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Chapter 20

Mbarara University of Science and Technology (MUST)



An Overview of Data Science Innovations, Challenges and Limitations Towards Real-World Implementations in Global Health

Richard Kimera, Fred Kaggwa, Rogers Mwavu, Robert Mugonza, Wilson Tumuhimbise, Gloria Munguci, and Francis Kamuganga

Abstract Health institutions are increasingly collecting vast amounts of patient data. However, mining data from those different institutions is not possible for various challenges. In this chapter, we will report on our experience on the trend of Data Science in Global Health in Uganda. The aim is to provide an insight into their challenges and limitations towards real-world implementation of a data science approach in global health. We also present a series of digital health projects that we implemented during the course of the project, and provide a critical assessment of the success and challenges of those implementations.

Keywords Data science · Global health · Digital health literacy · Information and communication technology (ICT) · Innovation

Learning Objectives

By the end of this chapter, you will be able to:

- Understand the landscape of data sources and providers in a low- and middle-income country.
- Estimate the challenges in building a connected and interoperable healthcare data infrastructure.
- Enumerate the current challenges and opportunities of leveraging data science in global health taking as an example the Uganda experience.
- Describe the importance of digital health literacy and training of local expertise for the success of a digital health roadmap.
- List and describe some digital health initiatives.

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20.1 Manuscript

20.1.1 Overview

Health institutions are increasingly collecting vast amounts of useful data concerning different issues such as compliance, regulatory requirements, record keeping and patient care (Kudyba 2010). Such data ranges from demographics, treatment appointments, payments, deaths, caretakers, medications to health insurance packages. High income countries such as the United States (U.S.) have experienced a big increase in the rate of growth of data in their health care system. It is reported that in 2011 alone, the data in the healthcare system of U.S. had reached 150 exabytes (Chluski and Ziora 2015) and (Cottle et al. 2013); and therefore, expected to have greatly increased as of today. On the other hand, low/middle income countries are experiencing demographic (including population aging) and epidemiological changes which are causing a disease burden shift from communicable to noncommunicable diseases. As the number of adults continue to grow in the low/middle income countries, the disease burden is expected to rise (Wang et al. 2016a, b) hence increasing the healthcare data.

With the increasing populations in developing countries such as Uganda, healthcare data has respectively increased. In this chapter, we will report on our experience on the trend of Data Science in Global Health in Uganda. This chapter focuses on Uganda simply because, it is one of the fastest growing population countries ranked 10th in Africa and 33rd in the world. It is also reported that the country experienced an average growth rate of 3.27% between 2010 and 2015 (Geoffrey 2017). Not only that, but Uganda is one of the known top refugee hosting nations in the world and with the largest number of refugees in Africa (MOH-A 2019). Uganda is a landlocked country boarded by Rwanda, Kenya, Tanzania, Democratic Republic of Congo, and South Sudan. Uganda's Healthcare system (more specifically Kabale Regional Referral Hospital) receives patients from its neighbors (Rwanda and Democratic Republic of Congo) hence adding to the amount of healthcare data in the country (MOH-B 2019). It is also important to note that Uganda's health sector under the theme "Universal Health Coverage for All" launched the Health Sector Integrated Refugee Response Plan (HSIRRP) to integrate the health response for the growing numbers of refugees and host communities in the country (MOH-A 2019). The Ministry of Health together with other National Level Institutions are the steward bodies that oversee the health care system across the country with the hierarchy of National Referral Hospitals (30,000,000 population), Regional Referral Hospitals (2,000,000 population), District health services (District level, 500,000 population), Referral Facility-General Hospital (District level, 500,000 population) or Health Centre IV (County level, 100,000 population), Health Sub-District Level (70, 000 Population), Health Centre III (Sub-County level, 20,000 population), Health Centre II (Parish level, 5,000 population) and Health Centre I (Village Health Team, 1,000 population) (Mukasa 2012). The ministry of health implemented a Health Management Information Systems (HMIS) The HMIS system captures data at the health

facility level from both public and private health units and is submitted on a monthly basis to the district health offices, where it is aggregated and later sent to the Ministry of Health for further analysis (Tashobya et al. 2006). The Ugandan government has endeavored to incorporate ICTs into the health sector through several policies such as the National ICT policy, Science, Technology and Innovations (STI) policy, as well as the Health ICT Policy (WOUGNET 2004). Although Uganda boasts in tremendous progress in the area of Science, Technology and Innovations (STI), the Second National Development Plan (NDPII) still notices a slow technology adoption and diffusion (UNDP and National Planning Authority 2016).

Mining data from all the above-mentioned institutions is not an easy task most especially when the required expertise is not often available. More so, the poor ICT infrastructure, the high cost of ICT equipment and internet access, coupled with low level of awareness and skills of the healthcare professionals represent some of the most shortcomings to support the assumed benefits of ICTs in the health industry (Litho 2010). The country still suffers the limited number of health workers to execute duties in these health facilities and most (if not all) of the data is still mined using traditional means through manual analysis. Not only that, but it is also noted that most of the healthcare institutions do not have the tools to enable them to properly mine the necessary data for quick access by the public, funding organizations, and the government itself. A number of hospitals fail to work together because of incompatibility of equipment and software (Litho 2010). The above aforementioned issues, in turn, have led to poor or delayed service delivery across the country; most especially areas that are located in rural areas and remote villages, where the healthcare needs are unmet and mostly needed (Madinah 2016).

Appropriately mining Health data can greatly enable the healthcare sector to use data more effectively and efficiently (Ahmad et al. 2015). The use of data in low/middle income countries can be of great importance most especially in improving the planning and delivery of public health interventions, stimulating rapid innovation and growth, promote collaborations through sharing information as well as facilitate the development of learning systems of healthcare and supporting better management of individuals to improve the health of their populations (Wyber et al. 2015).

This chapter presents the history and current narrative of Data Science-related innovations undertaken in Uganda, providing an insight into their challenges and limitations towards real-world implementation in Global Health. We aim that the lessons learned through our experiments of achieving a data-science driven approach in healthcare in low- and middle-income countries could help the discussion and the usher a wave of similar innovations in other regions across the globe.

20.2 The Need for Data Science in Healthcare

A number of agencies as well as the National Institutes of Health (NIH) emphasized the need to train professionals (data scientists) who would specialize in handling the unique challenges brought about by the health-relevant big data. It is important to note

that when the concern of biomedical, healthcare and health behavior data is raised, there is no distinction between biomedical (health) informatics and data science (Ohno-Machodo 2013). Health informatics as a scientific discipline is concerned with optimal use of information, usually supported by technology to improve individual health, public health and biomedical research (Georgetown 2019). Data science is a modern and powerful computing approach that can be used to extract vast patterns from patients' data and hence leverage useful statistics (Grus 2019; Ley and Bordas 2018). The growth of the healthcare industry greatly relies on the data and its analysis to determine health issues and their respective effective treatments (Savino and Latifi 2019). To fully harness health data's capabilities and improve healthcare and quality of life, data science knowledge is critical for all health-related institutions (Ma et al. 2018; Belle et al. 2015). With the powerful models and tools in data science, clinicians can be able to quicken diagnosis of disease and hence have better, more accurate, low risk and effective treatments (Stark et al. 2019; Pandya et al. 2019). With the help of data science, the government can also easily find cost-effective and efficient ways of maximizing the potential in healthcare data to improve and transform the healthcare industry.

The population in Uganda is on a high increase and this puts a lot of pressure on the health sector as the diseases increase. The burden of disease in Uganda has mainly been dominated by communicable diseases such as Malaria, HIV/AIDS, TB, diarrhoeal, epidemic-prone and vaccine-preventable diseases. It is also noted that the burden of non-communicable diseases has also grown. Lack of resources, unreliable information, timeliness and completeness of data are great challenges to the healthcare system (WHO 2018).

As recommended by NIH and other agencies, there is therefore much need to invest in health informatics research and also train more experts/professionals in health informatics who can develop technological tools that can fully utilize the large amounts of health related data (Ohno-Machodo 2013). Health informatics education programs can be a good start to have health-related practitioners acquire skills in data science specifically for the health industry.

20.3 Health Informatics Education in Uganda

Mbarara University of Science and Technology runs a Master of Science in Health Information Technology (MSc. HIT) offered by the Faculty of Computing and Informatics and hosted by the Department of Information Technology. This MSc. HIT is a two-year modular programme that is conducted over weekends (i.e. Saturdays and Sundays). It is led by faculty from both the Faculty of Computing and Informatics, and Faculty of Medicine. Additionally, staff from the healthcare industry provide guest lectures to present context and help translate classroom concepts into real life settings.

Prior to launch the programme, the Faculty of Computing and Informatics conducted a formal needs assessment to determine the viability of the program.

This assessment was based on interviews and a systematic review of secondary data and literature. The analysis found out that Uganda lacked professionals with knowledge and skills to develop, implement and evaluate innovations in both healthcare and computing. It was also realized that there were other healthcare challenges in Uganda such as; poor data storage, little or no accessibility and poor management of patient information, loss of patient follow-ups, and drug inventory and accountability challenges (FCI 2015).

The MSc. HIT was launched in 2015 to train professionals (e.g. physicians, nurses, clinicians, Hospital Directors, Pharmacists, Public Health Officers, Medical information officers, e.t.c and any practicing healthcare IT professionals) that could develop, implement and evaluate health information technology innovations aimed at improving healthcare in low resource settings. The program has provided opportunities for researchers to develop practical data science-related innovations capable of improving and transforming the healthcare industry in Uganda. A number of graduates from this program have exhibited knowledge in developing and deploying health information technology applications, been able to carry out health informatics related research, they are able to plan and manage health related projects as well as extract some meaningful patterns in healthcare data.

20.4 Innovations and Initiatives in Data Science in Global Health

With the help of the MSc. HIT at Mbarara University of Science and Technology, and through collaborative works with international researchers; a number of practical innovations have been developed either as pilots or proof of concepts focused on meeting the grand global challenges in health.

A brief overview of these innovations categorized along various lines is provided below. The section explores the various innovations in data science, aligns their impacts, exposes a diverse perspective of how these can help alleviate the increasing health burden currently in developing countries like Uganda in Africa, and also identifies the possible limitations/challenges in attempting to address the health challenges in context. Important to note is how this should be a focus for healthcare and services innovators, developers, and country level administration, since if not observed will limit/deprive the innovations from quick adoption.

Seven (7) different innovations are explored in this section. The health challenges, their impacts and related implementation strategies are also explored. d. These examples represent a proof of concept of the potential use cases in a developing country like Uganda to combat healthcare challenges ranging from neonatal care, diseases-specific solutions, to social care.

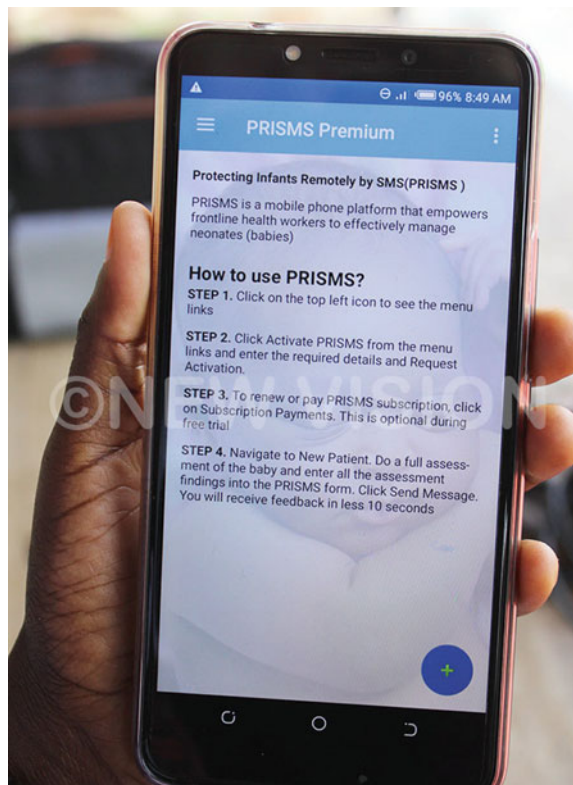
20.4.1 Neonatal Care

20.4.1.1 Remote Protection of Infants Through the Use of SMS (PRISM)

In Uganda, the death rate in newborn babies (0–28 days) is still high, with the 2018 Ministry of Health report indicating that Uganda’s neonatal mortality rate is at approximately 29 deaths per 1,000 live births and has not declined for the last 15 years. An SMS-based remote consultation system that uses routine newborn assessment findings to provide suggestions for appropriate comprehensive management for sick newborns has been developed (Tumushabe 2018). Over 85% (6/7) acceptance has been registered and promise for increased deployment for use. The application is able to remind health workers of aspects of care that had missed in the care plan with average time for feedback to reach server of 30 s. The application has improved and created capacity of health care providers (Fig. 20.1).

According to Trifonia Atukunda, a midwife at Bwizibwera, the app was introduced three years ago and has been a game changer in the management of diseases in infants (Mutegeki 2019a, b). The major challenge is now scaling up the project, as the funds

Fig. 20.1 PRISM prototype source (Mutegeki 2019a, b)



being used are from donor including a fund from the National ICT Support Initiatives Program (NIISP), from the Ministry of Science, Technology and Innovations that is expiring in 2019 (Kagingo 2018).

20.4.1.2 The Augmented Infant Resuscitator (AIR)

After an analysis, Southwestern Uganda was found to be characterized with a significant number of the well-trained medical professionals unable to give effective ventilation; with the implementation of resuscitation often failing due to incorrect rates of birth, blocked airways and significant leak at the face-mask interface. An AIR device was developed and evaluated to improve the effectiveness of healthcare professionals involved in resuscitation with a reusable, low-cost device that: (1) Enables rapid acquisition of skills; (2) Provides performance feedback during recurrent training, (3) provides real-time guidance for birth attendants during actual deliveries; and (4) stores data to enable the use of audits and programmatic improvements (GBCHealth 2017) (Fig. 20.2).

The device was tested in a randomized control trial from two sites, Mbarara University of Science and Technology in Uganda, and Massachusetts General Hospital in Boston US. Both sites demonstrated that time needed to achieve effective ventilation was reduced in half when using the AIR device, and the duration of effective ventilation increased by more than 50% (GBCHealth 2017) (Fig. 20.3).

There has been developments to scale the innovation, with the major one being a collaborations with Phillips (Russey 2018) to transform the prototypes so that ventilation provided is appropriate, by measuring air flow and pressure.



Fig. 20.2 AIR device (GBCHealth 2017)

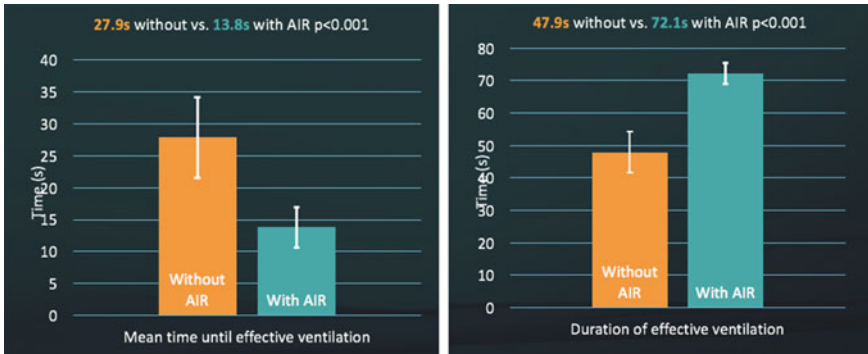


Fig. 20.3 Visualization of results (GBCHealth 2017)

20.4.2 Disease-Specific Solutions

20.4.2.1 SMART Adherence to Drugs Using the WISEPILL Device

Through a pilot randomized controlled trial (RCT) (N = 63) carried out between September 2013 and June 2015. A real-time antiretroviral therapy (ART) adherence intervention based on SMS, engagement of social support was piloted. Results indicated that the scheduled SMS's improved antiretroviral therapy (ART) adherence (Haberer et al., AIDS 2016) and are an important source of social support for medication adherence (Atukunda et al., AIDS and Behavior, 2017). The intervention was acceptable and feasible in low resource settings (Musiimenta, in preparation) (Fig. 20.4).



Fig. 20.4 The wisepill device source (Musiimenta et al. 2018)

Improved antiretroviral therapy (ART) medication adherence among the patients and facilitating treatment support through well laid social support mechanisms. The application and use of the Wisepill device, a real time monitoring intervention linked with SMS for HIV patients was found to be acceptable and feasible. The acceptability was attributed to motivating and reminding Patients to take medication, thus addressing forgetfulness (Musiimenta et al. 2018).

The device will continue to be utilized however, the device still inhibits three key limitations including battery life, connectivity and user interface at the data level. Future generation adherence devices will have to address these challenges if it is to be utilized in all settings for both research and clinical use. There is need for designers and manufacturers to embed “plug and play” capabilities with significantly lowered cost.

20.4.2.2 Resistance Testing Versus Adherence Support for Management of HIV Patients in Sub-saharan Africa (REVAMP)

Africa is home to >70% of HIV disease burden with as many as 1 in 3 develop virologic failure during the first two years of therapy. Virologic failure will result into Higher rates of poor clinical outcomes, Increased diagnostic and therapeutic costs, could thwart treatment as prevention strategies. REVAMP assesses whether addition of routine resistance testing for patients with virologic failure on first-line therapy in sub-Saharan Africa improves clinical outcomes and reduces costs. Suppressed viral load (< 200 copies/mL) at the 9th-month visit, and on first line therapy was reported (Harries et al. 2010) and (Abouyannis et al. 2011) (Table 20.1).

Table 20.1 ART adherence and viral suppression are high among most non-pregnant individuals with early (Haberer et al. 2019)

Factor	Univariate findings	<i>p</i> -Value	Multivariate findings ⁹	<i>p</i> -Value
	Percentage point change (95% CI)		Percentage point change (95% CI)	
Uganda				
Group				
Early/nan-pregnant	Ref	0.18	Ref	0.65
Early/pregnant	-4.4 (-9.5,0.7)	0.093	0.3 (-4.6, 5.2)	0.91
Late/non-pregnant	-2.9 (-7.3,1.5)	0.191	-17 (-5.5, n)	0.40
South Africa				
Group				
Early/non-pregnant	Ref	<0.001	Ref	<0.001
Early/pregnant	-22.7 (-31.1, 14.4)	<0.001	-19.2 (-28.7, -9.7)	<0.001
Late/non-pregnant	-13.3 (-19.8, -6.7)	<0.001	-12.1 (-18.7, -5.6)	<0.001

Primarily a data driven approach has been sought and developed towards management of virologic failure. This has increased greatly the proportion of patients that sustain successful completion of the HIV continuum of care. As a data intensive approach, it has improved allocation of resources for HIV management for national and multinational HIV/AIDS disease programmes and clinical management, hence the sustainability of the programs in the long run. Acquired data shall require specialized and timely analytical investigations from competent team of analysts. Nevertheless, national data centers need to be furthered with investments profiled for cost effectiveness assessments.

20.4.2.3 A Model for Predicting the Rate of Cesarean Section (C-Section) Mode of Delivery

A study conducted by World Health Organization reported that the rate of C-section has increased from 12.4% to 18.6% globally between 1990 and 2014, despite the World Health Organization's acceptable set C-section rate being at 5–15%. A demographic and health survey conducted in Uganda in 2016 reported a very high C-section rate of 30.18% (Harrison and Goldenberg 2016). It was found out that unpredictability of C-section rates was the main challenge that could lead to undesirable outcomes such as death. Using secondary data, a model based on contributing factors of C-section to predict the rate of C-section was therefore developed validated using an artefact. The findings from this study indicated that, C-section would increase at an average rate of 3.6, 116.0 and 1009.1 in 2019, 2022 and 2027 respectively (Munguci 2018). The C-section contributing factors would account for the procedures as follows: - maternal, fetal, social and institutional factors would account for 36.6%, 60%, 1.1% and 2.4% of the C-sections performed in 2027 respectively (Fig. 20.5).

The prediction model under the validation tests presents good and realizable estimates since the predictors are significant. It is assumedly to be used in clinical settings and practice to assist women and clinicians in the decision-making process about mode of birth after Cesarean section.

Since the validation of the model and tool were based on the local data, further validation studies may be required to validate this model and tool on larger national data. A prospective study could also be carried out to study the relationship between variables such as; location, occupation, parity of an expecting mother and the mode of delivery. Another prospective study can also be carried out to predict the mode of delivery

20.4.2.4 Breast Cancer Recurrence Using Support Vector Machines

Breast cancer is usually treated with surgery, which may be followed by chemotherapy, radiation, and hormone therapies. Shoon Lei Win (2014), argues that breast cancer recurrence is sometimes found after symptoms (e.g. Lymph node

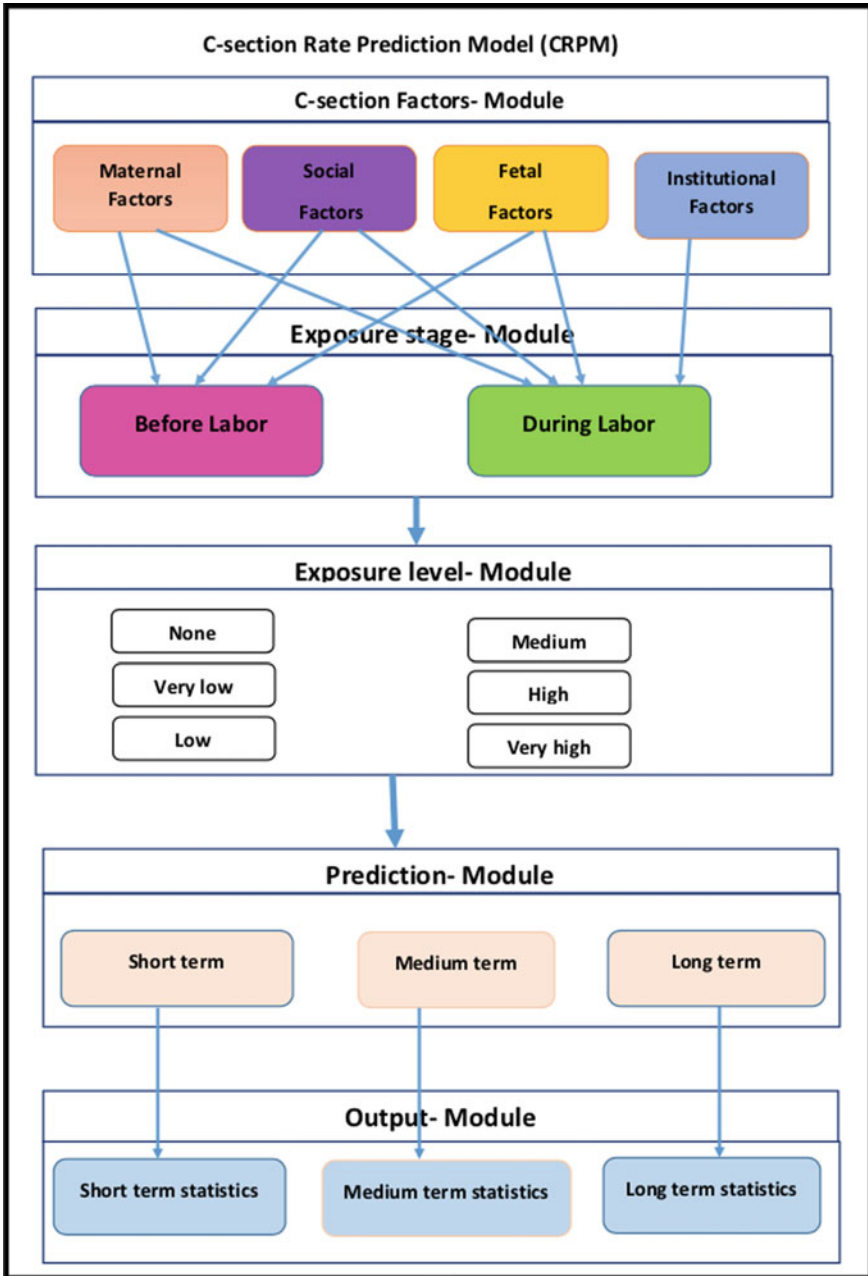


Fig. 20.5 The C-section rate prediction model (Munguci 2018)

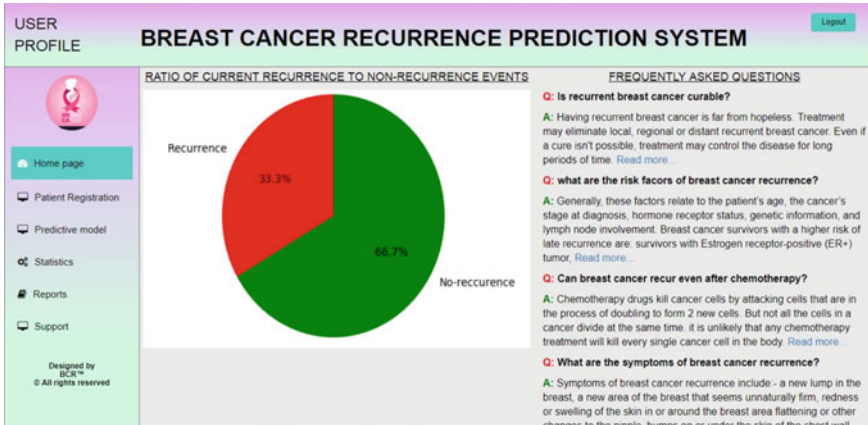


Fig. 20.6 Web system for breast cancer recurrence (Firdaus and Mpirirwe 2019)

involvement and histologic grade) appear. The researchers used a method or supervised machine learning technique known as Support Vector Machine (SVM) for classification of a secondary dataset, so as to predict breast cancer recurrence in women. Various measures including confusion matrix to get the precision, recall, and accuracy of the predicted results.

The SVM-based prediction model called BC-SVM outperformed on new secondary dataset with higher accuracy (80%), higher sensitivity (0.89), specificity (0.78), positive (0.75) and negative values (0.85). And since the prognostic factors utilized here can be observed in clinical settings and practice, the proposed model may as well prove significant (Firdaus and Mpirirwe 2019) (Fig. 20.6).

The model will require further validation studies for efficiency and efficacy against other machine learning techniques like artificial neural networks, other developed models for breast cancer recurrence predictions, as well as implementation for typical clinical use. Development of a prediction tool—artefact for use in the current clinical settings should be furthered for full realization of its potential.

20.4.3 Social Care

20.4.3.1 Evaluating the Use of Social Media for Sexual Health Promotion Among University Students

The prevalence of STDs among young people in Uganda is worrying. University students aged 18 to 24 are at a risk of getting infected with STDs due to lack of reliable sexual health information, peer pressure, and perception of independency. It is estimated that only 38.5% of young women and men in Uganda between 15 and 24 have knowledge about sexual education leaving the rest (61.5%) naïve (UAC

2015). Social media will have a greater impact and broader reach when the target population is the younger generation (Chou et al. 2009).

This research aimed at evaluating the acceptability, feasibility and preliminary impact of using social media for sexual health information among University students. Qualitative and Quantitative research methods were used whereby 106 undergraduate students from Mbarara University of Science and Technology (Intervention group) and Bishop Stuart University (control group) were involved in filling questionnaires and data was analyzed using SPSS 22 using paired t test to compare the means from both groups. Interviews were recorded using a voice recorder and transcribed for thematic analysis. 30 participants from the intervention group at MUST were purposively selected and interviewed.

The results indicated that the usage of social media for Sexual Health promotion is acceptable and feasible among university students favored by factors like convenience, ease of access of the platforms, internet availability and devices which these students use to access social media. The usage of social media for sexual health promotion plays a big role in increasing the university student's knowledge about STIs and encourages them to seek for medical advice thus reducing their risk of getting STIs.

The use of social media for sexual health promotion is acceptable and feasible among university and can improve their sexual health knowledge. There is a need for a longitudinal study that will enroll a large number of participants and follow them up for a long period of time to assess their health seeking behavior and sexual behaviors.

20.4.4 Reflections

Data science may require a number of tools to help collect, store, and analyze the data to make a more critical and relevant analysis. The accumulation of various innovations from prototyping to piloting is an indication of the presence of a gap in the health sector, and a need for more innovations in global health. Each of these innovations collects and processes data that can be used in proper decision making and therefore a call for scaling. From the above innovations, we can note that there has been use of (1) Mobile apps to manage disease specific illnesses and most importantly collection of data, (2) Locally made devices that have attracted international partnerships which are also to help inspire hardware innovators to think of ways in which the health challenges can be solved and (3) Software innovations that use data mining algorithms like Support vector Machines (SVM) to perform predictive analysis using existing records.

20.5 The Challenges and Limitations Towards Real-World Implementation

Implementation of practical data science innovations in low resource settings like Uganda meets a lot of challenges. These can be observed at the policy level while others are a characteristic of the implementation community. In particular, the challenges and limitations concerning data science innovations can be categorized into business, data, application, and technology as presented below.

20.5.1 Business Challenges

Job security. Many of the medical practitioners approached are always worried that the implementation of such automated systems would lead to the loss of their jobs. (Susskind and Susskind 2015) and (Barley et al. 2017). The issue of Job security has also limited the implementation of practical innovations in the health ecosystem of Uganda for example before the extensive application of technology, nurses relied heavily on their senses of sight, touch, smell, and hearing to monitor patient status and to detect changes. Over time, the nurses' unaided senses have been replaced with technology designed to detect physical changes in patient conditions. Consider the case of pulse oxymetry. Before its widespread use, nurses relied on subtle changes in mental status and skin colour to detect early changes in oxygen saturation, and they used arterial blood gasses to confirm their suspicions. Now pulse oxymetry allows nurses to identify decreased oxygenation before clinical symptoms appear, and thus more promptly diagnose and treat underlying causes.

Inexperienced staff and absence of skilled data scientists at health centers: Making sense out of the available data is another challenge. Even with good data science algorithms and considerably good computing power, there is still a need for a human in the loop especially when it comes to making sense out of the available data. Interpreting what certain things mean in the health field and their impact needs experts in the field and in statistical analysis. Human resource especially experts in the field of data science not readily available in Mbarara and even in the country (Uganda). The few who gain some skills in the field of data science leave to work in better-paying countries causing a phenomenon of brain-drain. Experts in the health sector have little motivation to work on these innovations, they find it not worth their time, especially if they don't find direct monetary gains. More so, most of the medical staff that have interacted with some innovation implementers are not trained in ICT skills (Kiberu et al. 2017). This limits the usability and acceptability of the developed innovations among the medical staff thus making sustainability and scale-up challenges.

Poor basic infrastructure: The Government of Uganda has tried to make efforts during the implementation of the National Health Policy I to construct and upgrade

health facilities. However, basic infrastructure such as electricity, water, communication systems, means of referrals, adequate staff quarters, and security (both cybersecurity and physical security) are the main obstacles to running 24-h quality services, especially in rural areas limiting the implementation of practical innovations in the health ecosystem of Uganda (Mugabi 2004).

Regulatory of legal and policy framework: Regulatory of legal and policy is a serious problem that has limited the implementation of practical applications in the health ecosystem of Uganda. It is difficult in Uganda to discover clear policies and coordination between governmental agencies and eHealth initiatives (Ministry of Health 2016).

Procurement process. Delays in the procurement of services and products for implementation of innovations caused by government requirements like contracts approvals, prolonged evaluation processes (Basheka et al. 2011) coupled with bureaucratic procedures cripples the process of acquisition of the products to be used in the development of the innovations. A quick and non-bureaucratic procurement process is important in driving innovation (Uyarra et al. 2014).

Limited data science partnership and health research collaborations in the implementation of practical applications. Throughout the developments presented in the practical applications, this challenge deprives the ability to explicitly identify, benchmark and apply latest in intelligent technologies combined with a deeply pragmatic world-class business approach, to automate and streamline complex healthcare processes.

Bureaucracy in obtaining approvals in the implementation of new health systems and rampant corruption have as well affected the studies and implementation of some health innovations. Not only that but having fully developed solutions to implementation is costly. The health field needs accurate solutions otherwise lives could be lost when the systems are flawed. Implementation, therefore, needs clearance from many government agencies which is often a bureaucratic process that takes forever.

Piloting versus Implementation: Institutions lack motivation for participating in pilot studies. Incentive models and other motivation to participate is required to manage implementation since most of our projects were expensive and required capital investment to build and operate the equipment and the technology infrastructure (UNCTAD 2013). More often, and because of limited strategic planning in Health IT and Data Science, implementation details from initial plans and most projects do not succeed to pass the piloting phase. the cost of some of these innovations like a wisepill device that goes to around 130 USD is prohibitive and expensive for a patient in a low resource setting like Uganda where the medium income per citizen is \$ 643.14 per month (World Bank 2018).

20.5.2 Data Challenges

In Uganda, data is captured by various health institutions and is presented in different forms and formats. This makes the data unusable and not actionable. Data is still

stored on paper files and is not systematically captured which is difficult to access, share and merge the different sources. For example, Lower level health centres at sub-county and county use paper forms or cards to capture data about patients. The data is then entered into the National Health Information System at a subsequent stage and is later transmitted electronically to district and national-level entities. This leaves room for errors due to double entry. More so, data is not collected and managed centrally, there is no government policy and system that stipulates how data is collected, shared and added to the national health data (Privacy International 2019). Especially information collected by private clinics or hospitals. Data accessibility is one of the biggest issues limiting the implementation of practical innovations in the health ecosystem of Uganda. This is because much of this data supposed to be used is stored in different health institutions and in different formats/forms and also calls for a lot of red tapes to access it.

The Data Protection and Privacy law to Information Communication Technology (ICT): The objective of the law is to protect the privacy of the individual and of personal data, confidentiality and information reliability by regulating the collection and processing of personal information (ULII 2019). The law provides for rights to the persons whose data is collected and the obligations of data collectors, data processors and data controllers. However, this law is limiting the implementation of practical innovations in the health ecosystem in Uganda because it regulates the use or disclosure of personal information. This has left many health facilities in fear to release people's data without permission from the patients because they don't trust that the data will be used professionally. It is however challenging to implement the policy, processes, and the technology that will be necessary to implement and apply such policy.

Data Security (Limited techniques for data security). Ensuring that data will be secure and will not be accessed by unauthorized people who could compromise patients is a challenge that needs to be addressed. This is due to lack of sufficient security features like data encryption, data anonymization thus leading to the exposure of patients information to unauthorized parties due to vulnerabilities that result from unprotected wireless access, and other access control measures (OIG 2019). Ensuring the privacy and confidentiality of patient data needs to be prioritized to gain the patient's trust by overcoming the vulnerabilities within the data protection system.

20.5.3 Application Challenges

Negative perception towards the developed innovations. Practical applications have increasingly garnered attention and have become integral to the educator's toolbox in medical education (Kim et al. 2017). However, there has been low confidence, knowledge and skills to operate practical innovations amongst health workers in rural areas of Uganda due to the inclination to traditional methods of doing work and

difficulty to integrate the innovation with their method of doing work and yet these are important factors to consider in promoting retention strategies in rural areas.

Lack of a proper communication channel between patients and health workers. Some patients lack mobile gadgets or well streamlined postal addresses. In cases where patients consent is required or follow up on the patient's progress, it becomes a big challenge. This cuts off the communication process and patient monitoring and in the long run affects the point of care due to lack of effective and efficient communication which is crucial in healthcare.

Most of the innovations are being piloted, have a short time period and are not available on the market, thus limiting their long-term impact. The short-term period is due to funder priorities and scope, and by the time the pilot phase is done, the innovation is left at an infant stage thus making little or no impact to the intended users.

20.5.4 Technological Challenges

Low ICT uptake and usage in most health institutions in the country (Sanya 2013). A few large healthcare sectors have deployed ICTs to manage patients' data in Uganda leaving the majority of the healthcare naïve about the uptake and usage of ICT. This is attributed to digital divide issues within the country, where some health institutions are located in rural areas with no ICTs while others are situated in the urban area but still with limited access to these ICTs. This limits the impact of ICT usage on healthcare despite the benefits.

Lack of knowledge on the state-of-the-art tools available for data science. Most researchers use tools that are not appropriate for the problems at hand; only because this is what is affordable. This makes the process long and complex yet with better tools, the same work would be easier and more elegant.

Limited and no access to the internet is another challenge. Government provided internet connection is of low bandwidth and only in specific health centers; yet buying internet data bundles is expensive. About 4 dollars are needed to purchase 1 GB of data of which most researchers or health workers can't afford on a regular basis.

Electricity power outages at all centres of implementation is another setback. Hydroelectric power goes off like twice a week and for longer hours. This necessitates embarking on more expensive power sources that use fuel (Generators) of which sometimes may not be available due to the prohibitive cost.

20.6 Lessons Learned from the Practical Innovation's Implementations

A number of lessons as presented below can be drawn from these practical innovations.

Creativity has been stimulated through the different data science innovations and there is hope that many will engage in their development.

It has been learnt that even though people tend to be rigid during the first days of implementation, they later adopt the systems after seeing the results and how fast work could be accomplished.

The uptake of these innovations has been noted to depend on several factors which include, structural factors, cultural and social factors. Structure factors round up the existing infrastructure, the organizations buy in, existing policies, and economic resources while on the other hand, cultural factors include cultural beliefs of an individual to use the application, moral values and traditions (What does my culture, tribe, believe about a certain intervention?), social factors include, religious views, friends, people around the user. Therefore, the adaption, use and acceptance of certain applications largely depends of such factors, there is a need for the developers and implementers to put such into consideration in order to obtain necessary results.

Intervention dependence has positive consequences on patients' adherence rates especially when the innovation or the intervention period ends (Musiimenta et al. 2018), therefore there is a need for the implementer to bear in mind of what might happen when the intervention is withdrawn, some individuals get used to the intervention that its absence might cause negative or poor adherence. Some might lack a sense of self-esteem, develop a negative thinking and might fail to access supportive relationships.

20.7 Conclusion and Way Forward

20.7.1 Conclusion

The action for leveraging data science for global health issues should be now. The vast amount of health-related data collected in healthcare institutions such as demographics, treatment appointments, payments, deaths, caretakers, medications and health insurance packages can only be useful to the individual institutions, clinicians, and the government if well mined, processed and analyzed. Knowledge to come up with useful practical healthcare data analysis management solutions that are affordable, secure, easy to use, manageable as well as scalable is critical. This chapter has presented a narrative of data science related innovations providing an insight into their usefulness, challenges and limitations towards their real-world implementation.

These practical innovations have exhibited potential to enhance access to health care services by patients, enable digital processes for healthcare professionals, stimulate creativity, improve awareness, improve medical adherence and effectiveness as well as health information communication among the youth through social media. On the other hand, a number of challenges and limitations towards the implementation of practical innovations ranging from business, data, application, to technology have been identified as: job security, inexperienced staff and absence of skilled data scientists at health centers, poor basic infrastructure, regulatory of legal and policy frameworks, delays in procurement, bureaucracy in obtaining approvals, lack of motivation, unstructured and heterogenous data, data inaccessibility, data security, negative perception towards applications, lack of proper communication channels, poor ICT uptake, lack of awareness, limited or no access to internet, and electricity power outages among others.

Although there are challenges and limitations towards the implementation of the aforementioned innovations, it can be firmly concluded from this chapter that there are a multitude of opportunities for researchers to develop practical data science related innovations capable of improving and transforming the healthcare industry in low resource settings.

20.7.2 Way Forward

Such practical innovations can only be developed by professionals and therefore the healthcare industry must invest in long term training of individuals to acquire the necessary skills. The government needs to institute working and implementable policies and frameworks for proper healthcare data storage, access, usage and management. This of course would require good political will in terms of funding and commitment to continuously supervise and monitor all the nationwide instituted innovations.

Bridging the digital gap in towns and villages is also key to have development and improvement of the healthcare industry to allow for better data science implementation. Such gaps can be bridged by empowering villages with more data science related trainings, improving the ICT infrastructure, reducing the cost of internet access, and provision of constant power (electricity) avenues.

Technology adoption needs to be emphasized through balancing the top-down and bottom up approaches.

Some innovations were identified to be expensive. Subsidizing such innovations might play a key role in establishing an impact in the health sector. There is also need for substantial funding which would address the issue of costs through established partnerships with funders, government and non-profit making organizations to facilitate a coherent incubation and application of these practical innovations to have an everlasting impact on health.

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