes
I am aware of the threats on my smartphone	2.70	1.008	Probably yes
I am aware of 2-factor authentication	2.51	1.116	Probably yes
I use a password manager application	2.82	1.136	Probably yes
I perform updates on my operating system	3.29	.840	Probably yes
I perform updates on my installed applications	3.34	.793	Probably yes
I install and maintain an antivirus on my smartphone	2.51	1.060	Probably yes
I know where to report the suspected incident or security breach	2.03	1.013	Probably no
The university has clear security policies on how to deal with a suspected security breach	2.34	1.002	Probably no
I back up my data	3.17	.910	Probably yes
I delete all data before disposing of a device	2.72	1.112	Probably yes

Legend: 1.00–1.49 (definitely no), 1.50–2.49 (probably no), 2.50–3.49 (probably yes), 3.50–4.00 (definitely yes)

5. Discussion

The results of the study are broken down into the following categories, user demographic information, devices and OS, internet usage patterns and lastly mobile security best practices. The research found that most participants were found in the age 18-30 which is expected given that the majority of university students fall in that age range. It should be noted that the study results show fair participation across study levels which assisted the research in obtaining valuable insights across the students enrolled. From the results obtained it is clear that the smartphones running Android OS are the most used mobile device and this is consistent with the researchers' findings in the literature. This is also evident in our research findings that highlight the dominance of the Android OS in smartphones being used by university students in EC. In terms of vulnerabilities, it has been found that the Android OS is most vulnerable owing to the large number of unsecured third-party mobile apps that Android users have got access to via distribution services [42]. Even if there exists a threat in terms of theft to mobile devices, most of the threats are cyber threats and this turns the focus of the study to Internet connection patterns to ascertain Mobile Security issues.

The observed results show that at least 65% of participants use public network connectivity as opposed to 33% who use private network connections. This finding shows the level of exposure the users have to contend to, it is even direr because the results show that students often connect to any available network with ease. A noteworthy concern is that users sometimes access their confidential data on a public network without any fear and this goes as far as transacting on sensitive applications such as banking Apps while connected to a public network. It is unclear whether this usage of public networks for sensitive applications was due to lack of security awareness or it was driven by necessity as other users do not afford private network services. A further investigation into this could contribute towards the proposed security awareness models' revision. It is notable that the participants in the study often download and install 3rd party applications and sometimes download from unknown sources which is one of the biggest attack areas used by cybercriminals. Android OS as the most prevalent OS used by the participants is central to this phenomenon of 3rd party applications being installed by their users even without knowledge of their sources. Another area of concern noted is how users sometimes access their personal electronic accounts of borrowed devices thereby potentially leaving behind some personal information that could be used in mounting an attack. The study however found some encouraging practices such as participants checking permissions or access authorizations when installing applications, turning off Bluetooth and location services when not in use, therefore, reducing their attack exposure. It is interesting to note the good practices of turning off Bluetooth and location services and future studies could investigate whether this is driven by security awareness or it is a battery saving strategy. The results of which could assist in customising the proposed model.

When considering security threat awareness, the study found that most of the users have an antivirus installed and are aware of threats of their smartphone resulting in them implementing a 2-factor authentication as well as a password manager. The majority of smartphone users indicated they perform updates on their OS, installed applications as well as their installed antivirus. It was encouraging to find that most users back up their data and also delete all their data before disposing of their devices. Unfortunately, most participants displayed little to no knowledge on how to deal with a suspected security breach or intrusion and they do not believe the university has clear security policies on how to deal with suspected security breaches. This finding is consistent with literature that suggests rural universities have not done much to actively fight against these cyber security threats and possible breaches. It should also be noted that when it comes to security a simple majority of users are aware and practicing best practices though encouraging is not enough to secure the network infrastructure of the university, therefore more initiatives must be executed in a bid to bring all users to be fully aware and by extension significantly reduce points of attack.

On assessment of the usage patterns captured in the students' responses, the researchers inferred that the generic understanding of mobile security awareness of EC rural university students was basic. This assessment triggered the development of a proposed mobile security awareness model which is discussed in the section that follow. Some students displayed a fair understanding of best security practices as they have antivirus software installed on their devices which they regularly update, use of a passport manager and their usage of 2-factor authentication amongst other protective mechanisms.

5.1 Proposed Model

The researchers have analysed the finding of the study to find the gaps in security to bridge the gaps and increase security awareness propose a security risk management model. This risk management model in Figure 4 focuses on the identification of risk, assessment, control and a review controls model where the researchers propose actionable initiatives and steps the university could take in increasing awareness and reducing attack exposure. The model focuses on the identification of possible risks, builds a risk matrix on the identified risk to treat the risk using a multi-thronged approach of introducing new students to mobile security during orientation which will increase awareness at an entry-level, the running of ICT security awareness campaigns will significantly contribute to increasing security awareness. Refining BYOD policies and procedures, as well as the reminders during enrolment and registration, will assist in concertizing university system users on the dangers they are confronted with. The procedure on enrolling personal devices into the university network which could include mandatory installation and updates of antivirus software could be vital in reducing network attack points. Assessment surveys on security best practices will form a valuable input to the department of ICT support tasked with ensuring that a stable and reliable network is available at the university. From the feedback provided by the assessments, new risks could be identified which will need to be addressed to strengthen the security of the university network. These risk management measures could be used to increase awareness of security challenges confronting the university community. The proposed model is envisaged to significantly improve awareness and lead to security best practices thereby improving individuals' mobile security and by extension that of the institution.

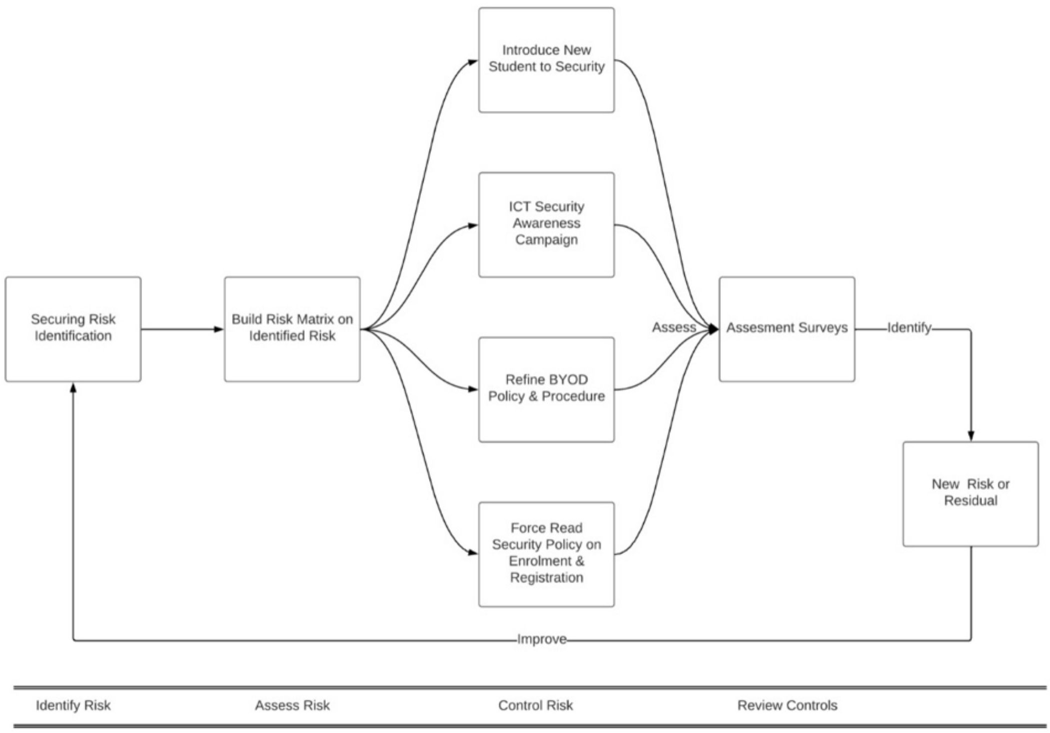

Figure 4: Proposed Mobile Security Risk Awareness Model

6. Conclusion

In this study, the researchers have identified a mobile security challenge in the form of a lack of awareness of possible mobile security threats users have to grapple with and have further investigated the knowledge users have on mobile security best practices. The study found that most users are engaged in risky behaviour that possibly exposes them to security threats. Although some users displayed some understanding in terms of other best practices, the larger groupings are often engaged in usage patterns and behaviour that could easily compromise their mobile security.

The researchers having sight of the problems confronting the users of the university community developed a model to remedy the lack of awareness of users on mobile security issues. The proposed model is envisaged to significantly improve mobile security awareness amongst users in the university community and thereby assist the users to apply security best practices on their usage of mobile devices. The future of this work could look at implementing the model and reviewing the results as well as improving future models that could improve mobile security awareness.

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Post-pandemic Reflections of University Students' Perspective on the eLearning in South Africa

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ABSTRACT Covid 19 and forced lockdowns in 2020 acted as a catalyst forcing the South African (SA) education sector to fully adopt technology in teaching and learning with the banner "*let's save the academic year*". This paper provides reflections on where the SA education sector is coming from, where it is, student perspective, and where it ought to be if they are to save the seriously affected education sector. Literature review and focus groups were used to conduct the research. From the focus groups results, it was noted that students prefer blended learning when compared to face-to-face and online learning. Bandwidth constraints made most respondents use mobile phones instead of laptops during the lockdowns, but the reasons for returning to campus later on were more varied.

Keywords: Face-to-Face Learning, Online learning, eLearning, mLearning, Blended Learning, Students' Perspective

1. Introduction

Over the last decade, Africa has been seriously affected by several pandemics such as Cholera, Ebola, severe acute respiratory syndrome (SARS), human immunodeficiency virus (HIV). Moreover, natural disasters such as volcanos, cyclones, drought, and human-caused disasters such as civil wars/unrest, corruption, and social imbalances. One might wonder and ask which sector has been seriously affected by all these pandemics, natural disasters, and civil wars? In many people's eyes, the answer might be the economy. As it might seem to be true, is it factually correct, or it is just assumptions? Or maybe, it is because that is how we were made to believe by those in positions of power who choose to see that way and preach to the nation the same word. Contrariwise to the things we were made to believe, another school of thought strongly believes the education sector has been badly affected in several African countries like DRC by Ebola, Zimbabwe by cyclones, Mozambique, and Nigeria by civil wars. It is a fact that in 2020, universally all countries were seriously affected by Covid 19 pandemic which forced many countries to go in forced and unenviable lockdowns resulting in many primary, high schools, colleges, and universities to close. This had a severe impact on the education sector again [1]. As a reactive approach using the banner "*let's save the academic year*", many universities in South Africa were told to adopt the use of technology in learning due to lockdowns [2]. Even though information communication and technology (ICT) policies exist at the national and university level which stipulated how technology (laptops and mobile phones) should be used to enhance teaching, learning and at the same time benefit the students, technology has not been fully utilized in most historically black South African public universities, even though we are living in the 21st century [3].

Regardless of the implementation and adoption of the use of ICT during Covid 19 times, the way it was implemented raises many questions whether it was implemented well and if the resources at the ground were sufficient, and if students who are the key stakeholders benefitted from the adoption of technology. If we are to follow the age-old adage; "*education is the key to success*" and the "*young ones are the future*", then definitely there is a need to look at permanent solutions that will rescue the education sector to keep it the "*key to success*". Therefore, this paper provides a post-pandemic reflection of university students' perspective on online learning, reflections on where the SA education sector is coming from, where it is, and where the sector ought to be.

It is the answers from the above reflections that will help the researchers to highlight the best approach for the South African education sector in times of similar crisis. The insights from this work can be adopted and incorporated in the South African education sector (and possibly other African countries) by policymakers, researchers, designers, and developers of curriculums to save the education sector from the above-mentioned pandemics, civil wars, and natural disasters. Moreover, students ' *futures*' will be saved when strategies are put in place. This will also prevent challenges such as "drug abuse", which was experienced in South Africa during the 2020-2021 times when students were just "*idle*" at homes without doing anything academically as a result of lockdowns.

2. Methodology

This research adopted qualitative research methodology as it is the best way to have an accurate and full communication of ideas between the researchers and the individuals who are providing information [4]. The literature review method [5] was used for the gathering, presentation of the theoretical background on the related research. Focus groups [6] were used to gather data on the students' perspectives concerning the three learning approaches face-to-face learning, online learning, and blended learning at the University of Fort Hare

2.1 – Literature Review

The reason for using the literature review approach was because it helps the researchers to identify, summarize, and critique existing theory and methods; highlight ontological, epistemological, and methodological flaws and gaps; and provide evidence for decision-makers when identifying and supporting priority topics [5]. Based on this research, a literature review approach was beneficial in pinpointing the areas covered by previous research as well as revealing the gaps. The literature review addresses the literature from diverse viewpoints of using face-to-face learning, online learning, and blended learning. Moreover, literature review promotes the transmission of fresh ideas.

Literature was searched on the Scopus database using keywords face-to-face learning, online learning, hybrid learning, and blended learning. The researchers looked at papers that critically analyzed the benefits and disadvantages of face-to-face learning, online learning, hybrid, and blended learning.

A discussion was then made to see how best these approaches are, in the context of South Africa during these Covid 19 pandemic times and how they can be adopted and adapted.

2.2 – Focus Group

Over the past years, policymakers were finding solutions to the students' problems, but it is also best to make sure the students are allowed to provide solutions in education since they are the ones affected by any decisions suggested. As such, focus groups were used to get insights from students and what they think will be best for them. Moreover, since the research required sentiments and or impressions that cannot be readily addressed with simple "yes" or "no" answers, focus groups became the best research approach when compared to the use of interviews and questionnaires. Additionally, a group conversation where students would respond with an answer to inquiries (Questions used in the focus groups) was most suitable since we were curious about real-time, unfiltered replies to how students feel about traditional learning, e-learning, and hybrid learning. Thus, this research required thoughts, beliefs, and feelings which focus groups helped to discover [6]–[8].

Voluntary response sampling method, convenience sampling, and stratified sampling approaches were used to select the forty (40) students who were selected from the University of Fort Hare which is a South African university in the Eastern Cape province. The forty (40) students comprised of ten (10) students from the first year, second year, third year, and fourth-year (Honors) levels, respectively. Each focus group had ten (10) students each. The reason for selecting participants from all streams (level) was to get a true representation since these streams (levels) have different needs and see things differently. Engagement, exploration, and exit questions were used in gathering students' perspectives. The information and insights obtained from the students helped in the understanding of students' perspectives towards the three methods of learning as seen in *Table 1*.

3. Where is the South African Education Sector Coming from?

3.1 – Face-to-Face Learning

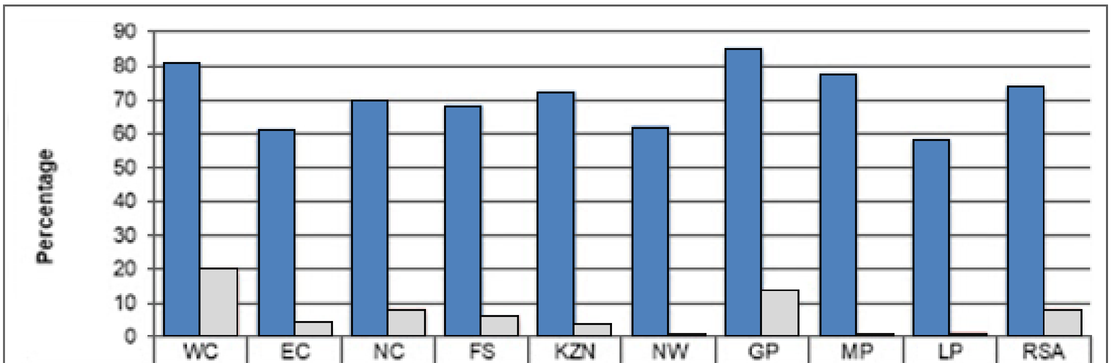
Pre 2020 before the Covid 19 pandemic, many universities in South Africa were using face-to-face methods of learning. In this approach in the University of Fort Hare context like many other South African universities, the lecturer would come in a lecture hall, goes through a topic in front of the students whist students listen and take notes. Students were engaged through discussion during the lectures making this a two-way communication "flipped classroom" approach. Moreover, students were conducting assignments, group work during the lectures. In such a setup, the lecturer has control of the class, what the student learns which removes sharing of misinformation and minimizes the chances of students getting wrong unfiltered information. Face-to-face learning is fundamental as it allows lecturers not to feel as they are talking and being alone unlike the online (eLearning) way of learning. Even though online learning was being preached since the beginning of the millennium, one of the challenges that were faced by South African Higher Education Institutions (H.E.I.s) is the tension between acknowledging and progressing outside of institutional contextual problems. As highlighted by [9], the problems were inherited from previous educational policies which lacked participatory parity and prepare future generations of emerging technologies. The advantages and disadvantages of the face-to-face learning approach have been well researched and articulated in many publications including the work of [10] [11]. These challenges also affect the students in South African universities.

4. Where is South African Education Sector?

4.1 – Online Learning (eLearning)

In 2020, with the motto "*let's save the academic year*", many universities were "forced" to adopt and use technology. This saw many universities using Zoom, Moodle, Ms. Teams, Blackboard among other platforms. All these technologies as highlighted by [12], offer several amazing characteristics that would address the challenges faced in many tertiary institutions during natural disasters, civil wars, pandemics as noted during these times of COVID-19 pandemic. Technology-enhanced learning is defined as a mix of a teacher's learning and teaching methods and understandings, combined with the proper use of technological resources to achieve educational goals and maximize student outcomes and experiences [13]. Technology enhances learning includes integrating the classroom with important digital resources such as laptops and mobile phones, extending course offerings, improving student engagement, and speeding learning [14]. As pinpointed by [15][16], students can use technology (laptops and mobile phones) to conduct research, exchange ideas, and develop specialized skills. Technology offers so much flexibility in learning that it helps students work together more effectively [17]. Technology is a critical component in supporting collaborative learning [14] [16][18]. As evidenced by many South African universities, in the 2020-2021 academic years, technology helped to "*save academic year*". Despite eLearning benefits as cited by [12], an extensive literature survey done by [10][17][18] and [19] pinpointed some challenges which are faced when using the e-learning approach. Among them are technological challenges, lack of technical support, lack of awareness, university readiness, quality course content, localization of content, IT skills of both students and lecturers among other challenges [10][17][18] [19] (cf. also [20]).

Many students in the context of the University of Fort Hare and South Africa faced the above-highlighted challenges especially those from disadvantaged provinces with low internet connectivity. According to a survey that was done in 2020 by [22], many SA provinces still experience challenges with network connectivity both at home and anywhere as shown in *Figure 1*, of which network connectivity is key for the successful adoption of online learning.



	WC	EC	NC	FS	KZN	NW	GP	MP	LP	RSA
Anywhere	80,9	61,2	70,0	68,5	72,3	62,3	85,2	77,6	58,4	74,1
At home	20,3	4,4	8,2	6,3	3,4	1,0	14,2	1,3	1,5	8,3

Figure 1: Access to the internet at home and anywhere in South African provinces [22, Figure 13.2]

As cited in [23], many lecturers pinpointed the challenges with online learning. The lecturers noted that:

1. the traditional academic and professional expectations on staff remain unchanged, staff have to navigate this new world of life, and work making it difficult to teach;
2. how to make students feel like they are not alone in regards to making sure the students feel they are part of a class, a group, that they have a social connection is a challenge;
3. how to make the transition as easy as possible for students and how to assist students through effective online learning activities that would engage them in their own learning process and make a success of the academic year is also a challenge.

From the above analysis, it can be concluded that technology in the hands of someone who knows it and have the resources can be a helpful tool. Contrariwise, if people do not have the skills, knowledge of how to use it, and the resources, online learning can be a disaster that can cause more harm in the education sector than good.

4.2 – Blended Learning

The blended learning paradigm combines face-to-face learning (classroom instruction) with online learning (virtual classroom) settings. In other words, blended learning entails combining activities from several contexts, such as face-to-face instruction and online learning, each with its own set of procedures. Blended learning is typically characterized as combining the strengths and advantages of in-class face-to-face learning activities and web-based online learning to obtain the best results [10]. It blends face-to-face instruction with computer-mediated education as a pedagogical technique. In the blended learning approach, face-to-face classroom learning, and internet-based online learning are merged in educationally useful ways. Blended learning is accomplished by integrating four aspects. These aspects as highlighted by [24] and [25] are (1) using several web-based technologies, for example, virtual classes, individual learning on either laptops or mobile phones, in order to achieve educational goals, (2) bringing together different teaching (pedagogical) strategies such as cognitive, structuralism, and behavioral by using different educational technologies to attain the highest learning outcome, and (3) combining a teacher-centered and face-to-face learn (videotape, web-based learning, movie). Fourthly combining instructional technologies and real-world challenges to achieve a synergistic impact [24][25]. Many advantages of blended learning have been pinpointed in several works such as the work of [11], [21], and [25]

In the context of South Africa, many universities ended up using this approach when the country moved from lockdown "Alert level 5" and "Alert level 4" to lower alert levels such as alert level "3", "2", and "1". As stipulated in the South African Disaster Management Act of 2020 [27], Alert level "5" meant that '*drastic measures*' such as complete lockdowns were implemented and only those who offer essential services such as doctors, nurses, those who work in shops were the ones only allowed to '*go out'*. Alert level 4 meant that '*extreme precautions'* were applied which also limited people to move. This meant the students were attending classes online from home. It was only on Alert level 3 where 33% of the students were allowed to go back to school in limited numbers [28]. Alert level 2 allowed 66% of the students to gather in a place and also observe '*physical distance'*. Alert level 1 allowed almost 99% of the students to gather with '*precautions and health guidelines followed'*

5. University of Fort Hare Student Perspective

Even though a lot of advantages of the above-mentioned learning approaches were highlighted by [10], [12], and [21], there was a need of getting student perspective which would help policymakers, designers, developers, and researchers when they are crafting policies to help students in South African universities.

Students in the focus groups were asked questions (column 1 in *Table 1*) and what they think would be the best approach for them when looking at face-to-face learning, online learning, or blended learning. *Table 1* reflects the student perspectives. The responses given are examples of the major reasons voiced by many students for each type of response.

Table 1: Student Perspectives Captured in the Focus Groups

Questions Asked	Number of Students per Response Type	Examples of Major Reasons Given by Students
Were you given laptops by National Student Financial Aid Scheme (NSFAS) or you bought them yourself?	**18** Yes **21** Bought our own **1** No laptop used mobile phone.	
Were you receiving 'mobile data' from the University?	**40** Yes	We were given mobile data based on your mobile number network registered with the University of Fort Hare online student account (MTN, CellC, Telkom)
After being given/ buying a laptop for online learning, did you only use laptops to attend classes, or you also used your mobile phones?	**35** Ended up using mobile phones	1. Since we were given and using mobile data, connecting to laptops made the internet not stable and the laptop was consuming more bandwidth. 2. Carrying a laptop going where there is a network was risky due to thieves in our areas and it is heavy. 3. Phones made it easier to attend classes even when you are in a taxi.
	5 continued using laptops	1. When using a mobile phone sometimes it "freeze" during essential learning moments. 2. It is boring to use a phone as sometimes you receive a phone call during classroom setting as it affects concentration 3. Using a laptop allows you to do many things at once which you cannot do on the mobile phone as the screen display and key sizes are small. 4. Where I stay in Gauteng, connecting a laptop on a cable makes life easier as the network is stable
What was the reason for coming back to campus instead of studying home?	All **40** Students came back to campus	1. "I had difficulties with the network (Network connectivity issues at home) Other distractions such as doing chores during lesson times" 2. "Domestic abuse at home" 3. "Just came, learning at home was difficult even though the network was there." 4. "Apart from network connectivity issues and other disturbances at home, I want to study with others, like study group to get help and communication is important during the study time"

		5. “Studying at home was difficult (it’s impossible to concentrate). Again Yes! we were offered data but some of us are from areas of low network coverage, therefore internet connection was a bit of an issue always”
Which mode of learning (face-to-face, online, or blended learning) do you prefer and why?	**30** Students preferred blended	1.“Online alone makes it difficult to ask questions from the lecture if I didn’t understand something because sometimes there are connectivity issues which we can’t control. Traditional attendance will help us as students to easily form groups to study and work together unlike when you are studying alone at home.” 2. “Learning online-only is not quite a problem but the problem starts when I want to familiarize myself with the practical part of the course. It becomes hard because in classes we are only taught the theory but theory alone is not enough to enable one to fully understand the whole course. It can be a wise idea to attend practical’s traditionally and classes either traditional or online.” 3. “I prefer blended learning because traditional gives opportunity to understand more about some practical’s studies and online makes marking for assessment to take short time resulting in us knowing our results early” 4. “Although I’ve never attended physical classes, I strongly believe that they can do a difference since online learning is sometimes difficult because we were not used to and some of us, it is difficult to get used to based on our background where we come from. On the other hand, online learning is good since a student doesn’t have to walk up and down the campus searching for the class and sometimes even attend a wrong class and then realize later. What I can say is that we can continue with online learning but sometimes we need face-to-face classes in our modules.” 5. “Online learning has been an eye-opener and has blended me with technology faster than I think I would have loved also if it were traditional too, that would be quite beneficial for some of my modules. Also, even though I never got the chance to experience traditional learning, I still believe it would have given me a greater chance of connecting with lecturers and colleagues as we would be seeing each other more often. Thus, making it easier to enquire about coursework throughout the year”. 6. “Personally, there is a better understanding from sitting down, physical engagement, other than connecting with everyone behind the screen, it makes it even hard to fully concentrate. Online learning is kind of challenging, of course, we can pass with good marks but the thing is that we don’t actually master the concept. I think both of these choices can help us out.” 7. “Because it’s not safe yet because of Covid, blended learning will be best to cater also for our practicals that require laboratories” 8. “It gives me personally enough resources for a test or any type of assessment given by a lecturer and makes the workload easier to handle. Blended learning would suit us better because I’m that person who needs to be in a proper learning environment for better understanding. Online learning is okay but not all the time. There are distractions in residences/homes that were never there when we used to attend physically. Some things just need real-time (face to face/ contact learning) especially for demonstrations purposes like hands-on stuff (working with computers, practicals, etc), then the rest can be administered online since it can also save time.”

	7 Students preferred online	1. "I was able to study and have a part-time job. I managed to pass my grades and have an income" 2. "Because it gives me more time to familiarize myself with the computers. Even furthermore, learning is quick and I have enough time to study at my own pace being able to access the learning material and classes anytime and anyplace." 3. "As the departments are too many around campus, I prefer online. It's easy to get lost and end up missing the important class when we are attending physically. Announcements done in class physically are difficult to get if you miss them when the lecturer is talking since there will be no recording but when you missed an online class, you just go to recordings listen to them, and try to catch up. As lectures always record when they do lecturing online" - Because you can watch again and again the recorded classes if you want to revise" 5. "Online Learning, since some of us also have to provide for the family it helps a lot. Moreover, because in this time of covid 19 we prevent the spread of coronavirus."
	3 Students preferred traditional	1. "I prefer it because it's an easy way to learn and it's a convenient way of learning." 2. "Traditional way. I understand better when something is demonstrated to me in having eye contact, it makes it easy for me to remember." 3. "The modules am doing are more practical than theoretical, so it's easier when you can ask something whilst showing it rather than having to screenshot the problem and struggle through it. When it is traditional, we can interact and counter the problems more efficiently." 4. "I prefer the traditional way because for me it's easier to understand things when taught that way, and online it becomes hard for me to catch up or grasp the information but attending classes physically gives me more interest in the modules I am doing and more pressure on studying."
Did you pass all your modules?	**39** students passed **1** Failed some of his modules	1. "Using online learning helped us to pass as we were able to replay the recorded videos/audios over and over the same way we do movies and songs. As a result, learning became interesting as it was easy to grasp concepts." 2. "Being a first-year student without NSFAS, I did not have a laptop and I used my mobile phone. The network in my home area was bad and when I came back to campus, it was difficult to access laboratories which affected my first and second-semester programming modules as it requires more practice"

From the table above, it can be noted that students have different views on the different methods of learning. Of particular interest was the suggestion highlighted by some of the students who said:

> *"Learning online-only is not quite a problem but the problem starts when I want to familiarize myself with the practical part of the course. It becomes hard because in classes we are only taught the theory. However, theory alone is not enough to enable one to fully understand the whole course. It can be a wise idea to attend practicals traditionally and classes either traditional or online."*

Another student also has the same sentiments as the above students when he/she said:

"Personally, there is a better understanding from sitting down, physical engagement, other than connecting with everyone behind the screen, it makes it even hard to fully concentrate. Online learning is kind of challenging. Of course, we can pass with good marks but the thing is that we don't actually master the concept. I think both of these choices can help us out."

Microscopically looking at the results, 30 out of 40 students strongly supported the use of blended learning as an approach that will solve their problems. It is also important to note the reasons why students opted to come back to do their online classes whilst they are at school rather than being home. Of particular interest was the reasoning of one of the students who said:

"Studying at home was difficult (it's impossible to concentrate). Again Yes! we were offered 'data' but some of us are from areas of low network coverage, therefore internet connection was a bit of an issue always"

A key to the success of the intervention that should be implemented in the education sector is to put students at the center of providing solutions and to listen to students' needs. Then, try to address challenges if there are any since students are the key stakeholders in the education sector. Without students, there is no education and the future to talk about. The fact that the students recognized the challenges they faced in completing the 2020-2021 academic years is of paramount importance. Another suggestion that needs attention was offered in the words of one participant:

"Although I've never attended physical classes, I strongly believe that they can do a difference since online learning is sometimes difficult because we were not used to and some of us, it is difficult to get used to based on our background where we come from…."

It is true based on the pass rate of those interviewed that *'when students discover what sparks their passion, great things happen'*.

"Using online learning helped us to pass as we were able to replay the recorded videos/audios over and over the same way we do movies and songs. As a result, learning became interesting as it was easy to grasp concepts."

Nevertheless, there were also problems emerging from the use of technology. While some mobile technology such as SIM cards made it possible to access eLearning, a proper computer screen provided by a laptop was far from always a usable alternative.

"Since we were given and using mobile data, connecting to laptops made the internet not stable and the laptop was consuming more bandwidth."

"Carrying a laptop going where there is a network was risky due to thieves in our areas and it is heavy."

6. Points to Ponder

For successful adaption and adoption of technology for the '*new normal* ' in the education sector, policymakers, researchers, designers, and developers of curriculums in South African universities should take note of the following.

Even though many students who were in the focus groups were given data and had laptops, many students opted to come back to study at the campus than to study at home. The students sighted different reasons for their decision to come back home. One major issue sighted was that of network connectivity.

- *Access to the internet is key for either online learning or blended learning. Without good connectivity, learning cannot take place, especially in this 21st century. According to a survey that was done in 2020 by [22]* (Figure 1), *internet connectivity is still a challenge in South Africa with the Western Cape province with the highest internet connectivity of 80.9% anywhere and Limpopo with the lowest at 58.4%. At home, Western Cape province also has the highest of 20.3%, and Northwest with the lowest of 1.0%.*

- *Another point to note from student concerns is, we should provide better environments for both digital teaching and learning if students are to benefit.*

- *Even though students were all given mobile data in the previous two academic years, affordability of data still definitely remains an issue that still needs to be addressed now going forward if the dream of either online or blended learning is to bear any fruits.*

- *It is important to note the advantages brought by online learning and borrow some concepts that worked into the classroom environment to cater to those who prefer the traditional way of learning. Things like recording lectures whilst doing traditional teaching so that students have a point of reference in form of videos/audios of the lesson when they are reading is important.*

- *Digital equity encompasses not only access to network connectivity but also the skill and knowledge to successfully exploit that connectivity. As such, students and parents who assist students should be taught how to exploit that connectivity to the student's advantage.*

7. Where the South African Education Sector should be Going

With the look of things, it seems Covid 19 pandemic is now an epidemic, and it is here to stay. As such, as supported by most of the students in the focus groups, it is in their best interest that the blended learning approach be adopted. Following the suggestions by students, practicals should be done face-to-face whereas the theoretical lessons are done online to minimize the spread of Covid 19. This will help the students to benefit from the many advantages of blended learning as articulated by [11], [21], and [25].

7.1 – Time to Seriously Consider the Potential of Mobile Learning (mLearning)

As supported by the works of [26] and [29] who highlighted the advantages of mLearning in university education, it is a fact that mobile phones are a force to reckon in addressing the online learning challenges in South Africa. The smartphone is progressively becoming an appealing learning tool for enhancing transferring knowledge, education, and learning [30]. Its use provides flexible course delivery, allows learners to access online learning platforms, course contents, and engage digitally as confirmed by the students (*Table 1*) when they ended up using mobile phones instead of the newly acquired laptops.

Access to the internet via mobile devices represents a low-cost way to reduce digital access gaps. Smartphones are less expensive than desktops and laptops; and remove access restrictions such as infrastructure, equipment, and necessary expertise [31]. As a result, 35 of the 40 students (*Table 1)* in this study preferred smartphones even though they had laptops as a quick and relatively affordable alternative to give physical internet access and, as a result, reduce access inequities. The users of mobile phones in Bangladesh as noted in [30] also shared the same sentiments.

There is unanimity that digital inequality for students does not end once access is granted since a more comprehensive digital inclusion approach includes additional dimensions such as access type and quality, digital skills, and differentiated internet activities, as noted in [26]. The findings of this work, also, considered the effects of mobile phones on online learning. A handful of students disclosed some inhibiting factors with the use of smartphones, which included mobile phones freezing during essential learning moments, volatile internet connectivity, an intruding phone call during classroom setting, and the screen display and key sizes, which made them decide not to use the mobile phones as they highlighted that they are uncomfortable for learning when compared to laptops.

8. Conclusion

In a nutshell, it is important to note that to successfully benefit from technology in the education sector, fundamental things such as improving internet accessibility, reducing "data" prices, erecting of state of the art infrastructure, reducing the price of ICT gadgets, educating and skilling people with ICT skills is key. There is a need for partnership between industries expects, the private sector, government, and policymakers if the dream of adopting online and blended learning in South Africa is to come true practically not just on paper. It is vital for people who understand technologies to partner with people who understand educational pedagogy and students so that they work together to implement this 'new normal" in the education sector. Technology is here with us and it is here to stay, as such students should adopt technology in their traditional way of learning and keep "*learning, unlearning and relearning*" for them to benefit fully from hybrid learning.

This research also recommended that to address the digital divide which is a serious threat in the use of technology in education, access to devices and internet connectivity is only one element of the dilemma in the context of South Africa and Africa at large.

We proposed the use of mobile phones as it solves some of the problems highlighted by the students. Mobile learning devices such as smartphones can accelerate educational development in remote areas and urban areas. Hence it bridges the gap between the developed and developing educational setups by making education accessible to all.

Another discovery was that infrastructure isn't everything when it comes to digital equity and learning. Students and parents must be taught digital skills if we are to bridge the digital divide so that the use of technology will be helpful in the education sector. Thus, creating conducive conditions for digital teaching and learning is key.

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5G Bases for a physical Metaversity in Africa

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ABSTRACT Africa, with its young population, faces serious challenges when it comes to designing and implementing a functional concept of a university that would educate the continent's future workforce and talent that has research, development, and innovation (RDI) competences at the highest global level, but at the same time is eager to work academically at the grassroots level in real-life contexts. We Africanize, i.e. extend and deepen, inspired by African resources, the currently existing concept of a university by that of Metaversity as a cross of the continent's possibilities and contemporary technologies, such as augmented and extended reality and high-speed broadband communications. Contextually, the concept of Metaversity is inspired by the heterogeneous requirements voiced by, in particular, students and the technology that they normally use for learning. The realisation of Metaversity requires creative integration of the metaverse that, again, requires fast and reliable communications, at the moment 5G, for example for remote presence. Derived by a lite application of design science, our concept of Metaversity exceeds that of any virtual reality: we presume that any functional instance of Metaversity has also a physical appearance in the concrete community that it operates in.

1. Introduction

Universities have largely followed the same structure since their inception. Classes are usually attended in a physical building or online in a video conferencing software like Zoom, which recently has been the case and transitioned more and more due to covid-19. Richard Branson, the founder of Virgin, described a "Travelling University" concept, one in which university isn't bound by buildings, there is the freedom to explore, discover and set up bases in communities even in remote and rural areas. These bases are all connected to one another to ensure constant collaboration. The metaverse is a term gaining wide attention thanks in large to Facebook's recent announcement to change its name to Meta. A metaverse connects people immersively and virtually using virtual reality (VR), augmented reality (AR), extended reality (XR), and Remote presence (RP) technologies [1]. In order to utilise these features, a stable and reliable high-speed broadband connectivity is needed, and 5G is the most suitable communication technology available at the moment providing ultra-low latencies required by the new applications. Currently, 5G technology and its edge computing and edge intelligence features are rising and getting more attention. A lot of potential and attention is seen in new applications that are making the most use of 5G radio and hardware developed by the hardware designers and engineers. Currently, there is a huge gap between the market needs and the talents and experts in the field of 5G. Experts in software and electrical engineering designing and implementing the 5G applications, including encapsulation of a wide variety of existing technologies, such as artificial intelligence (AI), machine learning (ML), Internet of Things (IoT), sensors, data processing, and analysis, edge cloud computing just to name a few. Thus, new and faster ways of producing, training and educating new talents are set by the big players, including 5G radio hardware manufacturers, such as Nokia and Ericsson. Moreover, the sights and visions are already put on 6G, e.g. in Finland, which is one of the leading countries in wireless communications, those applications and mobile network development (https://www.oulu.fi/6gflagship/). 6G is and will be even more about the digital content add ons by utilizing more and more integrated and immersively connected applications through VR/XR etc., which all are basically implemented with software and the physical radio technologies are "just" used as a carrier. Thus, the global need for talented software engineers and experts will only continue to grow.

All the market areas and continents, especially Africa and its youth as an unutilized source for future talents is well acknowledged [2]. The challenge in Africa as well as in other emerging markets is the missing or limited infrastructure; power systems delivering electricity access, as well as internet access, in Africa less than 30% of the population has access to the digital world [3]. As an example, people living in rural areas for instance are left in unequal position. There is a huge digital divide in these areas, which again are also a source for future talents to be educated and sourced.

Currently, young people in Africa are moving from their home villages in the countryside to the outskirts of megacities, They are heading there after work, training, and/or education, and accordingly, just to be able to be a short distance from universities, which are located in big cities and capital areas in Africa. Roughly, it is expected that by 2035, about 50% of Africans will live in cities [4]. To get these existing resources fully utilised, new, fast and light solutions are needed to not only connect these communities to the global value chains, but to also transform the traditional university architecture. For instance, in [5], "5G + Smart Education" approach for the reform of the teaching and education system is proposed. Similar approach and proposal is addressed by authors in [6]; The role of online learning due to covid-19 pandemic has become more crucial, and the contribution of 5G technology in digital education is seen as crucial. So far on-line learning has faced challenges caused by limited network speed and latency. 5G technology provides major improvements to both old, and new prospects of online learning in near future. Another recent study [7] addressed the requirements initialising from courses going to online form, to the communication network and its data capacity and latency. 5G is proposed as the base for online teaching platforms in campuses in China.

The result of combining universities with all this is a "Metaversity"'. A university that goes beyond the usual by connecting staff, students, and other interested parties using a metaverse. This paper describes the "Metaversity" concept and gives a layout of how it can be implemented. Currently efforts have been made to integrate VR and AR technologies into universities. The University of Sydney used 29 Oculus Rift headsets to test out the technologies in select departments. During the study there was a 250% increase in student enrollment in the selected departments showing that students are interested in the new technology [8]. However, focus on a virtual university community has not been explored in depth. The Metaversity will focus not only on allowing students to explore concepts using VR and AR but will allow students and teachers to form virtual communities for a more immersive experience increasing collaboration.

2. Key Concepts

While Africa is known to have had one of the first universities in the world (see references in https://en.wikipedia.org/wiki/University_of_Timbuktu), the status quo of the African university landscape is lagging behind the global academic scene, indicated by international university rankings, as misleading as they can be. Therefore, an average African university can choose between two main alternatives: either incrementally develop itself by following the models in the rest of the world and their conventional designs, or radically transform by making use of the unique resources of Africa: young talent and inspiring challenges. In this paper, we explore the second option. However, it does not mean sacrificing academic excellence, underestimating the demand for quality of performance, or undermining international standards. It only means that the novel concept of the university that we call Metaversity does not need to take into account or include all the heavy loads inherited from the past and built in the expensive and possibly unnecessary traditional architecture-structured infrastructure of the existing institutions. While Metaversity can make use of lessons learned in the past, it is fundamentally liberated from the problems of its predecessors. To reach the goal, Metaversity is based on, but also uses and promotes imagination, invention, research, development, and innovation, as well as is to be built on new technologies, such as 5G, AR and VR.

From the aspect of technology integration to Metaversity, which is needed in its implementation, we follow the principle of reforming or renewing the concept by technology, rather than the conservative approach that is limited to making the current processes more efficient by technology – an approach that would only fix the legacy systems, without evaluating or rethinking the possibly outdated processes themselves.

2.1 – University

A university is an institution where one can study for a degree or do research, or both combined.

Universities started out using a traditional model with a great focus on research: "research is in the foreground whereas teaching and knowledge transfer are less important" [9]. Over the years universities realised that having a research-centred design was not financially sustainable as it limited universities from expanding their services. Universities have now adopted a modern model with a focus on entrepreneurship and taking the innovations from research to the establishment of new business and start-up companies. With this model, there is more competition between universities who realise that the better their ranking the more opportunities arise due to recognition. Accordingly, in the model from research to entrepreneurship, and innovations to new business, it is also a source of real-life and practical problems and challenges, which is to be utilised more in teaching and learning for students in universities. This is much more fruitful ground to keep bringing up highly educated students with comprehensive skill-sets and expertise more ready to move to industry, even earlier and faster during the studies, compared to the traditional model of university studies, where the majority of studies is in gaining theoretical knowledge without touching point to practicality or real world. Table 1 shows a comparison between the traditional and modern university models.

Table 1: Traditional and modern university comparison [9].

	Traditional University	**Modern University**
Autonomy	High researcher autonomy	High institutional autonomy
Management and participation	Democratic decision making	Autocratic leadership
Organisation and hierarchy	Structures decided by government	Structures decided by university
Demand orientation	Research oriented	Teaching oriented

A modern university has a higher institutional autonomy but a lower individual researcher autonomy than traditional universities. One can argue that this limits researcher creativity as their activities are constantly monitored and restricted according to the institutional goals which are usually monetary related.

Modern universities have moved away from a democratic decision-making process in favour of a more "professional management" approach with restricted participation. This is effectively taking power from the people who in this case are researchers and students. This is a top-down approach that limits the voices of those the university is supposed to be serving. A top-down approach gives "less opportunity for school actors to influence and adapt the framework and methodology they are based on" [10]. An important shift from traditional to modern universities is that modern universities can determine their own structures and organisation instead of being controlled by some governmental body. This is important for fast decision-making and flexibility to modern universities to adapt to surroundings and trending research topics or areas following the trends in industry. Focusing on teaching in modern universities is quite an achievement because now students who enrol in the institutions are equipped with the skills necessary to thrive in their respective fields. This however is not always the case, some universities still focus on outdated syllabuses and teaching methods over equipping students with modern industry-required skills.

2.2 – Travelling University

A new type of university was proposed by Richard Branson, one with more freedom to explore than the modern university design. He called it a "Travelling university" [17]. A travelling university is a university on the road where most learning is facilitated through the identification and solving of real-world problems from various communities, which are all immersively connected enabling forming international research groups to solve complex problems, projects, leading to cross- and multidisciplinary approaches and solutions. This is the source for new knowledge. A travelling university can be implemented by setting up remote campuses [11] with a reliable internet connection to ensure constant communication between the different bases.

Setting up a remote campus sets requirements for the internet connectivity both locally in the remote campuses in communities and in the university campuses, and regarding the smooth and close-to-real time interactions, the backhaul connectivity connecting these immersively together are the critical parts of the communication infrastructure. 5G standalone (SA) technology with edge core provides a viable solution for these bases, where the data transmission runs under the local 5G network, but it does not solve the backhaul connectivity. To interconnect the university campuses to remote ones seamlessly and immersively together, the only option in principle today is the optic fibre networks, that is, the backbone of the high-speed internet and world wide web. The global coverage of fibre backbone networks are very high level between the continents, but the challenge in developing markets, especially in African continent where the distances between different areas are huge, and population sparsely distributed to villages and countryside have basically led to that there is no good coverage of fibre backbone networks in rural Africa. One reason for that is that it is not economically feasible to build the fully-covered fibre network, as it requires huge investment for connectivity infrastructure, and there is no funds for that in emerging market. This is one key factor and reason for digital divide. However, the concept of travelling university can be there changing this scheme and unlocking the world's annual education budget to be allocated to more conductive cross-border learning where campuses share information with each other and also to communications infrastructure development in Africa. Obviously, this calls for other infrastructure investments too, but this could payback the investments very fast, as the outcome of these would be more talent to the missing talent pool. Currently, there is already a $39 billion funding gap in children's universal education [12].

One alternative is the use of satellite connection for the backhaul connectivity, and for instance, huge potential is seen in the Elon Musk's satellite internet venture – Starlink (https://www.cnet.com/home/internet/starlink-satellite-internet-explained/). If and when that becomes available, that would solve the challenge to provide affordable internet access for all to all locations with rather low costs. Private SA 5G networks and its predecessor 4G LTE Advanced, namely 5G-ready technology with edge-computing capabilities have major role in this satellite-based internet connectivity scheme. The backhaul connectivity could be shared to multiple users at the 5G sites and local cloud is place for local contents, which can run there, and the usage and preserving the backhaul connectivity could be done in optimized manner. This would remove the digital divide and provide platforms and tools to start doing research and development activities on the 5G technology. Most likely this would also be very good assets for students motivation; to be able to work and get familiar with the latest technologies.

2.3 – Metaverse

A metaverse is "a collective virtual shared space, created by the convergence of virtually enhanced physical reality and physically persistent virtual space, including the sum of all virtual worlds, augmented reality, and the Internet" [16]. A metaverse is designed to bring people together in a virtual space using AR and VR and RP technology to make interactions feel more personal. The metaverse is the base for the Metaversity as it provides the technology for physical communities to communicate with other communities and form virtual collaborative communities. Augmented reality (AR) is a technology that allows virtual elements to exist in the physical world. With this users could make digital blueprints in the metaverse and show them to people outside the metaverse easily. Virtual reality allows users to access the virtual space while remote presence technology enhances the experience by allowing users to view other users with a 360-degree view.

3. Research design

3.1 – Research problem

The expectations that African governments set for universities are wide and deep. The demands of the citizen society and the taxpayers, especially students, their parents, and other relatives, are equally if not more pressing. While the older generation would like to see their sons and daughters exchange their academic knowledge and skills for a good livelihood, the young ones are more interested in self-realisation and the integration of academia with the modern technologies that they live with and within. Last but not least, the industry expects to be able to hire graduates that would easily join their teams, not only following the orders of bosses but also coming up with their own initiatives and suggestions, expressed, say, by the 21st-century skills among the newly recruited [13].

Even a shallow look into the media, whether traditional or social, shows that there is a serious discrepancy between the realities and the expectations. This conflict, threatening the future of Africa (applies also to other continents too), requires a courageous analysis of the situation and a creative, yet realistic design for a university – or Metaversity – that functions in an African setting, and, for that matter, also elsewhere in the contexts that are audacious enough to adopt the concept of Metaversity and adapt it to their environments. The findings and new concepts to be found here in the context of Africa and the Global South can also be extended and applied in the Global North. Thus, there is capacity building elements and potential to both directions.

3.2 – Research questions and goals

The research problem generates the following questions and goals that we will explore.

RQ1. What expectations do students set for a modern university in an African context?

RQ2. What kinds of university models or schemes do match the expectations?

RQ3. How to structure a metaversity?

3.3 – Research method

For coming up with a new design for a university, an appropriate research method is to follow Hevner's design science [14] for finding answers to our questions. For designing an artefact, such as Metaversity, design science requires three interrelated cycles: relevance cycle to identify the requirements (RQ1), rigour cycle to be aware of the state-of-the-art knowledge base (RQ2), and design cycle to build the concept (RQ3).

4. Outline of results from the three research cycles

4.1 – Relevance

Students look for a variety of factors when choosing a university some of which were identified in [9]. More factors must be identified but the following give a base for discussing the design of the Metaversity.

- **Reputation and attributes of universities** – Universities with a good reputation are more sought after. A university's reputation is determined by multiple factors including what people say about it on social media (bottom-up criteria) and world ranking (top-down criteria).

- **Location of the university** – Students prefer to live closer to busy cities or in a familiar area closer to home.
- **Job prospects for a good career** – Most students want to be assured that when they graduate they will receive employment, find an interesting and meaningful job to work within things that matter and have an impact to society, this is the current trend.
- **Information sources** – A stable internet connection is important as traditional structures like libraries are used less than online resources.
- **Cost of university education** – The university must not cost too much, otherwise it will be viewed as not worth the price, unless its reputation which almost guarantees a future job warrants the price.
- **Financial aid-scholarship** – There must be some sort of financial aid for students who cannot afford tuition.

4.2 – Rigour

Using Table 1's comparison between the structure of traditional and modern universities and the factors students look at when choosing a university we can derive the kind of university that matches students expectations.

A balanced university that is both Academic and Research oriented is ideal as these types of universities give the highest world ranking according to the Times Higher Education (THE) and QS World University Ranking Systems [15]. Universities that offer online learning with physical campuses in multiple areas especially in the city are quite desirable to students as this gives them the flexibility to be in an area they desire. Being goal-oriented and loosely structured also gives students the flexibility to expand their knowledge base by venturing past normal methods in pursuit of a final goal. Collaboration with companies and industry is almost a must as this exposes the learners to the industry and gives them valuable connections when they are job hunting, also small steps to get in to a company, when the part of the studies are closely connected to real industrial cases. Works both ways, as the companies can filter the talents from the early stage of studies. Access to the digital world should be provided by the university so students aren't limited to information and people in their immediate vicinity.

4.3 – Design

Table 2 provides a comparison between a traditional university structure and the proposed Metaversity structure.

The following aspects form the key attributes of the Metaversity and must be related to the requirements (relevance cycle).

Physical spaces vs Augmented reality – Normal universities have physical structures like administration buildings, classrooms etc. but a Metaversity doesn't need all that to function, the classes can be entirely virtual in the multiversity with basic structures such as accommodation and physical workshops, co-working spaces where designs could be exported and/or imported into the metaverse. This at the same time enables more flexible space/location independent co-design and co-creation processes by using high-speed communication technologies. Obviously, the prerequisite in this case is that there is needed 5G technology hardware solutions and platforms, including a base station, end nodes and edge core for metaverse available and equipped within these 5G remote bases. Moreover, besides the 5G SA local network there needs to be reliable high-speed broadband backhaul connectivity to the

Table 2: Comparison University vs Metaversity

Traditional University is bound by	**Metaversity extends by**
Physical spaces	Extended Reality
Time constraints	Serendipity
Given representations	Freedom to explore (by) unorthodox methods
Disciplines	Loose structures
Teaching pedagogy	Learning by doing and by being
Formal (current Normal) learning	Natural Learning
Industrial inspiration	Imaginative inspiration
Bureaucracy	Community/Common sense
Top-Down approach	Bottom-Up approach

other base to enable real-time immersive connection between those for metaverse implementation.

Time constraint vs Serendipity – In the Metaversity, it is easier to assemble randomly, have discussions, and immediately start designing and doing something practical and concrete with all the tools available virtually, locally in 5G SA edge core base or globally between the bases. In universities, there might be restrictions on when people can access facilities. This requires certain facilities to be open for students; co-working open spaces, open also for the public. This could lower down the barriers between the university and the surrounding world and people not in the university to get better understanding what all activities and themes there are studied, taught, researched etc. This could make the universities more attractive also to public and common man/people.

Given representations vs. Freedom to explore – In universities courses have a set syllabus with set material whereas in the metaverse learning will be project- and problem based where participants gain knowledge through problem-solving, following learn-by-doing approaches.

Disciplines vs. loose structures – Traditional universities have set faculties that restrict what a student can and can't learn, the Metaversity will have a more loose structure where students are free to explore different concepts in order to solve problems.

Teaching pedagogy vs. learning by doing and by being – University pupils are used to a certain way of learning, a top-down approach where information is given by lectures thought of as "superiors" whereas the Metaversity will have more of an emphasis on identifying "problems", designing innovative solutions and implementing those solutions all with the help of experts guides, not superiors.

Industrial inspiration vs. Imaginative inspiration – Current curriculum is mostly geared around industry expectations (what's currently being done) but because one of the main aims of a

Metaversity is freedom of the mind from “in the box” thinking current industry skills will be taken into account however participants will be encouraged to be imaginative and come up with different ways of accomplishing a task.

Bureaucracy vs. Community/Common sense – Important decisions are made by management who may be disconnected from the students, they may make decisions that aren’t what the students necessarily want. In the Metaversity decisions will be made by the community employing technology such as blockchain to ensure equal voting amongst affected members of the Metaversity.

Top-Down vs. Bottom-Up – This is a major difference as normal universities are governed by high-ranking members and those at the bottom have little to no say. The Metaversity will be driven by its entire community, not just the decisions of a chosen few.

The Metaversity is an extension of universities using VR, AR, RP and 5G technologies, and the travelling university concept. The student requirements for a metaversity were taken from students’ expectations from modern universities which were used to identify a university structure which matches students expectations to expand into a metaversity.

5. Discussion

Gone are the days when students quietly accepted sub-par education. Nowadays there are so many options students can choose from for universities that if a university does not put its students as its first priority, its enrolment rate will decline affecting the entire university system. Students in Africa expect to receive a quality education and have hands-on student works with latest technologies from their institution which is why metrics such as a university’s world rankings are more important than ever. Universities are required to keep up with the latest trends in order to be competitive, the recent pandemic is an excellent example of this. Universities that couldn’t adapt and evolve their models to suit the current online learning model were left behind by those quick to adapt. In fact, many universities are keen to get the latest technology platforms and tools, because those are seen as the prerequisites to keep up with the latest solutions what comes to online learning and new approaches and concepts in teaching and learning, and new tools to foster and develop those, including 5G, VR, AR, etc, technologies.

Students’ opinions and complaints cannot be easily silenced because of social media which has given regular students a large platform to engage with other students, air out their opinions and discuss potential solutions. Universities are slowly adopting a bottom-up approach where change is driven by students, not just management. The Metaversity can assist the rate of adoption of this new approach by providing mechanisms such as community voting with the transparency provided by blockchain technology. The pandemic taught us that learners and institutions can adapt to new technologies, but not everyone will initially welcome the Metaversity. However after a few brave students and institutions show everyone else the benefits of utilising the new technologies, more will be following and willing to adopt to it. The time is now, post covid times are behind the corner, there is no turning back to old and traditional ways of work, especially now when the technology (AR/VR/XR and 5G) are there to be utilised and level up these new concepts.

5.1 – Limitations

First, the focus of the paper was on the rigour cycle rather than the relevance cycle which we only managed to cover by secondary sources, not primary data from a (given set) of factual user environment(s). This led to a concept that might not satisfy the range of expectations from the Metaversity.

Secondly, we investigated the concept from the perspective of Africanization which is a somewhat controversial term. We hope that our pragmatic approach, along with our definition of the term, justifies the use of the term.

6. Conclusions

In conclusion, we argue that if a university successfully implements and declares itself as a Metaversity, its reputation will rise as a pioneer and adaptor of new technologies. This will lead to more and closer collaboration with industry which will bring in more funding for education and research so it can go to areas such as financial aid and technological development to ensure the Metaversity does not stay stagnant. With an increased reputation and more industry collaboration due to using advanced technology students' job security will increase as they will be introduced to companies while studying and have the required skill set to be internationally competitive.

The Metaversity exists online with physical bases so the location will not be much of a problem for students. Students living in rural areas can have access to the Metaversity using remote bases and still interact with those who prefer to be in town. With the normal online classes, most universities in Africa did not bother to set up remote bases to give students access to the internet, the Metaversity will be based on a fair access policy with bases established in strategic areas. The Metaversity provides most of the identified demands of a student in RQ1; however, in its early days without external funding the Metaversity will have a high cost for students as the university will accrue additional expenses. These expenses could however be covered through projects driven by students.

In RQ2 a university that caters to students needs in RQ1 was derived and using this a preliminary design for the Metaversity was made to satisfy RQ3. In order for a Metaversity to be successfully implemented, it will have to follow a bottom-up approach with a great emphasis on the student's satisfaction. If the Metaversity adopts a top-down approach, then students' opinions will be minimised in favour of bureaucracy.

Metaverse technology is in its early stages. Development is however rapidly progressing thanks to companies such as Facebook and Microsoft, and Nokia. Currently, developing a metaverse, especially one with a university-wide scale, takes a tremendous amount of resources. Once metaverse technology becomes more mainstream the cost of development will reduce, and there will be options to use existing metaverse technology for university purposes or develop systems from the ground up according to an institution's requirements.

Remote presence technology does already exist. However, more development is needed to make it truly feel like you are in the same location as someone else from another side of the world. VR, AR, and 5G technology is at the stage where it can immediately be integrated into current universities. Universities in developed countries are already taking these steps. There is huge opportunity seen in utilizing the new technologies in teaching, learning, education, and research.

Future tasks would be to gather more requirements for what African university students like and dislike about their universities to give a clearer picture of how to design the Metaversity around the student's needs. More technical research can be conducted where the focus is the integration of the various technologies to make the metaverse possible.

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Practitioners and Application Papers

Internet of Things Remote Monitoring Solution for Efficient Storage and Delivery of Temperature-Sensitive Vaccines in Rwanda

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ABSTRACT Lack of efficient and well-monitored vaccination systems leads to people's death and impact the economy of individuals and of the country in general. Some vaccines are temperature-sensitive, therefore, storing and delivering the vaccination to rural remote area in suboptimal conditions reduces their efficacy or even spoil the vaccine. Currently, monitoring of these vaccines is often done manually, and this is unreliable, making it impossible to know if their effectiveness has deteriorated by the time they are injected in individuals. This research project has been conducted with the objective of developing an Internet of Things Vaccine Remote Monitoring Solution (IoT VRMS) to provide a real-time monitoring of storage and delivery of these temperature-sensitive vaccines together with the ability to alert whenever there is an issue. There is no remote monitoring tool used for all vaccine stores as well as for vaccine delivery process. To design IoT VRMS, Sensors, Microcontroller Units, wireless communication technology and user interface have been connected together and configured to produce an IoT VRMS system. Test results proved that the designed system will be a suitable solution to the existing cold chain challenges.

Keywords Cold chain, IoT VRMS, COVID-19, Vaccine Storage, Vaccine Delivery, Web App

1. Introduction

Vaccination is among the most effective strategies for preventing diseases. However, its success depends on a well-managed cold chain that keeps vaccines within their recommended temperature range which is the only way to ensure that vaccines efficacy is preserved till they are injected into individuals. Not all vaccines must be kept in cold temperatures but most of them are stored within the WHO recommended temperature range which is 2 to 8 degrees Celsius [5].

Immunization is largely regarded as one of the most successful public health initiatives, but global immunization rates have remained steady for several years at 85 percent [1][3]. Increased vaccination coverage rates, according to the World Health Organization, might prevent an additional 1.5 million deaths per year [2].

To attain the high vaccination coverage rates, proper cold chain management is necessary to keep vaccine quality [5]. Within this context health and economic crises created by the COVID-19 pandemic will only be fully resolved with the discovery and global dissemination of an effective vaccine. It is essential not only for the health and well-being of the populations of developing countries that nearly every individual there receives a vaccine, but also to the rest of the globe, in order to prevent small pockets of unvaccinated people beginning new outbreaks of the disease. Keeping consistent cold chains throughout the vaccine delivery system is a complex, but crucial, process that requires precise, temperature-controlled environments to store, manage and transport vaccines. A limited temperature range (often between 2-8ºC) must be maintained from the time vaccines are manufactured until they are delivered to the beneficiary [5].

Variation of temperature in vaccine supply chains are rather prevalent for industrialized as well as Third world nations, according to a number of studies. In low-income nations, it has been found that 37% of vaccines are subjected to temperatures that are outside of the acceptable range, making this an important issue to address [7] (cf. also [6]). Monitoring techniques have been shown to be unsatisfactory in existing research, resulting in vaccines being exposed to temperature extremes [7]. According to a study conducted in Cameroon's North West Region, about 76 percent of health centers assessed had a working thermometer for their vaccine storage facility, and 20% of those had abnormal temperatures when data was collected [14].

The Fridge-tag 2 (FT2), a continuous temperature monitoring logger, is used to manually track and record the faults identified in the evaluation, as well as the temperatures of cold chain equipment at facilities and sub-country stores. The FT2 has a history of issues relating to users' lack of understanding of how to use it, how to read and interpret FT2 results, and how to respond to temperature excursions. [1] (cf. also [15]). The majority of people in low-income nations, are not adequately taught to use these devices, the cold chain system is frequently inefficient and under-monitored which results into a significant portion of the vaccines thrown away at the session sites [1]. Furthermore, vaccines are typically transported in refrigerated boxes with ice packs and cold water packs. Vaccines frequently freeze below the required temperature range, leaving them useless and potentially dangerous. Vaccines are also lost or stolen throughout the trip to the health clinics due to a lack of accountability. All of these factors create a loss of over 30% of vaccines in delivery [8].

To address the above challenges for maintaining a cold chain, we propose a healthcare IoT platform with remote monitoring along with sensors for cold chain monitoring of vaccines, for real-time recording and reporting. The proposed solution help in remote monitoring of the vaccine stores by providing an access to temperature data of the stored vaccines and getting notifications in case of any temperature excursion. The DHT22 temperature sensor was used for reading vaccine temperature values. The Raspberry-Pi in vaccine storage monitoring and NodeMCU in vaccines delivery monitoring were used as control units while the user interface consists of a web application accessed via a PC or a smart phone. Notifications to the users are sent through a GSM module to the users’ mobile phone.

This study is organized into six sections. Section 1 is this introduction that describes the context of this research, the overview of the problem to be solved, the relevance of this project, the proposed solution and the research organization. Section 2 describes the review of the related literature. Section 3 describes the methodology to conduct this research project, and Section 4 describes the prototype design model that show how the system is wired and the interaction of different components. Section 5 shows the obtained result and discussion, then the last section concludes the paper.

2. Related work

Over the years, many research works have been undertaken to develop online web and mobile-based applications that can aid in increasing vaccine coverage and controlling the cold chain. The majority of mobile applications developed are primarily responsible for collecting data on vaccine coverage in hard-to-reach parts of third world nations and for monitoring vaccine administration [9][10][11]. Nevertheless, all those previous studies have demonstrated, adequate vaccine coverage in these remote regions can only be assured if the vaccine supply system's cold chain is working properly. While these tools can accurately analyze vaccine outreach rates, they do little to boost coverage rates.

According to a previous WHO report [12] two alarm-based temperature monitoring systems have been implemented at national immunization storage facilities in Sudan and Iran. These systems provide for continuous cold-store temperature monitoring at their respective sites. The systems, however, do not go beyond specific facilities, making it impossible to monitor the entire vaccination cold-chain.

Haghgou writes about the National Vaccine Stores Temperature Recording System used in Khartoum, Sudan [12], to monitor the temperature. The system was developed with one temperature sensor (gas type) installed in each cold/freezer room. The sensor measures the cold/freezer rooms' internal temperature. A transmitter is linked to those sensors on the roof of each cold room and delivers a wireless signal to the hub, which is then connected to the computer for recording and saving the data. Outside the cold room, an extra sensor was mounted to record the store's ambient temperature [12], It also features an arming system that sends a warning to the staff phone and the extended Programme on Immunization Manager (EPI) when the temperature rises above 10 degrees Celsius and falls below 0 degrees Celsius.

In Iran [12], In 2005, a local company, Sardzasaz, designed, manufactured, and installed an autonomous temperature recording system. The company is also in charge of system maintenance and has had a contract with the Ministry of Health and Medical Education for the past five years. The same company deployed similar devices in a few other provincial vaccine outlets [12]. These systems, on the other hand, are only acceptable for use in vaccine cool rooms and refrigerators at delivery sites. Those aren't designed for use during vaccine delivery, where cold chain breaches are most prevalent.

FoneAstra [13], a programmable platform based on a low-cost microcontroller that enhances the capabilities of low-tier cell phones commonly used in developing countries. FoneAstra comes with a digital temperature sensor as well as a vaccine cold-box for keeping vaccinations in a controlled environment. The temperature of the cold-box is continuously monitored by FoneAstra, which aggregates information over time. It sends periodic SMS messages with temperature updates or instant alerts if it detects abnormal temperature conditions using the mobile phone to which it is connected [13]. It also allows for the tracking of vaccines in transit using cell tower-IDs from mobile phones. This system is an online-based application with the basic limitation that it does not include the function of allocating separate IDs to large numbers of vaccines that are sent out together on different trips, and it also does not have the ability to identify which vaccine delivery trip the definite data is being sent from, limiting its use to a single trip at a time.

In Kenya, Remote Temperature Monitoring and Data Review teams were used in a research project [1] that was carried out and implemented in Isiolo, Kajiado, and Nairobi to see if employing remote temperature monitoring (RTM) devices, as well as a structured problem-solving and action-oriented strategy to data utilization, will help with vaccine management. Over 50 vaccine fridges were built across 18 sub-country vaccine storage and 18 high-volume health facilities as part of the system. When the temperature went above or below the vaccine's recommended temperature range, the system devices delivered an SMS alert to the employees. Following that, it collected and recorded continuous data before uploading it to the ColdTrace dashboard. However, this approach does not allow for remote monitoring of vaccines while they are being transported.

In the World Health Organization (WHO) Vaccine Management Handbook [5], the Department of Immunization, Vaccines, and Biologicals has released a document developed by the Expanded Programme on Immunization that explains how to monitor temperatures in the vaccine supply chain. Among the methods described are the use of an electronics freeze indicator, which are "small digital devices that are placed with freeze-sensitive vaccines during transport or storage" [5, p.13]. It has a visual display that shows whether or not it has been subjected to cold temperatures.

The vaccine manufacturer included an electronic shipping indicator, which is a "single-use temperature monitoring device placed with international or in-country vaccine shipments" [5, p.VII]. It contains visual warnings set to indicate the vaccine's heat and/or frost sensitivity thresholds and maintains track of temperatures at regular intervals. A computer that consistently records temperatures in cold rooms, freezer rooms, refrigerators, and freezers utilizing several sensors is known as a programmed electronic temperature and event logger system. A temperature sensor that is permanently put in cold areas, freezer rooms, refrigerators, and freezers is an integrated digital thermometer. Temperature sensors monitor the temperature in real time, which is digitally reflected outside the room or in the refrigerator/freezer. Temperature threshold indicator is another device that uses a chemical indicator to identify whether a vaccination has been irreversibly exposed to temperatures above or below a pre-determined limit.

All of the preceding technology, however, presents the lack of a cold chain that can be remotely monitored throughout shipment. As a result, the constraints of existing works were taken into account when designing this system.

3. Methodology

This section describes the methodology used to conduct this research project. It involves the preliminary review and analysis of technical and design needs which refer to collection of data that assisted in the design of the system mainly basing on the needs and technical requirements from cold chain technicians. The methodology in this project is described in the following three steps.

1. *Preliminary review and analysis of technical and design needs.* In this phase, 20 district stores were visited in order to hand over questionnaires to the cold chain technician at each site. These were permanent employees of hospitals in different provinces in Rwanda. The cold chain technicians are in charge of monitoring vaccine stores and were asked about vaccine storage and monitoring practices. From the answers to the questionnaires, common challenges and needs of cold chain technicians could be identified.

2. *Design and development of the IoT RMS system.* Following the identification and assessment of cold chain technicians' needs, we began the design and development of a prototype system, in which both physical and logical components required for the smooth operation of the entire system were modelled, simulated, and evaluated in order to produce a complete cold chain IoT Remote Monitoring Solution.
3. *Testing the developed cold chain IoT Remote Monitoring Solution for a period of time.* The developed Internet of Things Remote Monitoring Solution (IoT RMS) was tested in a controlled environment, to determine the system accuracy, power management, and connectivity over a given period of time. Data were gathered, including comparison tests to determine the accuracy and durability of various types of sensors to be used in the final IoT RMS product. In this phase we deployed sensor nodes into fridges from three different locations and gathered temperature data recorded from each fridge via the designed web application.

4. Proposed system model

The design model consists of two separate parts, the remote monitoring solution in vaccine storage refrigerators and remote monitoring solution in vaccine delivery. Different sensor nodes were used to collect data and post them in the same database for accurate and better monitoring from one place. Figure 1 illustrates the block diagram of the IoT Remote Monitoring Solution in storage location, which is the first part of this project.

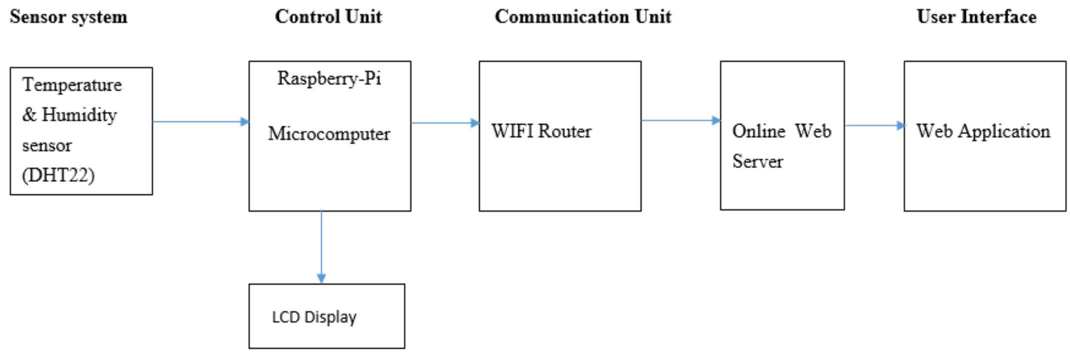

Figure 1: Vaccines Storage Remote Monitoring System.

The block diagram shown above explain different phases from collecting temperature to the data visualization point, which is a web application, the DHT22 sensor was used to capture the temperature and humidity, the control unit for process the data, Wi-Fi router for sending data to server and the user interface web application that allow the user to view and monitor those collected temperature. The Liquid crystal display (LCD) is mounted to the refrigerator to display the temperature value on the field.

Figure 2 shows the second part that represents IoT Remote Monitoring Solution in vaccine delivery from the country stores to referral and district hospital in Rwanda. The WiFi router used in the delivery system is based on a 3G/4G cellular network which is available countrywide. This will help the data recorded to be stored in the online database.

The system consists of four main types of units:

1. Sensor system
2. Control Unit
3. Communication Unit
4. User Interface

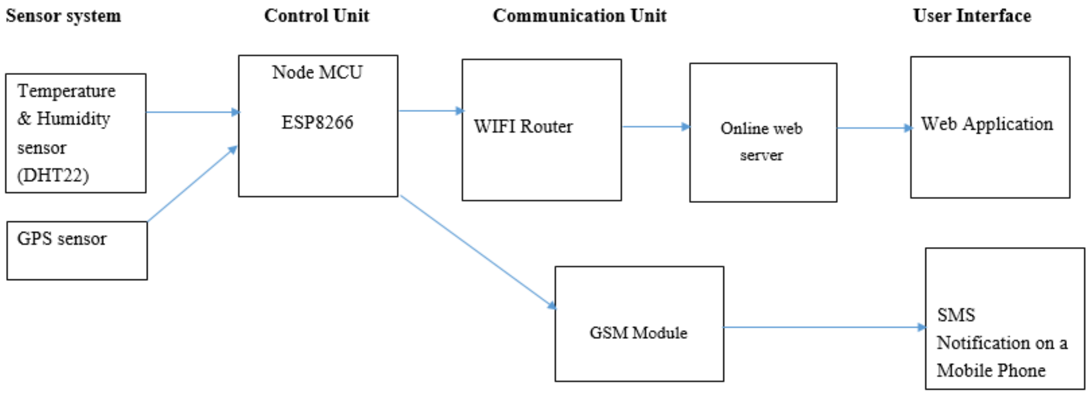

Figure 2: Vaccines Delivery Remote Monitoring System

The sensors used in the vaccine delivery IoT Remote Monitoring Solution are: the temperature sensor DHT22 and a GPS sensor for sending geographical coordinates during vaccine delivery.

The Control Unit is made of Node MCU, an open-source based firmware and development board specially targeted for IoT based Applications. It includes firmware that runs on the ESP8266 Wi-Fi SoC from Espressif Systems, and hardware which is based on the ESP-12 module. In this project the control Unit is used to process the data from the sensors and evaluates these data for decision making.

The Communication Unit consists of a wireless communication system to allow the end users to access the data collected from field and real-time monitoring, from any place by using different types of wireless or wired communication protocols (Figure 3). After collecting data from different sites, the data is sent to the developed cloud platform by using Hypertext Transfer protocol (HTTP) using POST method. HTTP is a standard application protocol that serves as a client-server request-response protocol. The protocols are illustrated in Figure 9.

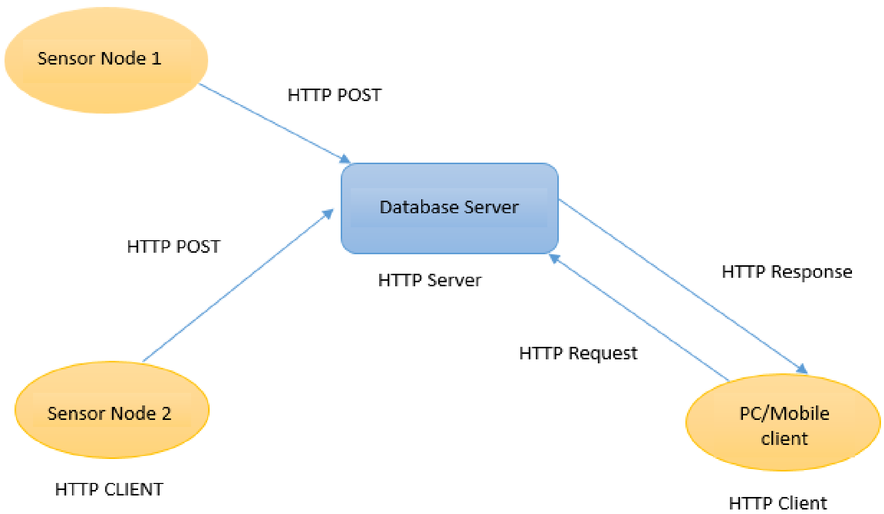

Figure 3: HTTP Communication Protocol

In the proposed system model prototype, the temperature from DHT Sensor connected to the control unit forms a sensor node from different stations and use the HTTP client and sent the data to cloud database server which uses HTTP response and request to communicate with the web clients. Hypertext Pre-processor (PHP), a widely used open-source general-purpose scripting language that is especially suited for online development and can be incorporated into

Hypertext Markup Language HTML, is used to obtain the data stored in the database. The data from many sites is shown on the dashboard developed in Hypertext markup language (HTML), and cascading style sheets were utilized to produce dynamic effects within web browsers using JavaScript, which is an object-oriented computer language. The HTTP client aids in the transmission of HTTP requests and the receipt of HTTP responses from the HTTP server. The connectivity between sensor nodes and the web application is depicted in Figure 4.

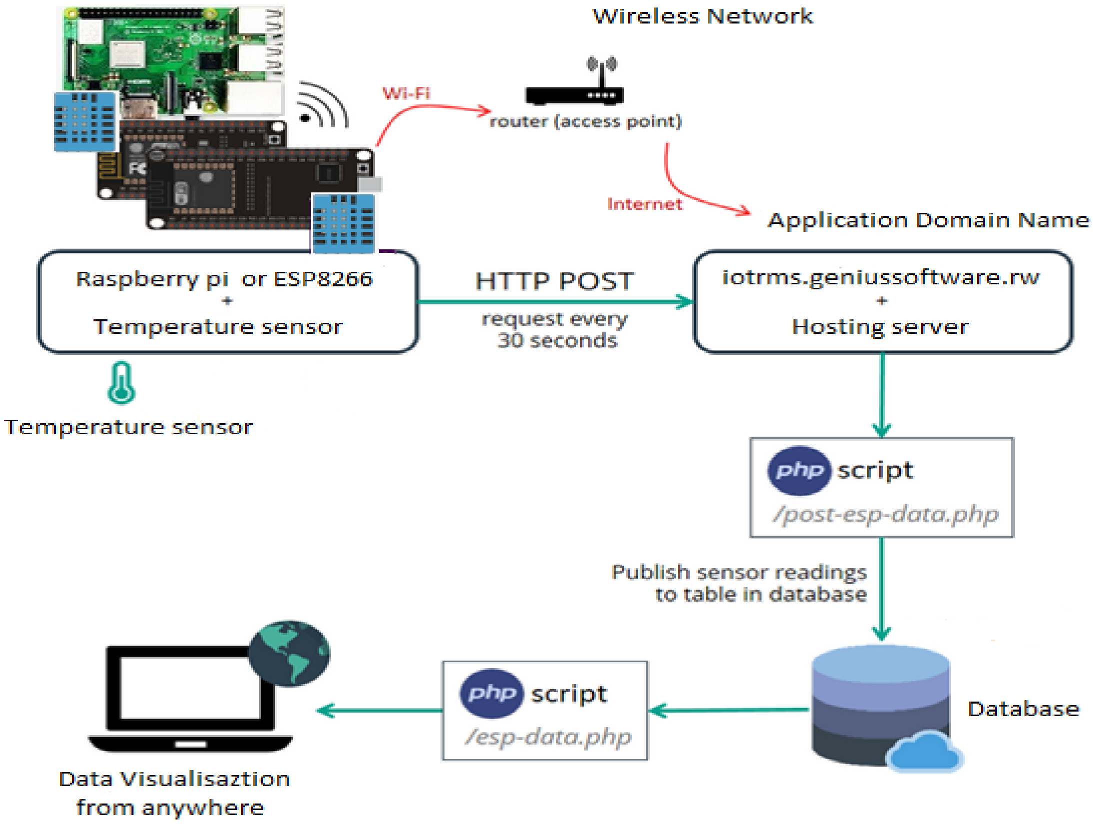

Figure 4: Architectural Design of the System

Since this project is dealing with the temperature remote monitoring from different vaccine stores and during vaccine delivery, having a domain name and a hosted account that allow to access sensor readings from the raspberry pi 3 and ESP8266 is crucial. This helps to visualize the readings from anywhere in the country by accessing the hosting server with a particular domain name over internet connection. In addition to the vaccine delivery, the system sends SMS notification using GSM to the responsible person in the cold chain and the coordinates on temperature change are included in the notification. Figure 5 shows the GSM connectivity between sensor node and the mobile phone.

The Web application consists of an application program that we developed but stored on a remote server. It is access from the internet via a browser interface. The GPS/GSM module consists of a circuit designed to detect the GPS location and use a cellular network to send its data/message to the specified user.

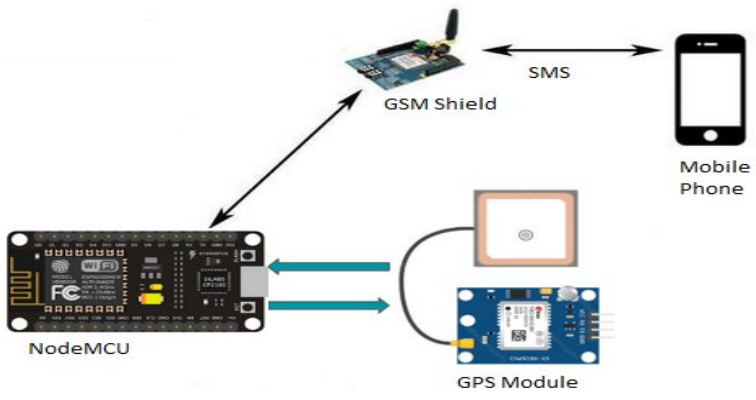

Figure 5: GSM Connectivity

5. Results and Discussion

The answers obtained from the questionnaires showed that 100% of all respondents (n=20) manually record vaccine temperatures on daily basis and that they store vaccines into refrigerators. Only 50% were aware of the (2-8^{o}C) WHO recommended temperature range for most of vaccines storage. All of the vaccine stores we visited were lacking a proper system for ensuring that vaccines are kept in the acceptable range of temperature. Only cold boxes are used during vaccines transportation which do not have any means of temperature monitoring. 60% of vaccine stores have standby generators for automatic power backup in case of power outages. There is not any remote monitoring tool used for all vaccine stores as well as for vaccine delivery process. Excel packages for descriptive statistics were used for data analysis. We also found that the refrigerators used for vaccines storage have built-in thermometers with a display that provides the readings of the current temperature and cold chain technicians must keep reading on the display to note any possible unexpected temperature change. Figure 6 provides the findings.

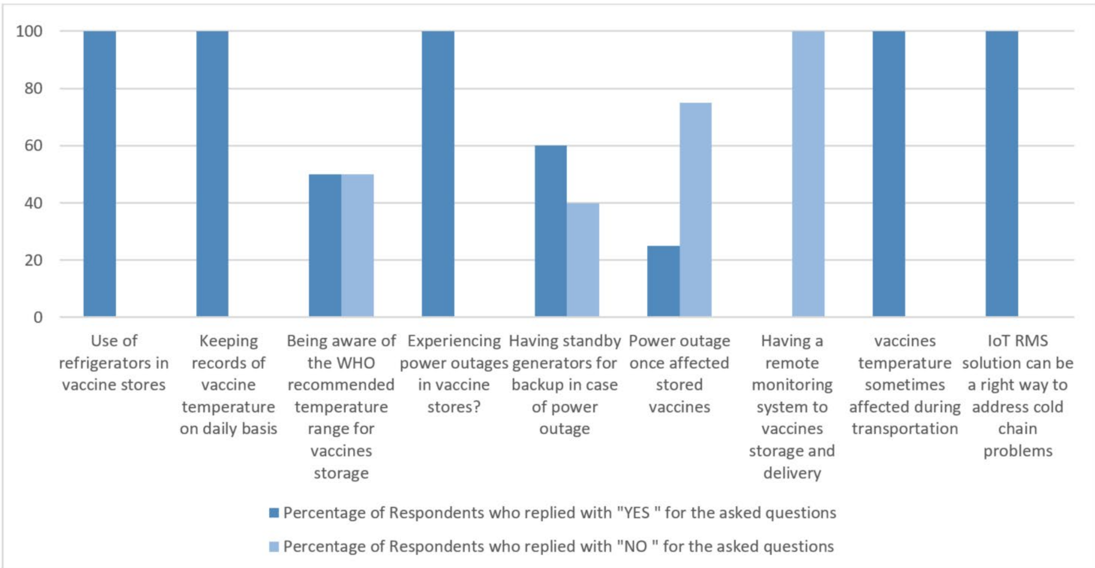

Figure 6: Analysis of the data obtained during visits to vaccine stores

The results of the IoT RMS solution for efficient storage and distribution of temperature-sensitive vaccines in Rwanda are provided and discussed in this section. It describes the results obtained from sensors to user interface of the system during prototype implementation and the graphs of temperature variations from different location where sensors are deployed. The common result from both site location is the temperature which is monitored through a web application interface. The other result is an SMS notification from delivery monitoring system which is sent to the cold chain technician's mobile phone to show exactly the location of vaccines during transport and the change in temperature if any.

For different site locations, the cold chain technicians can monitor different temperature data from any site location of their choice. Users can select one or more locations he/she want to observe either at real time or visualize it at selected time interval. According to the graph in Figure 7, the selected average temperature is ranging between 2–8ºC and the slight variation in certain period of time. The system was able to generate a report on temperatures values read at any time when needed. Notifications in case of temperature excursions were received on the user's mobile phone through the GSM module.

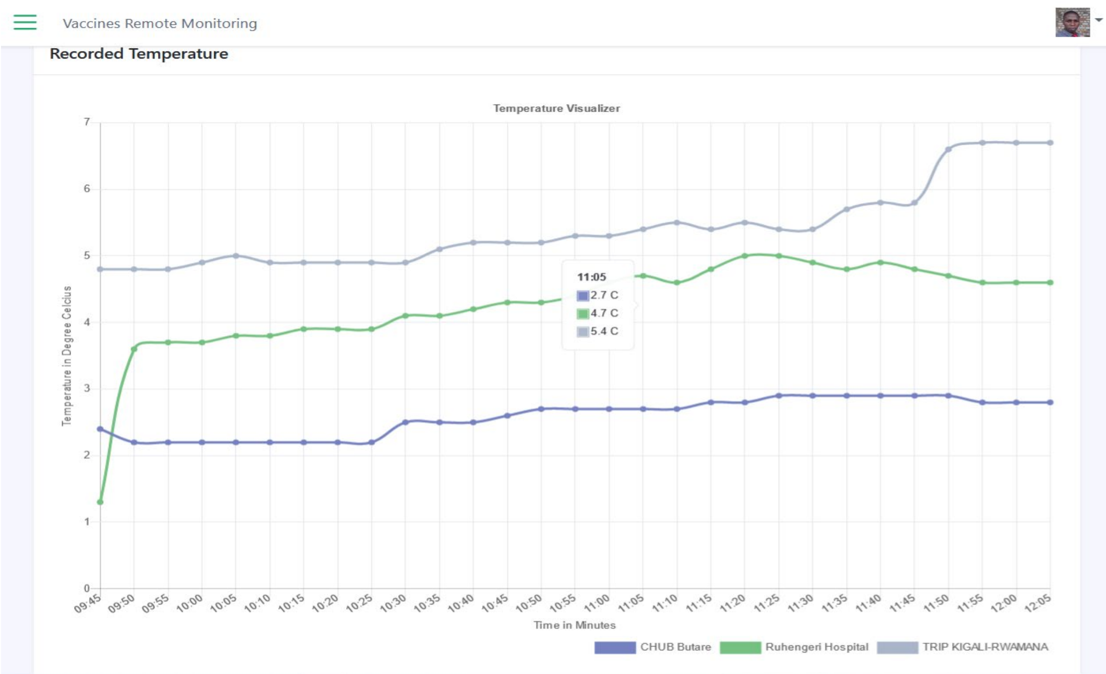

Figure 7: Temperature collected from different site location

The other results are from the SMS notifications generated from IoT RMS during the delivery, when the temperature goes below or above the prescribed range. The Figure 8 shows the SMS generated containing the detected temperature value in cold boxes and the location coordinates at which the temperature changes with the link for Google map for easy locating the place. Those cold boxes contain cold ices inside, the cold chain technician can immediately look for any assistance with other cold ices to avoid keeping those transported vaccines at high temperatures for long time. For them tracking the location is crucial.

The system allows users to generate the daily report on the temperature variations at a specified time interval.

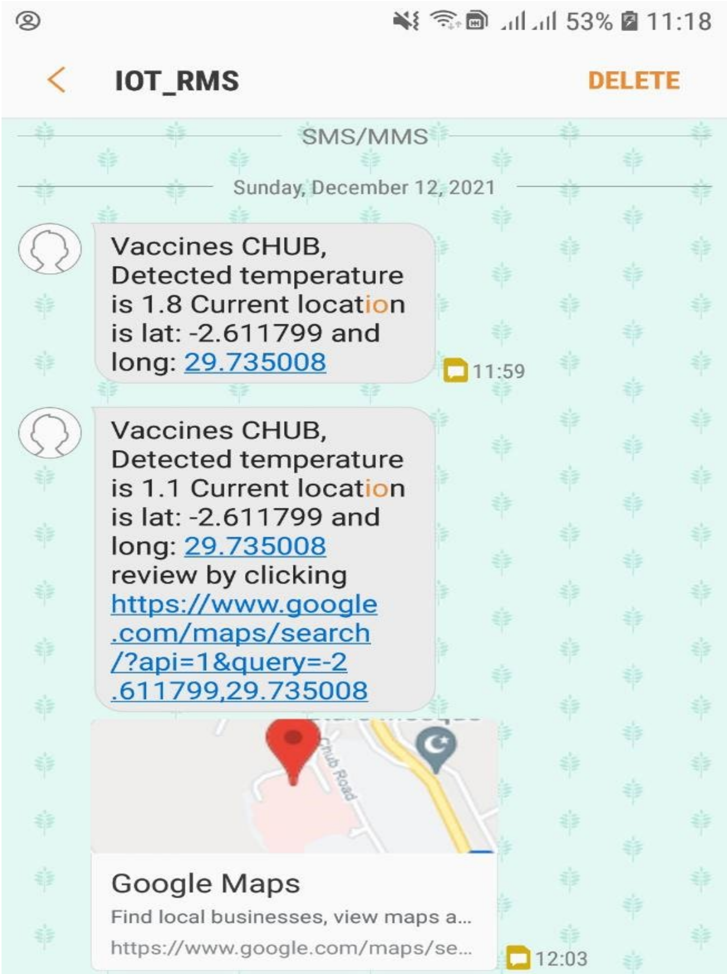

Figure 8: SMS Alert from IoT RMS

The system allows the users to generate the daily report on the temperature variations at a specified time interval. This report helped to analyse the temperature change for vaccine to make sure that the vaccines are kept at prescribed range. For different site locations, the cold chain technicians could monitor different temperature data from any site location of their choice. The system allows users to select one or more than one location he/she want to observe either at real time or visualize it at selected time interval. The system allows users to generate the daily report on the temperature variations at a specified time interval. Figure 9 represents the report generated from the system between 9:45 AM and 15:25 PM on 25th November 2021 at Ruhengeri Hospital Vaccines Stores in Rwanda.

5.1 – Data analysis

The accuracy of data generated by the designed system has been compared to three different data generated by the existing systems. As observed in Figure 14, the data from other existing system present much fluctuation where some of them have gone above and below the WHO recommended range. This may be caused by malfunctioning of used equipment and sensors which need to be replaced or maintained. The data from the designed system lie between 2.5 and 4 degrees Celsius which is a normal range for vaccine storage.

Temperature Recorded

Time	Recorded Temperature 2021-11-25 Ruhengeri Hospital
09:45	1.3^{0}C
09:50	3.6^{0}C
09:55	3.7^{0}C
10:00	3.7^{0}C
10:05	3.8^{0}C
10:10	3.8^{0}C
10:15	3.9^{0}C
10:20	3.9^{0}C
10:25	3.9^{0}C
10:30	4.1^{0}C
10:35	4.1^{0}C
10:40	4.2^{0}C
10:45	4.3^{0}C
10:50	4.3^{0}C
10:55	4.4^{0}C
11:00	4.6^{0}C
11:05	4.7^{0}C
11:10	4.6^{0}C
11:15	4.8^{0}C
11:20	5^{0}C
11:25	5^{0}C
11:30	4.9^{0}C
11:35	4.8^{0}C
11:40	4.9^{0}C
11:45	4.8^{0}C

Figure 9: Temperature Data Report

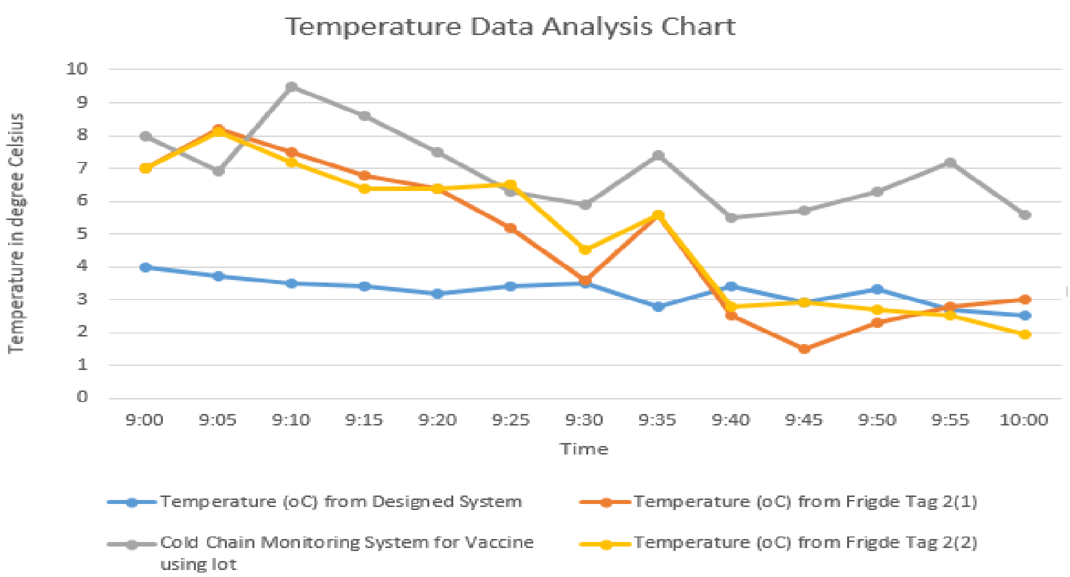

Figure 10: Data Analysis Chart

6. Conclusion

The literature reviewed revealed that the existing cold chain monitoring approach has a number of drawbacks. These include the manual vaccine temperature recording, intermittent power outages and insufficient knowledge of cold chain monitoring techniques. In this study, a web application has been designed to help cold chain technicians view vaccine temperature data anytime and anywhere. In addition, a GPS/GSM module has been added to send the notification to cold chain technicians in case of any temperature excursion during vaccine delivery.

It is the hope of the authors that the designed system will help to save a big number of vaccines which were wasted because it is able to collect vaccine temperatures, detect changes in temperature and alert users whenever the detected temperature goes above or below the WHO recommended range.

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Utilizing Fuzzy Logic for IoT Shiitake Mushroom Farm Vital Parameters Monitoring with Water use Optimization

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ABSTRACT The mushroom need has been increased due to their use in medicinal and culinary practices. Besides, mushrooms are one of the good cash crops. Shiitake mushroom is the most important culinary medicinal mushroom which ranks at number two in terms of importance to the medicinal and culinary industries. However, the production in shiitake mushrooms is small because of traditional methods that are implemented with manual approaches, and thus present a gap in preciseness for the management of vital parameters of the farm as well as the resource optimization. In previous research the use of sensors in mushrooms cultivation has not sufficiently provided optimized harvest. Thus, there is still a need to improve the existing methods of mushrooms cultivation by using a real-time surveillance system of the mushrooms' farm vital needs to support in decision making. This paper introduces an automated system with intelligence based on fuzzy logic to maintain mushrooms substrate suitable for shiitake mushrooms and to save the quantity of water used in mushroom farming. Two types of mushroom farms with 10 seed bags per each farm are experimentally implemented (simulated). The two farms are equal in number and quality of seeds. Two substrates are made with the same materials and components, with a difference on the technologies used to grow the seeds. One farm uses fuzzy logic, and another uses an existing watering system based on time interval watering. The results of this research identified that a farm with current method is stable for 25% of the period of the day and water is conserved at 90% while the farm with the method proposed in this paper makes a farm stable for around 66.67% of the period of the day and water is conserved at 98%. For future research, this study can be implemented with many other types of mushrooms to improve their harvest.

Keywords: Precision farming, Mushrooms farming, Shiitake mushroom, Fuzzy logic, Internet of Things (IoT).

1. Introduction

In the field of precision farming (PF), mushrooms farming which is also called fungi culture is defined as a process to produce mushrooms either at home or in a small-scale farming substrate [1]. Even though mushrooms strictly impose a specific substrate in terms of humidity, temperature, a light intensity, producing a viable harvest can be achieved by taking critical mushroom breeding steps and by varying the types of seeds and various growing methods such as growing mushrooms on logs, growing mushrooms on spawn, and growing mushrooms on straw [2]. Differently to most agricultural species, mushrooms specifically, must be grown in a particular medium with a restriction to not being exposed to the light to produce the best possible harvest. Traditionally, mushrooms have been bred in the wild and picked from there [3]. Because mushrooms are of capital importance for healthy nutrients and medicinal applications, mushroom farming was chosen in this work to contribute to the improvement of the yield of mushrooms, to support the availability of medical ingredients and food.

Shiitake mushrooms have not been introduced quickly in many countries, for instance, the U.S. started growing them in the early 1980s, and research have not often focused on shiitake mushroom cultivation, to identify how to monitor the substrate, seasons, laying yards for this type of mushroom which is important in boosting human immune system. Thus, the type of mushroom requires specific attention because of its various applications that are important for society in general. Shiitake is used medicinally for diseases involving depressed immune function including cancer, environmental allergies, Candida infections, and frequent flu and colds [4].

Shiitake is also beneficial for soothing bronchial inflammation and regulating urine incontinence as well as for reducing chronic high cholesterol. Lentinan, a cell-wall constituent extracted from the fruiting bodies of shiitake is an immunomodulation agent which may be useful both as a general rejuvenate for older persons, as well as prophylactically to protect healthy, physically active young people from overwork and exhaustion. Several methods in growing shiitake mushrooms get their significance in providing enough water to maintain the farming medium with desired parameters for an imperative medium to grow mushrooms and focus on an optimized way to utilize water [4, pp. 23-27].

Works by Pravinth Raja et al. [5], and Najmurrokhman et al [6] identify the main gap as that the harvest in mushrooms is still insufficient and water resource is not efficiently exploited for mushroom cultivation, and the research that is currently being done does not attain the satisfaction in mushroom yield. Shiitake mushrooms, that are used for both medicinal and diet purposes, have not been worked on by many researchers to avail them with sufficient harvest and there are gaps in using technological approach to control the cultivation medium parameters on real time basis and manage water resource.

To alleviate the drawbacks above said, this research aims to designing and implementing a fuzzy inference-based system that will be a tool to maintain a favourable environment for shiitake mushrooms cultivation by supervising and keeping in a desired range of medium parameters (soil humidity, air humidity, temperature, and light) in real-time basis.

This will be done by applying the Internet of things (IoT) concept of wireless sensor network and a fuzzy inference system which is used to obtain a control system with imprecision inputs, many parameters, and good results like how humans perform decision making.

This research focuses on how to maintain a favourable environment for shiitake mushroom farms by availing real-time surveillance of the farm temperature, light, and soil humidity, to increase the yield. This system works on a real-time basis to identify any critical variation of the farm environment to act on addressing it on time.

To analyse and decide on the data collected by sensors, we use a knowledge base (database) storing the standard data about the desired farm environment parameters for shiitake and by benchmarking the collected data with the desired ones, once a variation is out of the desired range a decision to re-establish them to the desired ones is taken. To make that possible, we use a fuzzy-inference-based model. Fuzzy Logic (FL) is based on an approach of imitating human decision-making by including all in-between alternatives of digital values YES and NO.

2. Existing Method

In research by Pravinth Raja et al. in [5], IoT-based mushroom monitoring systems is focused on where the sensors are placed in specific places of the growing area to record data of the farm. This paper identifies those basic parameters to be taken into consideration are notably the temperature, humidity, and gas content. The methodology of this research work consists of using sensors to get the mushrooms' farm parameters and spray water based on the variation of any of these vital parameters which can cause inundation in the farm. However, this system lacks automation based on a combination of more than one vital parameter in acting on a variety of field parameters.

By focusing on oyster mushroom cultivation, Najmurrokhman et el. [6] worked on using fuzzy logic to monitor temperature and humidity in oyster mushroom form by detecting the temperature with one sensor DHT11 and the response to these parameters' variation is done by using a fan. The system in this work proposes a farm with DHT11sensor that is placed in the middle of room's roof to collect the temperature and humidity of the room. To keep the farm's parameters, duty cycling is used for the fan control. Watering is done by manual traditional system and thus needs to be improved by automating the use of the water pump and save water resource in the farm.

Our research works on using technology for shiitake mushroom farm monitoring and controlling. Shiitake mushrooms are a type of mushroom that is mostly used in medicinal applications to boost immunity and sometimes used as a dietetic ingredient. This study contributes to shiitake mushroom vital parameters monitoring and harvest improvements.

3. Proposed Method

This part of the paper identifies the overall components of the proposed system. We used IoT technology to build a system according to the requirements for shiitake mushroom cultivation. The built system implements fuzzy logic to monitor the farm's vital parameters namely air humidity, temperature, and soil moisture in the substrate.

In addition, a light and proximity sensors are added to notify the farmer about the light intensity changes respectively the presence of an external agent in the farm. We used a system with three main parts namely the sensing part (Sensors), controlling part (Micro-controller), and actuating part (Water pump).

The sensing side is composed of a temperature & humidity sensor for the farm air temperature and humidity collection, a soil moisture sensor for the substrate's moisture sensing, a PIR to detect movements, and a light sensor to detect the light intensity of the farm.

The controlling side is made of a NodeMCU ESP8266, Arduino UNO, and a cloud platform for data analytics, and an actuating module is made of one 12V DC water pump and one relay to make them controlled by a NodeMCU ESP8266. The design of the proposed system is summarized as of the following Figure 1 with three main sides stated above.

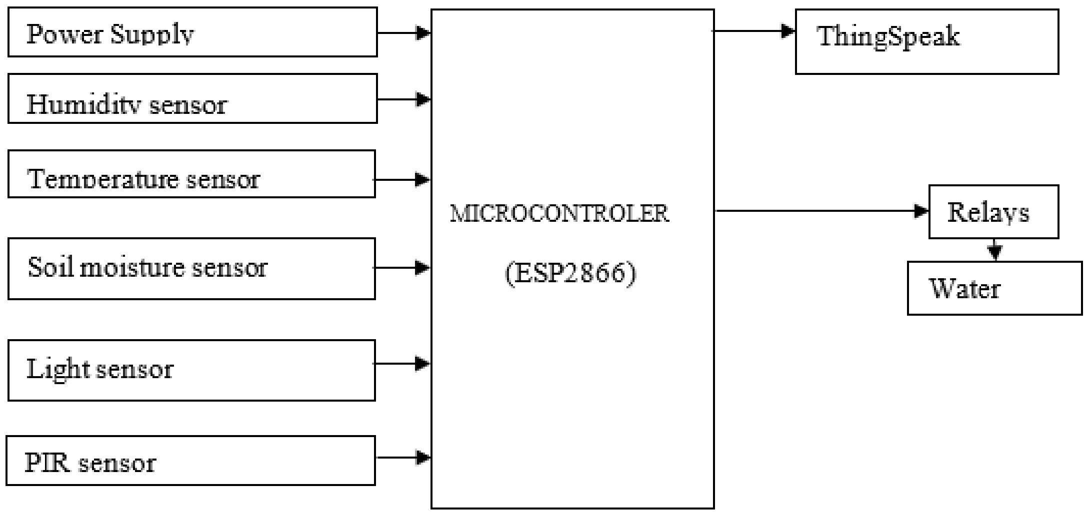

Figure 1: Components of the proposed system

Besides, the proposed system has four layers arranged from perception layer to application layer as illustrated in Figure 2. The purpose of these layers is to secure any communication and interactivity between the components of the system. All hardware devices of our self-powering automatic watering system of the mushrooms farm are placed in the device and perception layer, all the networking and communication components are placed in the connectivity and network layer, the management layer hosts all services such as cloud storage, device management, and storage, and application layer is for IoT application and actuation service. The flowchart in Figure 3 shows the functionality of the whole system.

Fuzzy logic is a logic built on a theory of graded concepts, a theory in which everything is a matter of degree. Unlike two-valued Boolean logic, fuzzy logic is based on degrees of membership. In this work, the fuzzy system is performed through three stages namely fuzzification, fuzzy processing, and fuzzification.

Fuzzification is the first operation in a fuzzy system that works on input data, it is a process mapping a crisp input value of a system into a fuzzy input, which is to associate with a fuzzy set.

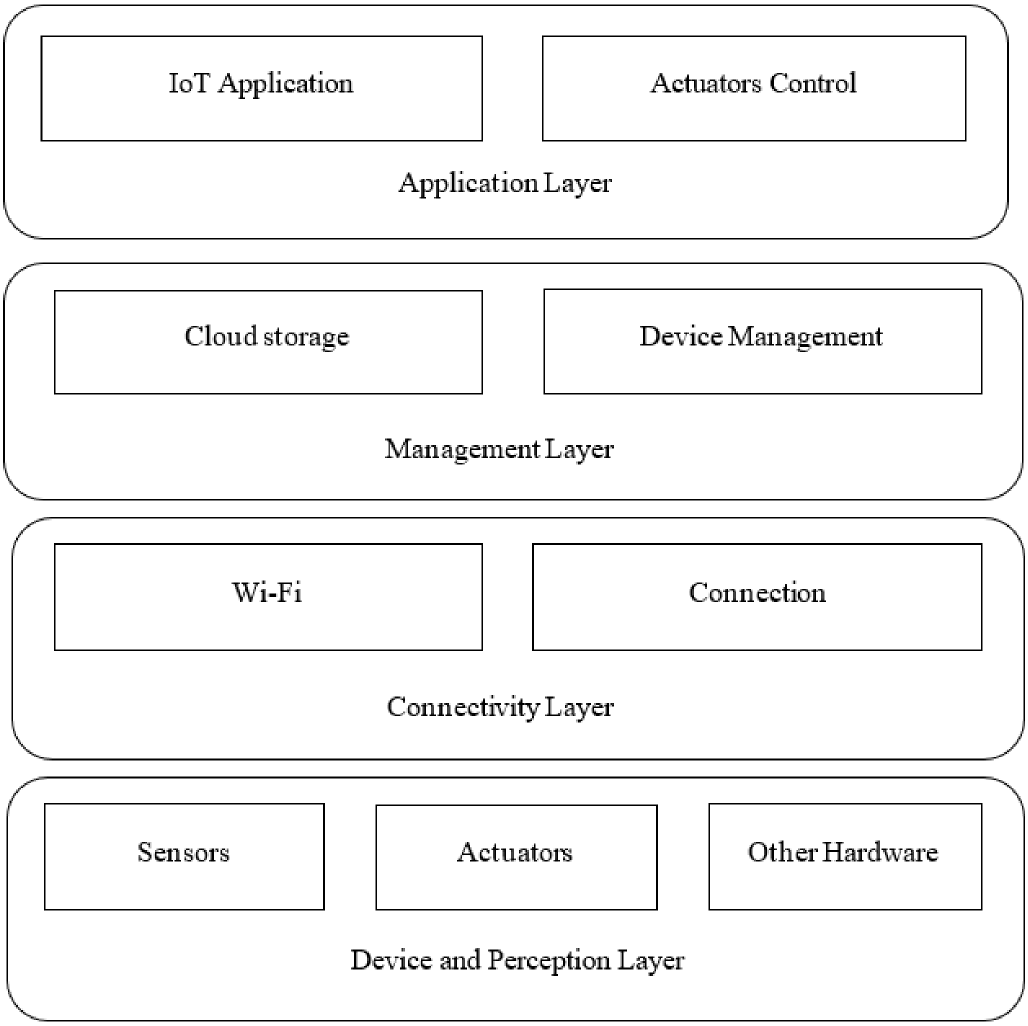

Figure 2: Layers of the proposed system

Mathematically, fuzzification can be defined as a mapping F of the crisp input domain I, to a set A of fuzzified input. That is as $F: I \rightarrow A$; (1)

In the context of our research, the crisp input domain I, is a set of all the data collected from the sensors, and the fuzzified input are the ones got after fuzzification. A is a set of fuzzified inputs.

Fuzzy processing consists of applying fuzzy rules on fuzzified inputs with the purpose to provide output. A Fuzzy rule is a form that serves to describe, in linguistic terms (words) a qualitative relationship between two or more variables. That is, it joins the input variable(s) and its (variables) influence with the output variable(s) and these may be linguistic or scalar [7].

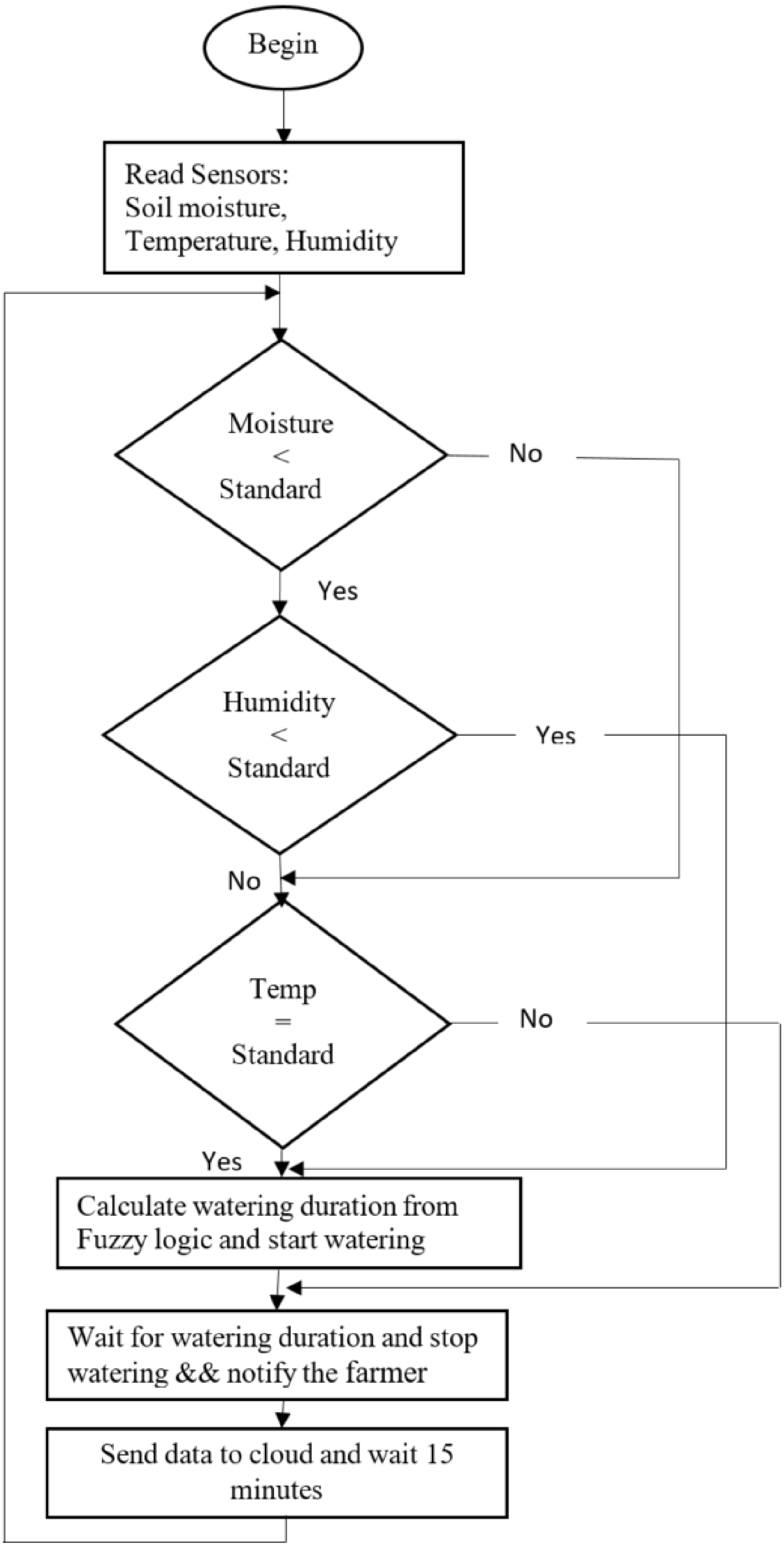

Figure 3: Algorithm of the proposed system

For our research, we have 8 rules as listed in Table 1 to monitor the water pump state based on the input values. These rules are set based on the threshold values that are the normal values of the Shiitake mushroom farm to grow efficiently. As of Pravinth Raja et al. [5] the normal ranges soil moisture, and humidity to grow shiitake mushroom are respectively 30% – 65%, and 80% – 90%, and if the two of them are satisfied, with the temperature in normal range 20 ^{O}C – 30 ^{O}C, the farm is in a normal state and otherwise if one of the two is not satisfied. However, in case a high humidity raises with or when the temperature is out of the standard, a farmer is notified and can manually handle it by adding some soil to absorb extra water, and every time the temperature is not in the standard range, the farmer is notified too.

Table 1: Fuzzy rules for the farm stability

Rules	Soil Moisture (M)	Humidity (H)	Temperature (T)	Pump state
1	30% ≤ M ≤ 65%	80% ≤ H ≤ 90%	20ºC ≤ T ≤ 30ºC	OFF
2	30% ≤ M ≤ 65%	H < 80%	20ºC ≤ T ≤ 30ºC	ON
3	M < 30%	80% ≤ H ≤ 90%	20ºC ≤ T ≤ 30ºC	OFF
4	30% ≤ M ≤ 65%	90% ≤ H	Out of the standard	STANDBY (Notify the farmer.)
5	65% ≤ M	80% ≤ H ≤ 90%	Out of the standard	STANDBY (Notify the farmer.)
6	M < 30%	H < 80%	20ºC ≤ T ≤ 30ºC	ON
7	M < 30%	80% ≤ H ≤ 90%	20ºC ≤ T ≤ 30ºC	ON
8	65% ≤ M	90% ≤ H	Out of the standard	STANDBY (Notify the farmer.)

Defuzzification consists of translating the output from fuzzy processing in commands understandable by the actuating system which is a water pump for this work. Fuzzification in this work, the following logic called center of gravity (COG) is used.

$$Ieval = \frac{\sum_{i=1}^{n} x_i \mu(x_i)}{\sum_{i=1}^{n} \mu(x_i)}; \quad (2)$$

With: x_i : The gradient value for a pixel

$\mu(x_i)$: Membership function

n : Number of gradient values for the cover image

*I*eval: The edges image needed

Cloud computing means storing and accessing data and programs over the internet instead of your computer's hard drive. The cloud is also not about having dedicated network-attached storage hardware or server in residence, it's as a service such that with all the various data stored on the computers in a cloud, data mining and analysis are necessary to access that information in an intelligent manner [8].

Three cloud platforms namely ThingSpeak, Beebotte, and DataGekko, have been evaluated to choose one of them for our project, Thing speak is an open-source Internet of Things application and API to store and retrieve data from things using the HTTP and MQTT protocol over the internet. It is an IoT analytics platform service that allows to aggregate, visualize, and analyse data streams in the cloud [9]. Beebotte is a cloud platform that provides key building blocks to accelerate the development of the Internet of Things and real-time connected applications. Beebotte enables the transformation of any physical object or software application into a channel of digital resources [10]. Beebotte is a cloud platform that offers infrastructure and connectivity with the help of REST, Web Sockets, and MQTT [11]. DataGekko is a fully managed enterprise-grade metrics as a service solution, DataGekko can ingest data over MQTT with millisecond precision of data points with full resolution, this is an IoT Telemetry platform ready for the next generation of internet-connected devices that scales with you from hobby plans to enterprise systems [12]. For our project, the ThingSpeak API is chosen because it has three channels where each channel can store 8 variables and we must store data about harvested energy, soil moisture, humidity, temperature, and real-time with an additional feature of best store and visualize data.

The Arduino Integrated Development Environment (IDE) is a cross-platform application (for Windows, MacOS, and Linux) that is written in functions from C and C++. It is used to write and upload programs to Arduino compatible boards, but also, with the help of third-party cores, other vendor development boards. In this research, Arduino 1.8 version is used.

4. Simulation Results

Based on the soil moisture content, whenever the system detected high amounts of water the pump remains closed. Tradition techniques that require visual aid to determine if the soil needs to be watered prove to be ineffective which leads to soil moisture going above 90% or under 80%. The use of an IoT system helps to regulate the soil moisture content by maintaining the soil moisture content at the recommended levels. The results in Tables 2 and 3 are obtained from data recorded from the system and recorded in ThingSpeak API for analytics (Figure 4).

Table 2: Estimated values for two mushroom farms of 10 seed bags each

Variables	Existing method		Proposed method	
	Average hours per day	Percentage (Hours/24) *100	Average hours per day	Percentage (Hours/24) *100
Soil moisture in the range 30%–65% (average hours/day)	6	25%	12	50.0%
Air humidity in the range 80%–90% (average hours /day)	12	50%	16	66.67%
Temperature in the range 20ºC–30ºC (average hours/day)	6	25%	9	37.5%
Farm Stable time (time without pump action)	6	25%	16	66.67%

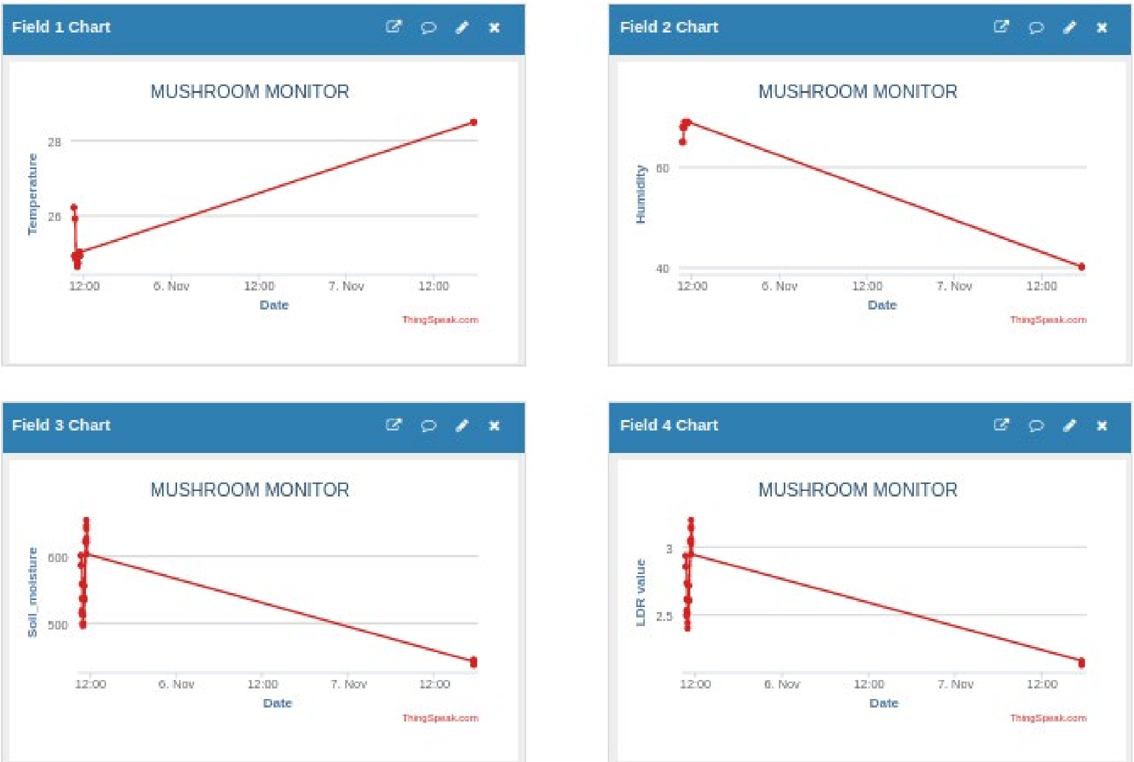

Figure 4: ThingSpeak visualization. Source: ThingSpeak application

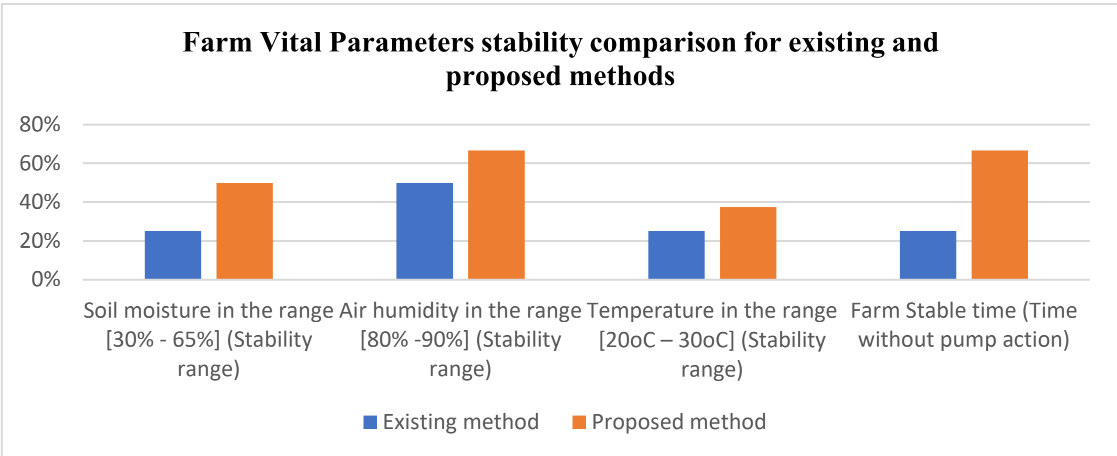

Figure 5: Histogram for farm Vital Parameters stability comparison for existing and proposed methods

Based on the duty scheduling, the system can regulate environmental conditions up to 95% of the monitoring duration. This metric is obtained by considering the number of times during the day the environmental conditions stayed within the recommended ranges against the total duration, that is, (Hours conditions stayed in range/24) *100.

Table 3: Water use optimization (100 litres are availed for both farms)

Variable	Existing method		Proposed method	
	Water used in 24 hours	Water saved in 24 hours	Water used in 24 hours	Water saved in 24 hours
Water utilization	10%	90%	2%	98%

5. Conclusion

In this research, an IoT fuzzy logic-based approach scheme was developed for shiitake mushrooms with an automated watering system to monitor on an automatic basis a mushroom farm. Based on related literature examined, the currently used techniques in mushroom farming are mainly manual and showed that the harvest is not sufficient and water resource use is not optimized. Most of the types of mushrooms are important for medical and nutritional ingredients, but shiitake mushroom is the most needed type of mushroom because of its nature to fit too many medicinal drugs ingredients, and many nutritional ingredients and hence this specific type of mushroom deserves attention in increasing its harvest.

Our research focuses on using IoT-based technology to maintain the farm's vital parameters stable The obtained results demonstrate that the use of IoT in shiitake mushroom cultivation increases the yield in shiitake mushrooms compared to traditional methods namely, fixed time watering because, with our internet of things-based approach, we can harvest more than one mushroom from all the 10 seeds at the 21st day after seeds plantation while with the existing fixed time watering at the 21st day we can only get the mushrooms on 3 seed bags. Further, using fuzzy logic in automating the control of the watering time, saves water quantity because the water pump opens based on data got from the field and hence the farm's vital parameters are kept stable, which means that when the farm parameters are favourable, a pump can remain closed for more than two days which saves water. With the traditional fixed time watering system, the pump gets open always based on time intervals that can make much water used without being needed based on the farm parameters or climate.

We recommend that this study should be implemented with many other types of mushrooms to improve the harvest of mushrooms because they are the crucial inputs for both nutritional and medicinal use and their harvest is still low. In addition, this research can be improved by controlling other factors of the mushroom farm such as wind speed and direction, water type and temperature control, and fuzzy type II can be used to handle with precision those suggested farm factors.

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The Use of Different Technology Within PlantScope: A Case Study of Plants in Nigeria

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ABSTRACT Agriculture serves as the primary source of food in Africa, and it predominantly affects the economy of Africa. To increase the productivity of cultivated plants, early detection of diseases is very important so that all other crops remain uninfected. The manual detection of disease realistically is an extremely challenging task. One can apply machine learning algorithms to develop a system that correctly identifies diseases in leaves. This will typically assist farmers to minimize crop failure and accurately identify the infections in plants more precisely and effortlessly. This paper is concerned with the development of an automated system that can automatically detect disease using leaf image classification. We are able to utilize machine learning to automatically find the changes in color or the existence of spots or rotten areas in the plant leaf. Furthermore, in this system, we also automate the process of capturing images of the leaves and crop using an unmanned aerial vehicle with a camera that automatically captures the images.

1. Background of PlantScope

Disease can negatively impact plant health before any obvious visible signs like leaf discoloration are noticeable. While these stresses are invisible to our naked eye, drone cameras using special filters could detect these subtle changes in real-time. "Evidence has shown that drone remote imagery can help to identify disease related stress in plants" (Dennis & Beales 2019). However, could the spectral signatures of infected plants be unique enough to differentiate the causal disease remotely and, if so, how could we use this to reduce the burden on inspectors in the field or better target our inspections?

PlantScope help farmers find more efficient ways to protect their crops from diseases by leveraging computer vision, Machine Learning and Deep Learning to monitor and precisely detect plant and crop diseases (Figure 1). By using unmanned aerial vehicles (UAV) plant and pest disease can be detected before any visible signs show, allowing farmers to stop infections in their tracks. Our multi-spectral and hyper-spectral imagery are often used to measure the responses of plants in the visible and near infrared parts of the electromagnetic spectrum to remotely detect plant stress using drone technology. Allowing farmers to identify stress before full infection occurs is particularly important as the climate changes. An unpredictable environment makes it challenging to track and forecast disease.

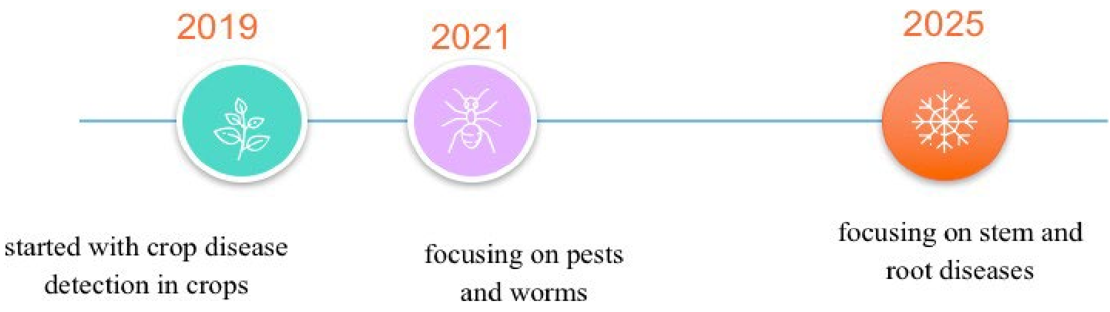

Figure 1: Milestone for PlantScope

1.1 – About PlantScope

PlantScope uses Deep Neural Networks based on the recognition of plant and pest diseases by a leaf and crop image classification dataset to detect diseases and pests in plants. Using images captured by a drone camera with various resolutions, PlantScope sends data in an offline way to the farmer's mobile phone (Figure 2) both on Android and iOS and to our server; our mobile App does the processing and sends real time results. It then broadcasts messages to the nearby farmers in the communities to allow them to get the specialized agronomist and their location. Currently, the database has over 1600 photos and covers eight crops. Every time a farmer uploads a photograph for diagnosis, it will be time-marked and geo-referenced. Hence, the database also facilitates pest and disease outbreak monitoring and can send early warning messages for specific locations in real time.

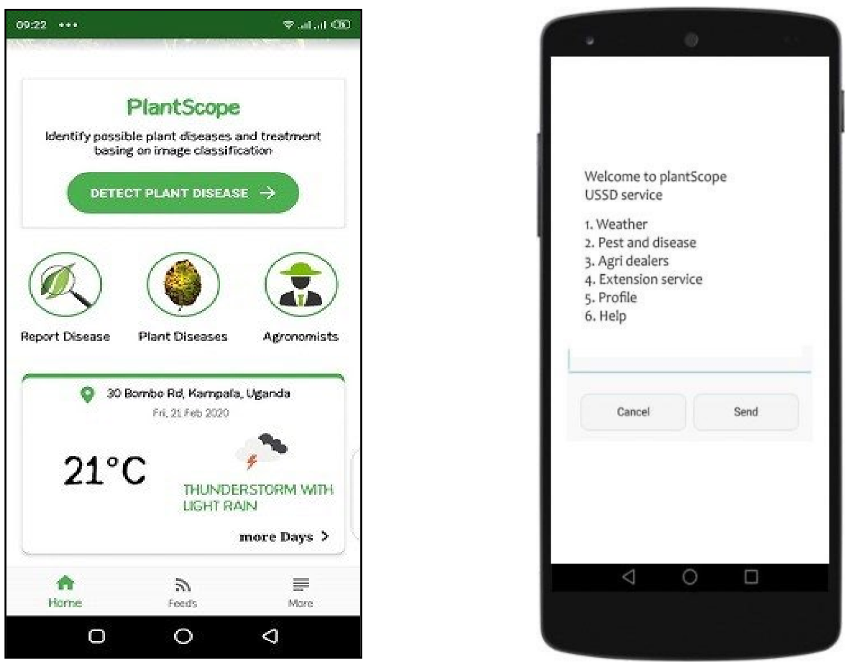

Figure 2: The PlantScope smartphone app and USSD app

1.2 – How the system works

We train and test our systems end-to-end on our large Pests and diseases Data set, which contains challenging images with diseases and pests, including several inter and extra class variations, such as infection status and location of the plant. Experimental results show that our proposed system can effectively recognize seven different types of diseases and pests, with the ability to deal with complex scenarios from a plant's surrounding area. Diseases reduce yields when we need them to be high, as the global population grows and we need to feed more people than ever. Reducing yield loss to diseases like Cercospora leaf spot in Maize, Rice Tungro disease, cassava mosaic disease and many others will allow us to grow more food, more efficiently and on less land, benefiting the agricultural industry, the public and the environment.

A farmer can use a drone to detect any anomalies, upload a photo of infected crops and send it offline to the farmer's mobile app. The mobile app does the processing, it broadcasts which disease has been detected to the nearby farmers within that community with all descriptions about that disease, the contact and location of the specialized agronomist to work on that crop and give advice in real-time. Besides giving a diagnosis and steps to mitigate the disease, the app also provides information on preventing the disease in the next cropping season. We believe that with the power of machine learning, we integrate the latest technologies into agriculture and always make them accessible to everyone. This is our contribution to securing global food production. Specializing in agricultural crops that feed the world, Plant Scope empowers farmers to make a living by providing comprehensive support on all issues that are important to farmers. Plant Scope algorithms integrate and analyse the captured images and data to provide a detailed report on the health accurately and faster to detect diseases and pests in plants and pest diseases. This helps farmers in early treatment technique while substantially reducing economic losses. The ability to control disease early enough is a top priority for farmers and an ongoing challenge such as herbicide resistance becomes more com.

No Lab Needed: Our system uses images of plant diseases and pests taken in-place (Figure 3). Thus we avoid the process of collecting samples and analysing them in the laboratory.

Figure 3: Kids taking pictures of drones making images in-place

Our Approach: Our approach uses input images captured by different camera devices with various resolutions such as drone, cell phone and other digital camera (Figure 3).

Figure 4: Agronomists in the field

It's Efficient: It can efficiently deal with different illumination conditions, the size of objects, and background variations, etc., contained in the surrounding area of the plant. Our drone and the app employs AI in real time so the farmer can be an active participant in disease diagnosis and crop health management, leading to more yields for smallholder farmers. Our artificial intelligence is also based on the world's best human intelligence on crops (including agronomists working in the field (Figure 4). We created cameras mounted on drones and the cameras can automatically detect early disease stages, and tell farmers when to spray, before the disease damages the crops and send the images to the mobile app for processing and after it broadcasts messages to people around that community. We also provide the latest management advice for all major diseases and pests which pinpoint the location of the nearest agricultural extension service provider for advice.

Proposed System: There are many techniques based on computer vision that are being used to extract features to a number of classifiers in identification systems. In this paper, a new proposed model involving neural networks is developed to reach improved performance and scalability.

Figure 5: Weather forecast for 21 days

USSD to Small Holder Farmers: The data is automatically uploaded on the cloud, where images are analyzed with an Artificial Intelligence model to determine crop health and thereby predicting expected yields and the presence of symptoms of crop pests and crop diseases. Moreover, crop data is mapped to our geographical information mapping system. From the data analysis, feedback to guide farmers is relayed through Unstructured Supplementary Service Data, that is USSD, and plain Short Message Service, SMS, to advise on Plant timings, the correct recommendations of exact fertilizer, pesticide and insecticide based on the data collected from the farm, weather alerts, seed recommendation and crop rotation advisory.

Present Roll-Out: We have rolled out in Oyo State in Nigeria, in the Ibadan area.

2. Architectural Model

The prototyped solution is composed of three subsystems: UAV (Drone); Training Neural Network model for predicting pests, worms and diseases in crops Information tool for farmers, agronomists and scholars; Mobile App for analytical as well as outbreak reporting.

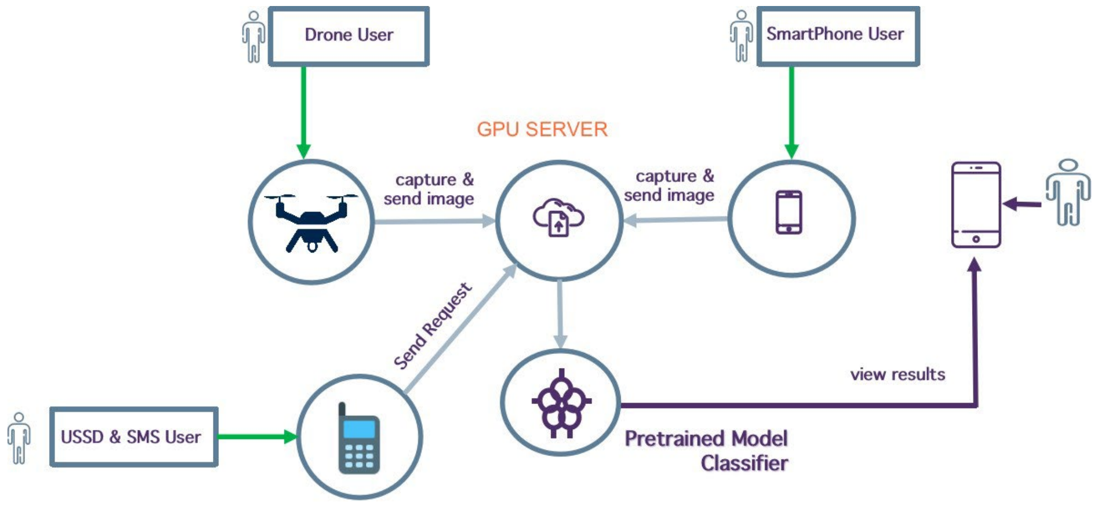

Figure 6: The architectural model of Plant Scope

Drone Mechanization: A powerful drone capable of making long missions to cover a scale of land will be required in this project. The DJI Matrice drone series can successfully be used because of their precision, accuracy and powerful cameras which can be unmounted and replaced to improve performance.

Ground station: The ground station is divided into two subsystems, the first being planning and monitoring, the second being flight controller. The ground station connects to the UAV network using MQTT protocol (MQTT 2022). Using an RC-Channel that bridges the control system and the drone, realtime feeds can be analysed by the flight controller at the command centre. The packets sent can then be relayed to the server in real-time basing on the flight controllers instructions.

Flight Controller: Using ground station software, flight controller can set the system in auto mode to do both monitoring and detection mission while tracking non-surveyed points to cover the entire landscape.

3. Classification model

The process of designing the proposed model comprises of two steps. The first step is creating a convolutional autoencoder (CAE) network that reduces the dimensionality of entity (leaf or worm) 256x256 to 32x32 (Figure 7; for CNN see e.g. Albawi et al. 2017). The CAE network also contains a decoder network that is used to reconstruct the original data from the encoded data. The training of CAE network is done such that reconstruction loss is minimized. This ensures that the CAE network reduces the dimensionality of the images without losing its important features. The different layers of the network as shown in Table 1.

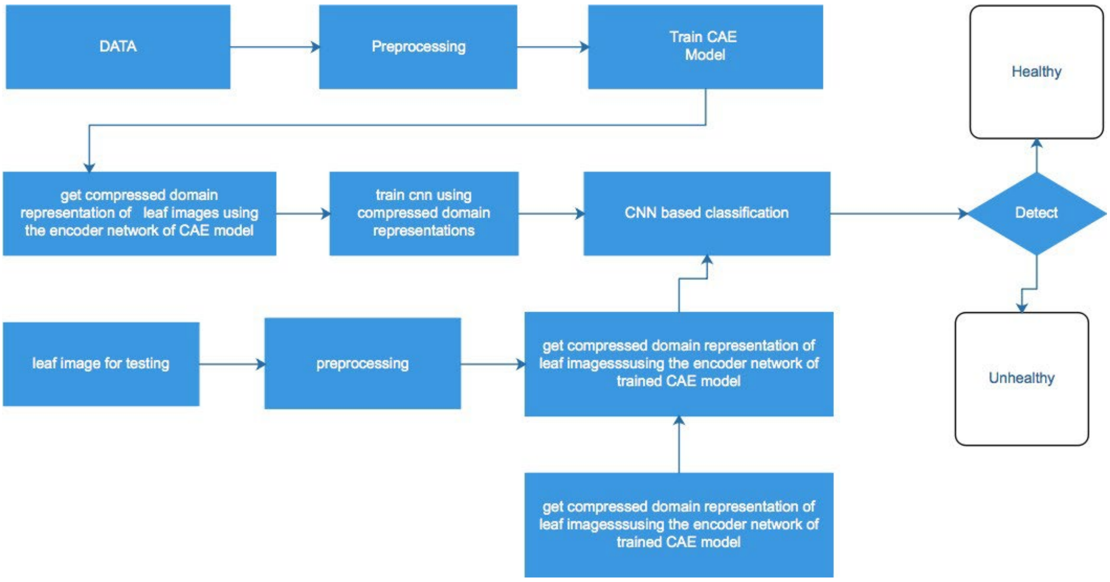

Figure 7. The classification model

Our model focuses on 5 crops – maize, rice, tomato, cassava and bananas – which are common crops grown in Nigeria. Examples of infected leaves are shown in Figure 8.

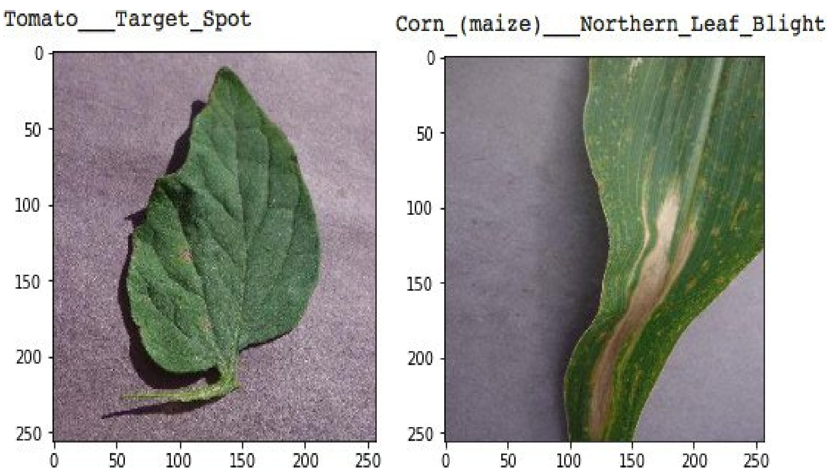

Figure 8: 256x256 images of various spotted greens

Performance: Basing on sample data, our model has an accuracy of 92%. (Figure 9 shows but one example for how validation data can look.)

Model Improvement: The model can be improved by increasing pre-trained models using K-fold cross-optimization or Ensemble Learning (Zhou 2021).

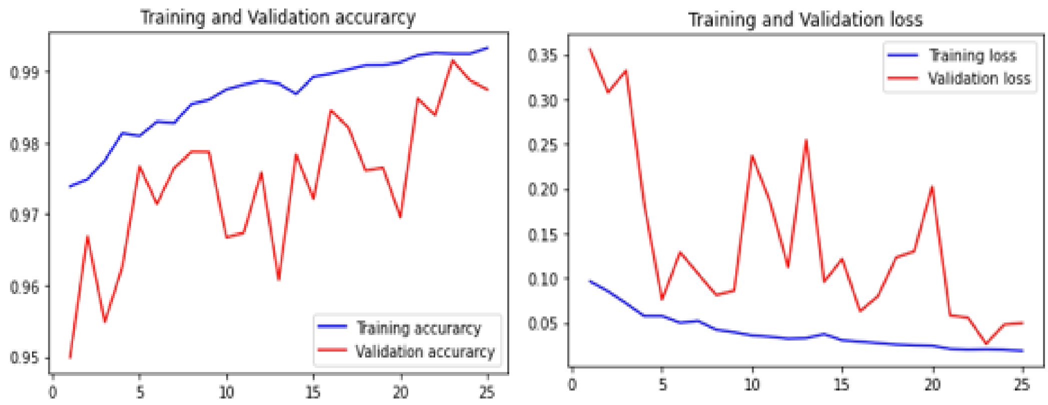

Figure 9: Performance for Training and Validation accuracy and loss

Table 1: The different layers of network

Layer No	*Layer (type)*	*Input shape*	*Number of filters/ channels*	*Size of each filter/ channel*	*Activation function*	*Padding*	*Output shape*
1	Input layer	256 x 3 256 x 3	-	-	-	256x256x3	0
2	Conv #1	256 x 16 256 x 3	3x3	ReLu	Same Padding	256x256x16	448
3	MaxPool #1	256 x 16 256 x 16	2x2	-	-	128x128x16	0
4	Conv #2	128 x 8 128 x 16	3x3	ReLu	Same Padding	128x128x8	1160
5	MaxPool #2	128 x 8 128 x 8	2x2	-	-	128 x128 x8	0
6	Conv #3	64 x 8 64 x 8	3x3	ReLu	Same Padding	64x64x8	584
7	MaxPool #3	64 x 8 64 x 8	2x2	-	-	54x64x8	0
8	Bottleneck layer	32 x 8 32 x 8	3x3	ReLu	Same Padding	32x32x8	584
9	UpSampling Layer #1	32 x 8 32 x 8	2x2	-	-	64x64x8	0
10	Conv #4	64 x 8 64 x 8	3x3	ReLu	Same Padding	128x128x8	584
11	Up Sampling #2	64 x 8 64 x 8	2x2	-	-	128x128x8	0
12	Conv #5	128 x 8 128 x 8	3x3	ReLu	Same Padding	256x256x8	584
13	UpSampling Layer #3	128 x 8 128 x 8	2x2	-	-	256x256x8	0
14	Conv#6 (Output Layer)	256 x 3 256 x 8	3x3	ReLu	Same Padding	256x256x3	219

```
# Initialize optimizer
opt = Adam(lr=LR, decay=LR / EPOCHS)

# Compile model
model.compile(loss="binary_crossentropy", optimizer=opt,

# Train model
print("[INFO] Training network...")
history = model.fit_generator(augment.flow(x_train, y_tr
                              validation_data=(x_test, y
                              steps_per_epoch=len(x_trai
                              epochs=EPOCHS,
                              verbose=1)
```

Figure 10: The Train Model

4. Conclusions and further work

Our proposed system allows the users to automate the entire process of plant disease detection thus reducing the difficulties that the farmers face while growing crops and saving their time. We achieved good accuracy in the prediction of plant and pest diseases. Our model trained using AutoML delivers a better accuracy as compared to the model trained by using the Inception_v3 architecture (Szegedy et al., 2015; general on Inception, see Alake, 2020).

Although this method can be effective for disease detection in plants, there is a very important challenge in designing this system, which is capturing the images using the camera and drone. The challenge is to get a high-resolution image of the plant leaf for which we need a camera with proper shutter speed, optical zoom, and a high resolution. We need to look at various parameters to make this system perfect.

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An M4D Sequel – Interview with Ronald Katamba

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ABSTRACT This paper about Ronald Katamba, founder of Afrosoft IT Solutions and Jaguza Livestock Ltd., tells the story of an entrepreneur who started by providing students internship placements, but later expanded to offer farmers advanced mobile tech-enhanced livestock tracking services, all through a Mobile for Development lens.

1. A presentation at M4D 2016

As Makerere University in Kampala, Uganda, struggled with finding internships for its IT and IS students, Ronald Katamba founded Afrosoft IT Solutions in 2012 to among others provide internship placements for students through attaching them to company projects as part of their practice and taking them through skill-based re-tooling sessions. However, alongside founding and running Afrosoft, other ideas were brewing in the mind of Ronald Katamba.

At the M4D conference in Mozambique in 2016, the CEO of Afrosoft IT Solutions presented a paper entitled “Jaguza livestock App: Powering livestock production to strengthen food security” [1]. This was one of the first presentations for a larger international audience. The local conference chairs had invited several people from Mozambican ministries and there was strong interest in this Ugandan innovation. M4D2016 closed and the following day Ronald spoke to the Minister of Agriculture in Mozambique. Rapidly, even more agencies got interested in this approach to using high-tech in an affordable form to help rural farmers in developing countries. At the beginning of 2017, we received an e-mail from Ronald where he told us that he had been invited to the Commonwealth ICT Application forum in February 2017 in Kigali “to give a motivation speech” to international innovators and entrepreneurs and that he was heading to Washington DC and World Bank in March. “I also want to thank M4D 2016 for giving me chance to be part of your conference in Mozambique – it was a blessing to me because I got a lot of opportunity.” (Email 2017-Feb-03.)

His entrepreneurship also caught the attention of news media. CNN, in its series “Inside Africa”, portraits four Ugandan “agri-tech” entrepreneurs in a video from 2021 [4], where the news agency notes that “In Uganda, innovators and entrepreneurs are modernizing an ancient industry by fusing agricultural methods with technology, and in the process, drawing in a new crop of young farmers to sow the seeds of a bountiful future.” This paper is *about* a practitioner rather than *by* a practitioner. We have interviewed Ronald and made some follow up questions by email to share the developments in his journey from the M4D conference in Mozambique back in 2016 to-date. The interview took place while Ronald was in Dubai in

December 2021 at the *Africa Internet of Things & Artificial Intelligence Conference* to present a paper about adoption of drone technology and AI in Africa with Jaguza as the case studied. (At the present M4D 2022 conference, he presents drone technology and AI for plant diseases detection [3].)

2. Background

Interviewer: “Where to start a paper on your work?”

“Afrosoft. Afrosoft has supported young entrepreneurs. Makerere University retained me for teaching computer programming courses after my undergraduate studies.”

“I started Afrosoft and so far we have had a hundred students do their internship with us. And trust me, by the time they finish, they have all the experience the labour market asks for.”

Student Internship or Field Attachment as it is currently called as per the current Makerere University Guidelines on Field Attachment[3] is a field-based practical training experience that prepares trainees for the tasks they are expected to perform on completion of their training. It means any approved field-based practical work carried out by staff and students for the purpose of teaching and/or research in places outside the University control but where the University is responsible for the safety of its staff, students and others exposed to their activities.

The purpose of field attachment at Makerere University is to produce practically oriented graduates that meet the required job-related competences of their future employers. Additionally, it serves as a linkage between the University and various partners who consume services and/or products of the University.

University Academic staff in each unit together with industry partners are supposed to identify suitable sites for students’ attachment. Students are also encouraged to look out for such sites and inform their Heads of Departments for approval.

It is recommended that all teaching units conduct their field attachment at the end of the second semester and each period of field attachment should last at least eight (8) weeks per year. Calendars of universities in Uganda, both government and private, are similar. Therefore, all universities send students for field attachment almost at the same time. This causes high competition and scarcity of field attachment places. Some institutions have resorted to setting quotas for the different major universities not to be seen favouring some universities over others. One of the categories of university students most affected by this scarcity is students of Computing and IT given the infancy of the sector in Uganda. Hence, every year a considerable number of students fail to get conventional sites for field attachment which affects their progression. It is this gap that Ronald Katamba and a few other tech entrepreneurs responded to by setting up Afrosoft Ltd. His teaching experience at the University in the early years of his career helped him to see what skills and attributes to focus the Afrosoft Ltd field attachment package on. Hence, students given field attachment places in his company did not get problems with approval. Whereas first priority is for work based sites, overtime, hybrid sites like Ronald Katamba’s have also become acceptable as valid field attachment placements for Computing and IT students at Makerere University so long

[3] https://policies.mak.ac.ug/policy/guidelines-field-attachment

as they offer relevant hands on skills training for areas either not adequately covered or not covered at all in the curriculum.

Afrosoft's inspiring environment also helped Ronald find people to work with on the Jaguza App as one can infer from an interview on May 20, 2021, with Christine Kihunde Kiiza, Co-Founder of Jaguza Tech U Ltd:

"I joined Afrosoft IT Solutions Ltd, which at the time was working on Jaguza Livestock App. During the course of business, I got interested in the innovation, became a co-founder and later registered it as an independent company." [5]

Ronald's own story is one about a struggling young person. As when he tells about how he tried to start rabbit breeding when he had become an orphan when he was twelve years old. Only to find them dead one day from a sickness he had no means to treat!

In our interview with Ronald Katamba, he underlines that Jaguza also brings help to young farmers. This is an interesting remark, as at his very first conference appearance, there was a researcher, Heike Baumüller, who made a literature review but found "a dearth of empirical evidence that could substantiate or contradict the pathways by which m-services could help farmers adopt innovations. […] Also, most studies do not differentiate between different user groups although the propensity and ability to use an m-service may differ considerably. Further research is also needed on difference in usage and impacts between those owning and sharing phones." [6, p. 142-143] With Jaguza's inclusion of young farmers in their target group, they might actually find more farmers willing to adopt their technology. It furthermore makes it conceivable for young people to start farming, and this is also one of the points made in the CNN video.

According to Ronald, Jaguza aims to help farmers increase livestock production. There are problems with malnutrition in Africa, he notes, and adds that often we cannot find information.

"That was the background of Jaguza, which is now in five countries. Rabbits died, and I started from afresh, and I managed to go back to school too. That was the background of Jaguza."

3. Jaguza

On their website, Jaguza prides itself on various features provided by the app, e.g.: "Our livestock record keeping software stores and organizes all information on an animal from birth to processing or relocation, with direct information flow across seed stock, cow, calf, feedlot and packing sectors. […] Here at Jaguza, we do not want to tell you how to run the show. Instead, we offer our superior livestock record keeping software to help farmers tell the story of their animals. Improve the quality, reputation and demand for your product with safe, secure and thorough historical records, bringing the relevance of the past into the present." [7]

However, Jaguza is not alone in the field of farm tech: co-founder of Jaguza Tech U Ltd. Christine Kihunde Kiiza mentions "Our competitors are E-Farm in Uganda and Daral Technologies in Senegal. Our system is both online and offline, and we use IoT devices and have a farm record system, marketplace, which gives us an upper hand over our competitors.

Our team is also in-house, passionate about what they do, and innovative and open to learning new technologies to keep competitive.” [5]

At a subsite of the Jaguza Farm website, support to registered farmers is provided through detailed information and through an open discussion fora about farming and related issues [8].

4. The development

Ronald tells about what spurred the development of the Jaguza. Detecting diseases was definitively one of the prime motivations after his experiences with the rabbits dying off. The number of veterinarians in rural areas is low. A photo or video to send to online vets should be helpful in many parts of the world. Language can be a problem when distributing an app internationally, but Ronald assures that Jaguza manages the linguistic issue even with the multiple countries they are in now: Uganda, Mozambique, Namibia, South Africa (Southwest Cape Town), and, a bit surprisingly, Fiji – ITU and Commonwealth funded his trip for a Commonwealth event there. Some knowledge of English is rather common among farmers in these countries except Mozambique, but the app has been translated into Portuguese and later into Spanish. In addition, the app has also been translated into Luganda, Swahili and Runyakitara. Luganda is the most widely used local language in Uganda. Swahili is used around East Africa where as Runyakitara (covering 4 different tribes) is used in Uganda. Furthermore, Jaguza Livestock Mobile App is available both for Android and iOS.

He also mentions markets. “We find markets. It is otherwise a problem in Africa. We have market intelligence so that everyone can find better markets.” (Subsite [9] shows a web-based market.)

Nowadays the Jaguza team works on machine learning and data science. As the company website so proudly declares: “Jaguza learns patterns about a cow’s movements from a wearable sensor. We use this data to develop machine learning models and Tensor Flow algorithm, and ultimately, Jaguza can detect activities from eating, drinking, resting, fertility, temperature and more […] to predict problems earlier, detecting cases like lameness or digestive disorders hence provide recommendations to farmers on how to keep their cows healthy and improve efficiency of their farms. Using these insights, we’re already seeing a 35 percent increase in livestock production on our customers’ farms.” [10]

Ronald says that the bigger vision is a data centre with a huge amount of data from the five countries they are operating in. “We try to visualize the data we have in meaningful ways. Visualisations can be seen by individual farmers, but data is centralized so that the functions are run by us.”

Moreover, “If someone came from a rich country and wanted to support agriculture, they would not know where to start. But if they come to Jaguza, they would get background information, we provide researchers with data, and we can point out where projects can be run. We do not yet service government agencies. We are working out plans where they have to pay us. This is a way to have our business economically sustainable.”

Ronald shows a small drone, palm-sized: “We use also drones. With machine learning, farmers could be counting their cattle in 10 minutes” (cf. photos from Jaguza in Figure 1). Then he shows a cattle tag and demonstrates its little solar cell (cf. Figure 2). The tag can send signals to the drone. Ronald wrote a patent application helped by the National Council

Figure 1: Drones of two sizes: hand-held and palm-sized (Photos: Jaguza Livestock Ltd)

of Science and Technology plus Uganda Registration Services Bureau. The National Council of Science and Technology is also important from another aspect. It grants permits for field studies: “They gave me a research certificate to do my proof of concept in two districts in Uganda.”

In the M4D conferences, presenters sometimes suggest greater use of USSD. And in a blog post on Jaguza’s website [5], we find Kihunde Kiiza saying that “we understand that many farmers in rural areas do not have smartphones or internet. Therefore, we also have a USSD Code and SMS platform where farmers can access our services. Our farm record management system is also offline to help rural farmers keep their records.” We asked Ronald about Jaguza’s USSD code launched a couple of years ago – how many new users did you reach? Are the numbers still increasing?

Figure 2: Solar-powered GPS as ear tag for cattle (Photo: Jaguza Livestock Ltd.)

“We have so far 22,000 registered users on USSD, 5,500 users of our Mobile application (IoS and Android) and 32,000 device installations so far. We could have more but the USSD code has been down this month. Our USSD farmer started using it in 2019. I can share with you the infographic report and clearly show the number of men and women who benefited, which country is using our product more and the districts.”

Interviewer: “Have there been any change along the IST-2017 paper recommendation [2] against import taxes on agriculture gadgets?”

“Yes, the World Bank, European Union and many organizations have been sitting on my paper and we have the opportunity that the government of Uganda under Uganda Revenue Authority has waived taxes on our devices we import from China and Taiwan.”

5. Diffusion of the company’s innovations

Finally, we had a discussion with Ronald over the diffusion of innovation [10]. Obviously, in some countries where presentations have been made, there has been interest from governments which has facilitated the adoption. Why not Tanzania or Kenya? Ronald emphasises that the adoption process is different in every place. He points out that Jaguza is small even in Uganda. But then again, “In Dallas, Texas, I have a contact which wants to test drones on two pilot farms. But this had been delayed due to the corona virus.” Ronald explains the slow adoption within each country and neighbouring countries as due to lack of demonstration facilities. Presently, Jaguza refers a prospective user to someone who is already a user. Their hope is, however, to set up demonstration farms – in Uganda four demonstration farms are being planned, in South, North, West, and East of Uganda. And among all other things ongoing in this company, Ronald says he is planning this for other countries too. (One can compare with the “trialability” and “observability”, and “communication channel”, mentioned by Rogers [11, p. 16, 18] and recently Baumüller and coworkers also recommend enhanced discoverability [12], section 5.6.)

Nevertheless, Ronald returns to a technological perspective again, and says that what they are working with now is investment. “For we need to invest in more functions. Presently we are looking for some researcher of eye diseases for cows. We think we can use it with video, to identify typical patterns so that a first diagnosis might be reached even off-line. If symptoms are there, a video clip can be sent to online vets. From Jaguza’s perspective, the technology already developed for other diseases would apply to eye diseases.” (Compare [3].)

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Other Presentations

Poster • Demo • Panels • Workshop

Demo Extended Abstract

Drones + AI Disease Detection = PlantScope

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The agriculture sector in Africa is greatly affected by crop disease which reduces productivity and creates food insecurity while hindering economic growth. Using Data Science through Machine Learning and Computer Vision, we have developed an early crop disease detection system using convolution neural networks to analyse and predict the likely disease found in crop leaves, stems and roots using image classification techniques. This system will be demonstrated at the M4D 2022 conference.

Currently, the system can be used to control epidemics including Banana Bacterial Wilt (BBW), Cassava Brown Streak Disease (CBSD), Maize, Rice, and Tomato diseases. We project to support more commonly grown crops and not limited to cash crops like Coffee, Tea, Cotton and many others in Uganda and East Africa, and in Africa at large.

The system can also be used to monitor crop health while providing relevant information about the different crop diseases, prevention methods and well treatment.

The system is extended to support Drone technology in order to effectively improve performance and efficiency especially on large farms. The system supports Android, iOS, and USSD technologies. Our main goal is to improve crop quality production by disseminating information about crop pests and disease prevention in order to improve their livelihood.

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Poster Extended Abstract

AI-based Smart Epidemiologist

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The world suffered from COVID-19 pandemic [1] and it was not ready to encounter such a disastrous pandemic because there was no technological infrastructure to control and prevent the spread of the pandemic. One of the challenges is that there is no mobile app that can provide the real-time status of the pandemic within a region of interest, and personal status to the pandemic. In service delivery, extreme measures have been taken to present the vaccination status and test results via sms/online or paper-based upon entrance. Sometimes, there is no device for cross-checking of the presented documents for forgery detection even though there is an increase of utilizing mobile apps in healthcare service delivery.

With the state-of-the-art of artificial intelligence in automating systems as trending emerging technologies that is currently powering the mobile apps, the novel approach to design the Smart Epidemiologist App with TensorFlow.js [2] was successfully completed. It accesses and displays the real-time data from COVID-19 test and vaccination databases with data mining approaches, gets quarantine status for those infected and its duration, detects if the app users wear face masks using selfie camera [3], geospatial data analysis [4] by geo-locating the app users within region on google maps so that one can receive the pandemic status information of the region they are entering or going to cross or pass by. The app checks for curfews, slowdowns, lockdown statuses within the region, and its users can search for the pandemic status of the region of interest so that they can plan their travels accordingly.

The app can warn its users with no facemask to wear it properly, and provide real-time pandemic trends notification to them. Travellers, tourists, conference attendees, and the general public can be recommended to use this app because it provides real-time pandemic information of regions of interest. And utilizing this app is like the users have the epidemiologists with them along the way.

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Panel Extended Abstract

Mobile Phones: Turning Rural Assets Into Relevant Skills And Enterprises

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Panelists

Damilola Fasoranti from Prikkle Academy in Nigera, who suggested this panel, and from Rwanda by invitations of the conference committee, Antoine Sebera, Chief Government Innovation Officer at RISA, and Jacques Kabandana, Country Manager, Ericsson.

The objectives of the panel

This panel will explore the importance of mobile communication technologies as a tool for rural development. It will highlight the use of mobile phones as a supportive catalyst for development programs and its contributions to growth in education, business and job creation in the pre and post-covid eras. Specifically, the panel will speak through the following key points:

- Strategies to engage and involve rural stakeholders on the potentials, programs and policies related to mobile communication technologies.
- Empowering rural communities to be among national and global players in the creative and knowledge-based economy.
- Different ways for African leaders and development practitioners to promote information as a tool and agent for development in rural communities.
- Creating and strengthening rural community development through Makerspaces and Innovative Community Centres.
- Case studies and stories of community-level socioeconomic changes, through the use of ICT.
- Documenting, curating, sharing and scaling the impacts of information and mobile communication technologies in rural communities in Africa.

The motivation of the panel

About 48 percent of Nigeria's population live in rural areas [1]. This means, over 99 million Nigerians live and work in rural communities, engaging in local occupations, mostly farming and menial jobs.

The digital divide or gap between the urban and rural communities has been one of the reasons for the widening income gap within and among many communities in Nigeria. Information poverty in rural communities has led to economic, social and educational inequalities.

The effect of the digital gap refers to the lack of benefits of e-learning opportunities, especially during the pandemic. [2, p. 6]

There are studies that have shown that mobile technologies have been beneficial to different stakeholders – farmers, young people etc. in rural communities from increasing connectivity and understanding how to leverage mobile communication technologies.

The panel organiser is an Education and Development expert with over 10 years of experience. Working in rural communities in West and East Africa had evolved around bridging technological gaps by leveraging on rural assets; the transformation within a few months of interventions in these communities are mouth grasping. The use of mobile communication technologies has helped young people learn new skills, connect with the global communities, start intercontinental businesses and support others to grow professionally.

Working with grassroots makerspaces to bring mobile technologies to grassroots communities has also shown positive effects in helping grassroots communities grow and develop.

Makerspaces allow people to try whatever idea they have and turn them into real-life possible solutions. This does not have to be the perfect innovation or with the real materials needed. There are several tools that can be used as improvised tools, if conventional tools are inaccessible. To see emerging solutions in all we do, there is need to pay rapt attention to practical knowledge by introducing makerspaces in our various homes, schools and learning institutions. [3]

However, the main question is if the benefits of these mobile communication technologies can be harnessed further and spread across more rural communities to bring about individual and community transformation – especially in the areas of education (at anytime and anywhere), businesses (starting, sustaining and scaling) and job creation (skill building and professional development).

I will like to have this panel to learn, share and have different views, ideas and practical tools that participants can use in their work, to creatively engage rural communities and create bigger impacts through mobile communication technologies. After the panel, there will be an opportunity for the participants to create or join a network or community of practice that are working with grassroot communities in Africa.

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Panel Extended Abstract

Decolonising community-based media

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The old communication for development traditions, majority of which were created by scholars away from Africa, have been under scrutiny for the past 50 years (Manyozo et al., 2013). Following Paulo Freire's tradition of participation, the media of development communication were theorised as participatory (Atton and Forde, 2016; Chiumbu and Ligaga, 2013). However, studies now note that even though theories explain a community-based communication approach that encourages community participation, community management and community access (loosely known as the bottom-up model), development programs are still implemented from a diffusionist view point (Waisbord, 2008; Servaes, 2016). The colonial legacy across the continent of Africa still influences how key aspects of life are negotiated and applied.

There is need therefore to assess the relevance of community-based media from the perspective of the independent communities they stand to serve. Such an approach differs from the practise of understanding communities as a universal entity that can be served by any media so long as the media is called: "community-based". This decoloniality of media form can help identify appropriate community-based media for various communities in Africa for development.

One the following pages, each panellist gives brief presentation of his previous field work within the area of community-based media.

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Panelists' previous field work on community-based media

Brian Semujju

This is my experience in the field of community media. I have examined both its practice and theory as the following papers show (the quotations are from the abstracts). After the first paper, which I published in 2014 about community radio (see first paragraph below), I realised community media meant so many things to different people. I then transitioned to a smaller form of community media known as community audio towers (see paragraphs 2-5).

2014 – Participatory media for a non-participating community: Western media for Southern communities

"This paper draws on the contrast between community media and the nature of its communities in Africa that are not participatory but use participatory media. The general contention is that participatory media in Africa preside over non-participatory communities. The paper uses data collected at one Ugandan community media to prove that the limitations between community media and 'the community' require over half a century to solve. The immediate solution should be to rethink the idea of community, pay more attention not just to the nature of which media can develop which community as if it (community) was a homogeneous entity but also the idea of which community has the ability to host which media. The paper concludes by suggesting a redefinition of media to include non-media forms that show more potential in enhancing participation for all than community media." (Semujju, 2014)

2016 – Community audio towers in Uganda and as alternative to community radio

"While community broadcasting has been documented for aiding development in the Global South, communities in Uganda engage in narrowcasting and share information using Community Audio Towers (CATs). This challenges our understanding of communication for development media since CATs employ both the one-way and the two-way approaches to ensure survival. Among the crucial areas of CATs that have not been attended to by academic scrutiny is the issue of how CATs sustain themselves financially." (Semujju, 2016a) Based on interviews with ten key informants, this paper discussed the local information gathering, processing and dissemination to show how CAT platforms that are not generating income are able to survive among the many economically-oriented media systems in Uganda. I also highlighted implications for local community development of the CATs.

In another paper from the same year, I note that "Community radio started as an alternative to commercial media. The need for an alternative was clear, with many societal voices unrepresented, indicating the domination of the means of mental production by a few. This article presents two communities in Uganda that use Community Audio Towers (CATs) as an alternative to community radio, and examines why the communities prefer the use of CATs to 'mainstream' community radio. […] the article presents findings indicating that CATs are self-sustaining, with no NGO influence, and they redefine news to mean local emergencies and occurrences, while having no structures (horizontal/vertical rhetoric) as they are started and run by one community member." Semujju (2016b)

2017 – The structure of news in Community Audio Towers

This article is based on the same two communities and ten key informants as the 2016 articles. Here the focus is to draw "attention to the current sensational modernist conceptualization of news as conflict and prominence to argue that news among the poor be understood as activities happening in a village." In essence, "this article concludes that the counter-ideological events redefine the concept of news from conflict and prominence obtained through professional newsmaking cultures to whatever information the village members take to the towers." Semujju (2017)

2020 – Theorizing dependency relations in small media

Here I introduce the Small Media System Dependency (SMSD) theory. This article challenges "the pervasive western intellectual universalism which disregards Global South imaginations for generalized approaches. Using field data from Uganda about Community Audio Towers (CATs), the western-generated community media theory is interrogated, accentuating its failure to account for the intricate relationship between the individual, society, and small media. To cover the gap, the Small Media System Dependency theory is herein introduced as a geocultural response to lack of theory from the South." Semujju (2020)

References Brian Semujju

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Jude Mukundane

The tail end of the 20th century saw the liberalization of broadcast radio in sub-Saharan Africa. State owned Radio stations, operating mostly on SW and MW frequencies were rapidly usurped by private radio stations operating on FM technology. This transfer of broadcast radio into private hands should have resulted in increased public equity whereas not.

The operation of FM radio was simply devolved to entities close to the top of social, economic and political echelons in a development akin to hijack. The resulting broadcast landscape exposes the need and space for community broadcast. Community broadcast has however remained elusive – the need and ideals thereof are well-articulated, yet its realization is hard to pinpoint. In many instances, compromises are needed to relax the ideals and revisit the meaning of community.

I argue that the flaws in community broadcast stem from a subtractive approach - one that holds for a tenet the thesis that by subtracting from mainstream FM radio practice, it is possible to arrive at a minimal broadcast arrangement. This top-down approach leaves little room for participation in the design of the media by practitioners that are going to use it.

I draw from my observations equipping communities to run their own broadcast platforms to demonstrate how additive approaches are better suited for the achievement of sustainable broadcast at grassroots level and are inherently the direction to take for community radio.

The previous engagement in community radio, presented not the least at the two last M4D conferences, were made in the belief that we would find the small-scale FM-radio station model that would suit communities in rural areas. At the M4D conference in Maputo in 2016, we presented these endeavours like this: "while ICTs facilitate communications between the farthest ends of the earth, a significant portion of the planet's citizens find themselves economically excluded from these technologies. Many of these communities depend on FM radio and basic GSM services (voice and SMS) to communicate, but while these technologies increase access to information, their affordances do not serve the important role of public intra-community dialog outside of urban centers. This paper examines attempts at tailoring GSM and FM radio technologies to the needs of small rural communities, based on early results from RootIO, a project conducted in Uganda by the authors to enable grassroots agricultural communities to setup and operate their own low-power FM radio stations, and drawing parallels with projects that have attempted similar tailoring with GSM telephone networks." (Mukundane and Csikszentmihalyi, 2016, Abstract).

By this approach, we could report some success, for example: "Inclusion: The RootIO station in Patongo has opened up space for content that before could not contend for regional airwaves. Hyper-local sports events (high school football matches) are now covered, unlike before, and the most frequent callers are market women." (ibid., p. 170) This made me later make "The case for parallel rather than peripheral ecosystems [¶ …] an argument for arrangements that create, recognize and strengthens ecosystems that are parallel to the mainstream but interlink well with it, albeit being appropriately sized to the needs of the communities that they serve. This is because the introduction of community sized entities leads to peer initiatives that both depend on and reinforce each other." (Mukundane 2018, p. 84)

However, several of the RootIO stations are not properly owned by a community but by an NGO – revenue streams are too small and technological knowledge not matching the requirements. There is an inherent difficulty in trying to shrink big-corporation technology to the grassroots. When pondering the different approach RootIO used in Romania and Uganda, for instance, I cannot deny that the success in Romania was due to the community taking responsibility for getting the technology they needed. In Uganda, it remained extrinsic.

For this panel my thoughts are that there is a need to discuss the definition of 'community' for a better approach to community-based media, in particular community-based radio, but the panel discussion on dependency relations in small media will show if we can find a common definition with community audio towers.

Part of the challenge in defining community radio is inherent from the broad definition of community. The Etymology of the term community suggests a commonality whether of beliefs, norms, interests or spaces. Communities therefore exist in different dimensions, and likewise, FM radio stations often are centered on themes in these dimensions such as language, religion, livelihood activities and shared geography.

The above definition is however not sufficient to isolate community radio from mainstream FM radio practice. Commercial FM radio stations bear listenerships that are united by shared geographies, languages and interests and thereby qualify as radio stations for community. A survey of stations that were categorized as community stations in Uganda also revealed operations that were hardly differentiable from those of stations qualified as commercial.

It is in light of this ambiguity that I abandon the "community" qualifier in preference of the more restrictive "grassroots". By many definitions – whether implying basic as opposed to sophisticated; ordinary versus elite; or lower versus higher situation on the various echelons that constitute society, the term grassroots better describes the communities that are often the intended beneficiaries of community radio initiatives.

A proper definition of the broadcast community is an important first step given that FM radio has a history of hijack by elite entities in the guise of serving community media interests. The common way to achieve community radio has been to subtract components from the setups of commercial radio – the listenership is subtracted, equipment is subtracted; the quantity and quality of manpower are subtracted; all the while leaving the core operational model intact. The implication is that community radio will always be an inferior version of commercial radio.

Grassroots communities are such polar opposites of the elites that dominate the commercial FM space that any attempt to craft FM radio for the former by subtraction is bound to fail – the market forces and resources are much different that FM radio for these communities necessitates a return to the drawing board as well as room for participation by these communities.

References Jude Mukundane

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Graduate Students Workshop

Organizers

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Target Audience

Master students and PhD candidates.

Objectives

This track is organised as a workshop to provide a forum for PhD students and Master students in the area of mobile communication technology in and for development to present their works and receive feedback. The goal of the workshop is to provide professional development in M4D with critical, but constructive, feedback and advice to graduate students on their ongoing research from senior researchers.

Workshop Outline

Student participants had prior to the workshop submitted their work plans. These had been reviewed and the more mature had been accepted for presentation and discussion at the workshop.

Time	Activities	Responsible person
9:00-9:050	Welcome Remarks to the postgraduate students	Assoc. Prof. Richard Musabe
9:05-9:15	Conference objectives	Prof. John Sören Pettersson
9:15-10:30	Abstracts Presentations IPID/UR postgraduate students	Dr. Solange Mukamurenzi
10:30-11:00	Coffee Break and Networking	
11:30-12:00	Abstracts Presentations IPID/UR postgraduate students	Dr. Rehema Baguma
12:00-12:30	Demonstration of PlantScope: Drones + AI Disease Detection by Katamba RONALD, Charles KALUNGI	Dr. Edgar Napoleon Asiimwe
12:30-13:00	Poster Title: AI-based Smart Epidemiologist	Dr. Edgar Napoleon Asiimwe
13:00-14:00	Lunch and Networking	
14:00-16:00	Abstracts Presentations IPID/UR postgraduate students	Dr. Solange Mukamurenzi

Duration

1 Day (7-8 hours). Held the day before the conference, 27th of April 2022.

Proceedings of the 7th International Conference on M4D Mobile Communication Technology for Development

This biannual conference series could not have its 7th conference in 2020 because of the COVID-19 pandemic restrictions. In spite of some remaining restrictions, the conference was held on 28-29 of April 2022 at the University of Rwanda in Kingali.

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