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The potential of Fourth Industrial Revolution technologies to transform healthcare: The question of access for the marginalised

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INTRODUCTION

Throughout the years, medical research, technology and innovation in their divergent forms have introduced noteworthy changes to medicine and healthcare globally. Countless advancements in critical knowledge of medicine and healthcare have allowed for several improvements to be made in diagnosis, treatment and care. With the onset of the COVID-19 pandemic, the need for these improvements became ever more urgent and the race began to develop technological innovations and scientific insights that would counter the pandemic. This chapter is being written at the onset of the COVID-19 outbreak, when governments, doctors and scientist worldwide are still grappling with what COVID-19 is, and what it will mean for our future. It is too soon to take stock of the role of technological innovations in tackling the pandemic. However, what is clear is that the world is turning to the

technologies of the Fourth Industrial Revolution (4IR) to solve some of its most pressing healthcare issues, and questions about the role of these technologies in transforming health practices have never been more pressing.

Researchers have turned to 4IR technologies during the pandemic as these are the latest in the cutting-edge innovations said to be transforming medicine, due to rapid advances in genomics, genetic engineering, nanotechnology, Artificial Intelligence (AI), Internet of Things (IoT), robotics and much else (Thuemmler & Bai 2017; WEF, 2019). These scientific and technological advances promise to provide more accurate and personalised healthcare, giving patients autonomy and the chance to participate in their treatment, as well as improving health outcomes (WEF, 2019). Essentially, 4IR technologies have the potential to answer the pressing challenges we have today in healthcare. These potential benefits are undoubtedly desirable. However, despite these potential benefits, these innovations and technologies raise important questions about the multifaceted medical, economic and social implications of their implementation in an unequal, resource-strained society like South Africa's, with a weak healthcare system.

In many countries, citizens are entitled to the provision of healthcare and it is commonly their constitutional right. Globally, the most critical issue in healthcare is providing widespread and effective treatment options that improve quality of life. Advances in medicine and the emergence of new concepts of healthcare should thus not necessarily lead to reduced access to basic services or exacerbated disparity of access for marginalised communities compared to the elite. Several health-related interventions have been implemented in Africa to improve health conditions and outcomes, yet the continent still carries the greatest burden of disease (MISTRA, 2019). In some measure, access to these health-related interventions has not been extensive nor sustainable, leaving the most vulnerable population groups with the persistent burden of disease. This chapter explores how we can ensure the benefits provided by 4IR technologies in healthcare are distributed equitably.

Part of what this chapter aims to do is to position 4IR technologies in healthcare within context – exploring the realities of introducing

technologies associated with the 4IR into a country like South Africa with its extreme inequalities, where internet penetration is uneven due to inadequate infrastructure; where data costs are high especially for poorer communities; where there are scarce human resources and skills; deficient legislation; and, sometimes, unreliable power supply.

The chapter attempts to identify the features of the 4IR that could pragmatically be implemented in South Africa's overburdened and under-resourced healthcare system and that could lead to a transformative impact on health and medicine. The analysis draws on secondary research in South African as well as other African and international literature to evaluate key challenges and opportunities for 4IR technology in South Africa's health sector. Using the conceptual framework for value co-creation (Prahalad and Ramaswamy, 2000; Voorberg et al., 2014), the chapter argues for inclusive innovation in order to ensure equitable access to new technologies. Citizens should actively participate in the development of technological and public service innovations meant for them. Innovations have traditionally been imposed on citizens, without in-depth understanding of their daily needs and without cognisance taken of their level of access to, and understanding of, the new innovations. Thus, the chapter puts emphasis on the importance of ensuring that patients from all socioeconomic backgrounds are able to access new technologies and are educated on how to use them.

Furthermore, through a description and brief analysis of South Africa's attempts to implement an electronic health records (EHR) system, the chapter explores the barriers to adoption of technologies that the government has attempted to implement previously. Technology adoption is an intrinsically social and developmental process, therefore involving users of technology in the process of developing technologies is crucial. The chapter concludes by reflecting on 4IR-related policies that can potentially address issues in the healthcare system and argues for complementary health policies and precautionary and realistic implementation of 4IR technologies in South Africa.

HEALTHCARE SYSTEMS AND TECHNOLOGICAL ADVANCEMENTS: GLOBAL TRENDS

Healthcare systems across the globe are grappling with an incessantly changing health landscape that comes with countless uncertainties. The increase in the number of people with chronic illnesses; the growing population (in many countries this includes an exponential increase in aging populations); expensive medical technologies and infrastructure; and a decreasing health workforce are common challenges the world over (Allen, 2019).

As we find ourselves in an era where ground-breaking technology is at the forefront of several industries, the pressing search for sustainable solutions to healthcare has seen increasing advocacy for the use of advanced technologies for improved healthcare to meet this need. So-called 4IR technologies have the potential to improve healthcare in providing both more efficient diagnoses and therapies (treatment and vaccines) as well as in the reliable and timely delivery of healthcare services (WEF, 2019). High-income countries are already enjoying the benefits of incorporating 4IR technologies (ICT, AI and high-performance computing technology) into their healthcare systems and continue to advance their healthcare using these technologies. Examples include an AI-based symptom and cure checker that uses algorithms to diagnose and treat illness; a digital pathology platform that uses AI to detect patterns in cancer cells, and AI software that notifies doctors when a patient's health deteriorates (Daley, 2020). Additionally, for innovative and transformative diagnostics and therapies, current and emerging technologies,[1] such as biotechnology and nanotechnology, have been extensively researched. Some have already been integrated into medical practice while others are still in the research and development (R&D) phase (MISTRA, 2018; WEF, 2019).

The opportunities presented in the initial stages of the global COVID-19 pandemic for these technologies were utilised to showcase

1 Emerging technology is a term generally used to describe a new technology, but it may also refer to the continuing development of an existing technology. The term is commonly reserved for technologies that are creating, or are expected to create, significant social or economic effects.

their value. The pandemic highlighted the importance of providing sufficient diagnostic kits in the initial stages of the spread of infectious diseases. Countries with well-established ICT and AI systems, such as South Korea, were able to develop COVID-19 diagnostic kits within a short period of time (Government of the Republic of Korea, 2020). The diagnostic kits swiftly became widely accessible and played a major role in reducing uncertainties in the early stages of the viral spread in South Korea. South Korea's ability to rapidly develop diagnostic kits is due to companies investing in nurturing an R&D environment based on ICT such as big data and AI.

To fortify their contact tracing process, the government in South Korea is using surveillance technology that had already been in place, to support a public health response (Fendos, 2020). Through electronic transaction data, mobile phone location logs, and surveillance camera footage, information on a patient's contacts and whereabouts can easily be accessed and used to rapidly quarantine affected individuals and decontaminate implicated locations (Fendos, 2020).

Furthermore, in South Korea AI is being used to detect lung conditions such as pneumonia, a major symptom of COVID-19 patients, and to identify expeditiously those who need intensive care (Government of the Republic of Korea, 2020). This technology has been valuable in regions where there is an insufficient number of healthcare workers to perform diagnostic tests and swiftly screen patients in order to prioritise patients with severe symptoms.

The unparalleled advancements in digital health solutions has stimulated the development of a range of digital medical technologies, such as the ones used in South Korea, for new care delivery models (Bartlett et al. 2017) that establish analytical, preventive and personalised healthcare (Reddy, 2019). These advancements also lead to large-scale collaboration among stakeholders in healthcare, which brings about rapid, more precise and less invasive diagnostics, treatments and therapies (Reddy, 2019). Consumers, particularly in high-income countries, have become accustomed to convenience, access and personalised products and services in other aspects of their lives (for example, shopping; food orders; banking; education) and are demanding the same for healthcare. There is growing pressure

for healthcare to be more proactive and focused on wellbeing with greater involvement of patients (more engagement and empowerment) (Allen, 2019). In this regard, advanced technologies are being utilised to address issues of simpler access; improved and early diagnosis; increased consumer engagement; and an emphasis on prevention and wellbeing and less on treatment (Allen, 2019). Furthermore, transformational technologies in healthcare are generally being used to expedite decision-making and reduce routine administrative duties, enabling healthcare workers to perform optimally (Reddy, 2019) thereby prioritising their time, attention and effort on patients.

While many applications of these technologies have been implemented in contexts where there are sufficient resources and relatively strong healthcare systems, their use in under-resourced settings remains comparatively limited. Nonetheless, governments globally (whether well resourced or not) have adopted the concept of 4IR and there is optimism that these technologies could have a transformative impact on public health in developing countries. The discourse, however, needs to be more nuanced. There needs to be a more critical look at the landscape in developing countries, particularly in Africa, where these technologies are purported to have a transformative impact. The introduction of imported policies or strategies from countries with an extremely different context deprives developing countries of an approach that is tailored to their milieu and one that could have a better chance of being successfully implemented.

4IR IN THE SOUTH AFRICAN HEALTH SECTOR

The benefits that 4IR technologies are providing in high-income countries could completely alter the healthcare landscape in South Africa. However, the South African healthcare system is facing challenges that require more than simply integrating AI, precision medicine and big data analytics into the healthcare ecosystem. The notion of the 4IR necessitates different considerations in South Africa, with its under-resourced and overburdened healthcare system. The country needs to satisfy foundational requirements first in order for its healthcare system to fully benefit from the implementation of 4IR

technologies, including socioeconomic redress; upskilling of its health workforce, and upgraded infrastructure This next section of the chapter thus presents what 4IR technologies have to confront in the South African healthcare system. It paints a different picture to the one in high-income, well-resourced countries, where the notion of 4IR was first conceptualised and advanced. In locating the 4IR within this context, one can provide a realistic analysis of the possibility of widespread and successful implementation of the 4IR in the South African health sector.

Context: The healthcare system in South Africa

The South African healthcare system and health policies have experienced many changes over decades, which have been closely linked to the country's political history (Katuu, 2018). Widespread inequalities entrenched by colonialism and apartheid have had calamitous and enduring effects on the health outcomes of the mainly black population. Notwithstanding considerable progress and continuous endeavours by the government to remedy past disparities, the South African healthcare system is still unable to meet the health demands of the majority adequately and efficiently. Not only does the South African healthcare system have to contend with a quadruple burden of disease (HIV/AIDS, TB, non-communicable diseases, and violent injuries) it has to do so with limited resources exacerbated by underfunding, mismanagement, shortages of health personnel and deteriorating infrastructure (Delobelle, 2013; Katuu, 2018; MISTRA, 2019).

The World Health Organization (WHO) describes healthcare systems as being made up of 'all the people and actions whose primary purpose is to improve health. They may be integrated and centrally directed, but often they are not' (WHO, 2000). The healthcare system in South Africa still carries the legacy of exclusion and fragmentation and this is apparent in how it is divided into two parallel sectors – a highly developed private sector and a disintegrated, dysfunctional public sector (Belli et al., 2018; Katuu, 2018). The public sector, which caters for 84 per cent of the population, is unduly underfunded and there is disproportionate distribution of healthcare workers between private and public institutions, as well as between urban and rural settings (Belli et al., 2018; Di Paola and Vale, 2019). The conditions

highlighted above have left the public healthcare system on very shaky ground.

Different studies conducted in public healthcare institutions across the country have confirmed the unfavourable conditions patients and healthcare workers have to grapple with (Di Paola and Vale, 2019; Malakoane et al., 2020; Maphumulo and Bhengu, 2019; Mutshatshi et al., 2018). Prolonged waiting time for patients is among the most widespread problems. In South Africa, visits to public health facilities commonly take a long time, sometimes resulting in patients missing appointments or finding alternative health facilities with a shorter waiting time (Maphumulo and Bhengu, 2019).

Another common issue is that of poor record-keeping in public health facilities. A study at particular public hospitals in Vhembe district, Limpopo Province, South Africa found that nurses, who are responsible for keeping records of every intervention they administer to patients, had challenges with keeping consistent and accurate records. This was due to 1) time needed to complete recording forms; 2) increased admission of patients; and 3) insufficient supply of recording materials resulting in incomplete recording (Mutshatshi et al., 2018). This is in the face of pressures resulting from management reforms to healthcare aimed at improving productivity and financial security over the need for patient care (Di Paola and Vale, 2019). Under the new public management,[2] healthcare workers have been assigned responsibility for stringent administrative measures, which have been prioritised in the running of the hospital in order to achieve cost-cutting and efficiency goals, neglecting the relationship between patient and healthcare provider (Di Paola and Vale, 2019).

The shortages of medicine and equipment have also been reported to be a major stumbling block in public health facilities (Maphumulo and Bhengu, 2019). A study conducted across healthcare facilities in the Free State, South Africa, to determine healthcare system challenges associated with poor public healthcare delivery, revealed several issues,

2 The new public management is part of management reforms in healthcare under which public services have been increasingly encouraged to behave like businesses, aimed at efficiency and performance management measured in terms of administrative rather than clinical goals (Di Paola and Vale, 2019).

including 1) 'non-functional ICT system'; 2) 'shortage of resources/ equipment'; 3) 'pharmaceutical system challenges'; and 4) 'supply chain problems' (Malakoane et al., 2020). It was found on one hand that patients experienced poor availability of healthcare workers, medicine and diagnostic devices, which translated into a lack of access to quality healthcare. On the other hand, healthcare workers were dealing with shortages in medicines, vaccines and technologies due to lack of access and high costs, as well as procurement and distribution challenges (Malakoane et al., 2020).

It thus becomes clear that the South African healthcare system requires extensive reform and strengthening. In its goal to rehabilitate the country's healthcare system, the South African government has pinned the healthcare system on the values of primary healthcare and the district health system (Katuu, 2018). According to the National Development Plan Vision 2030 (NDP), primary health care is anchored in 'values such as universal access, equity, participation, and an integrated approach' (NPC, 2013). Furthermore, some of the most crucial components of primary healthcare embrace preventive healthcare and the use of suitable technology (NPC, 2013). The NDP further states that other components entail 'better access to and use of first-contact care, a patient-focused (rather than a disease-focused) approach, a long-term perspective, comprehensive and timely services, and home-based care when necessary' (NPC, 2013).

In 2011, South Africa's National Department of Health (NDoH) launched the model for re-engineering primary healthcare (PHC) in the continuous efforts to transform healthcare in South Africa, followed by an audit on PHC clinics in the public sector (Health Systems Trust, 2013). In July 2013, subsequent to the audit, the NDoH established the 'Ideal Clinic' programme as a means to systematically reform and rectify the deficits in PHC clinics (NDoH, 2018). According to the NDoH (2018):

> an Ideal Clinic is a clinic with good infrastructure, adequate staff, adequate medicine and supplies, good administrative processes and adequate bulk supplies that use applicable clinical policies, protocols, guidelines as well as partner and stakeholder support, to

ensure the provision of quality healthcare services to the community. An Ideal Clinic cooperates with other government departments as well as with the private sector and non-governmental organisations to address the social determinants of health.

The introduction of a National Health Insurance (NHI), which is still under consideration by parliament, is also anticipated to address some of the shortages and inequalities in the healthcare system. The NHI Bill (NDoH, 2019) aims to provide universal access to quality healthcare for all South Africans regardless of socioeconomic status. Certainly, the issues prevalent in South Africa's healthcare system require radical, but also practical, solutions. Reforms should not leave the poor and vulnerable in worse positions than they are already in. Poverty, low socioeconomic status, and inequality have been linked to vulnerability to diseases (Farmer, 2004) and it has been shown that Africa has some of the widest gender income disparities in the world, which contributes to African women being among the poorest people. This makes African women even more vulnerable to the negative impacts of a weakened healthcare system (UNESCO, 2015; UNESCO, 2017). Furthermore, the challenges in the healthcare domain are exacerbated in rural areas in the country, something that is common throughout the continent. Attempting to uncritically implement imported strategies focused purely on advanced technologies, in a healthcare system with complex and clearly entrenched issues, will only serve to deepen those issues and leave the vulnerable in a worse state.

THE CASE OF ELECTRONIC HEALTH RECORDS

The discourse on 4IR technologies, particularly the AI and ICT-based technologies, has not adequately addressed the inefficient ICT systems that have been implemented in the healthcare system. Health information systems that the government has previously attempted to apply have not been effective. The ICT system in healthcare is like a fragmented healthcare system and it generates the same undesirable outcomes (Botha et al., 2016). In order for advanced technological innovations to be valuable, a foundational ICT system has to be in place, as well as skilled personnel to operate the system. A brief

analysis of the electronic health records implemented in South Africa's healthcare system reveals the challenges faced in this domain.

Prior to 1994, South Africa had several information systems in public healthcare which were not interoperable (Katuu, 2016; NDoH, 2019). These systems were fragmented and failed to deliver appropriate information to make logical design decisions. Thus, part of transforming South Africa's public healthcare system was to establish an integrated management system that would prioritise the patient (Katuu, 2016). However, fragmentation in health information systems used in South African public health facilities is still evident and this was detailed in a 2013 review of hospital information systems (NDoH and CSIR, 2014). The study revealed that several different systems from different suppliers were implemented and up to 31 per cent of these systems were unable to exchange patient information.

The National Department of Health together with the Department of Science and Technology (now Department of Science and Innovation) as well as the Council for Scientific and Industrial Research (CSIR) established a patient registration system compatible with an electronic health record (EHR) (NDoH and CSIR, 2014). This system aimed to provide an efficient process for integrating data about patient care throughout the public and private healthcare domains. This pooled data was intended to be used by health services for reporting and planning at provincial and national levels, and concurrently for addressing challenges in the absence of interoperability, disintegration and the lack of a National Patient Master Index.[3] However, in order to make these systems interoperable there is a need for further development of their structural design, and an integrated platform. In 2017, five out of the nine provinces in South Africa had some version of an EHR system operational in public hospitals. However, over 50 per cent of public health facilities in South Africa still utilise a paper-based filing system, years after EHRs were introduced (Cilliers and

3 An electronic database that holds demographic information on every patient who receives healthcare services. The MPI aims to accurately match and link records by uniquely identifying individuals. This is done by storing information such as name, date of birth, gender, etc., and assigning everyone a unique identifier.

Wright, 2017; Katurura and Cilliers, 2018).

A study by Katurura and Cilliers (2018) to determine the barriers to implementation of EHR systems found the following main issues from various countries in Africa:

1. insufficient user training, skills and commitment, meaning that healthcare workers are not equipped to use EHR systems resulting in a lack of adoption;
2. absence of information about the technology infrastructure and a high cost of implementation; and
3. strategies for the implementation of EHRs that lack coordination and synchronisation.

Additionally, there is a lack of specificity in national strategies.

These findings are supported by research conducted by Cilliers and Wright (2017) who established that because of unreliable electricity supply, poor internet connectivity and limited bandwidth, healthcare workers in South Africa found EHR systems to be undependable and inaccessible. Cilliers and Wright (2017) further report on a failed Google Health application implemented in 2008 and discontinued in 2012. Users of the application were not provided with adequate information on its use and benefits and there was thus a lack of trust and concerns about privacy for users. Healthcare workers were also not recommending it to patients as a useful product to receive health information. Deficiencies in EHR systems have further been attributed to limited computer availability, slow sign-in processes and convoluted methods of recording or retrieving information (Bardach et al., 2017).

Cohen et al. (2015) found that there can be unintentional consequences of an efficient EHR system such as a decrease in time spent with physicians but an increase in waiting time. Cohen et al. (2015) point to users' possible lack of experience in computer usage which reveals a lack of training and support to develop competences in overall healthcare.

Adequate engagement with end users of new technologies – whether patients or healthcare personnel – and the lack of sufficient and reliable infrastructure among other issues have led to the failed adoption of technologies with great potential to improve healthcare. Therefore, it is important to acknowledge that there have been many dynamic

initiatives that have been unsustainable due to the barriers mentioned. Resources have been directed towards establishing and advancing various ICT systems, without provision of an enabling environment for the systems to succeed. The application of technological innovations requires complementary strategies that will ensure the acceptance and optimal utilisation of the technology.

ENSURING EQUITABLE ACCESS TO TECHNOLOGIES IN HEALTHCARE

For the most part, technological innovations are enjoyed by those who already have good access to healthcare and who have a good understanding of the basic operations of current and new technologies (Van Winkle et al., 2017). It has been shown that the benefits provided by innovative healthcare technologies are unevenly distributed towards those from privileged socioeconomic backgrounds (Cozzens and Thakur, 2014). This population group is usually familiar with digital technologies and is able to navigate them easily to search for pertinent health information. This is usually followed by using the information acquired to attend to health issues (Nambisan and Nambisan, 2017). This means that interventions in healthcare that are focused exclusively on technology (particularly digital technologies) are likely to benefit the privileged with higher levels of e-health literacy while excluding marginalised communities (senior citizens; those who are illiterate and/or have restricted access to the internet and other basic digital technologies).

An example of inequality in health technologies is aptly illustrated by Cozzens and Thakur (2014) in an anecdote about a diabetic Mozambican man who lives in a small house in an impoverished area without electricity and with limited access to clean water. The Mozambican government has provided access to free recombinant insulin – a refined, highly efficient medical treatment produced through genetic engineering. The use of this treatment entails testing for blood sugar levels, storing and injecting insulin with a syringe, which all require a strict routine, a level of literacy and household infrastructure that the man does not have. His doctor makes the decision to rather provide him with a simpler treatment that is not as efficient, but that

will be more successful in the long run, given the man's circumstances. The doctor then sees another patient who is a professional and prescribes the recombinant insulin for the patient.

Thus, as much as the intention of the Mozambican government in this narrative was to provide an efficient health technology that would benefit all citizens, it ended up benefitting a middle-class patient while excluding an impoverished man who needs it the most. The value of health technologies is undisputed and, more so, the advantages of digital technologies ranging from simpler organisational systems such as EHRs and e-prescribing systems to more intricate digital healthcare systems such as personal health records, are widely accepted. However, in a country as unequal as South Africa and many others, funds directed towards technology-centred solutions (such as the ones promoted by 4IR strategies) would result in the majority of the 84 per cent of people that rely on the public healthcare system being excluded from the benefits. Therefore, mechanisms need to be put in place to ensure that the advantages of digital technologies and their associated innovations reach the intended end-users who need them the most.

The question of access to medicines and other technologies has been ongoing for years. Attention has been given to drugs and vaccines in contentious deliberations about poor access in developing countries; but, this also applies to other healthcare technologies (Frost and Reich, 2009). Furthermore, the debates on access have focused on barriers such as pricing and patents and less on distribution, delivery and technology adoption challenges. Inadequate access to healthcare technologies in developing countries is a multifaceted problem consisting of a mixture of market failures and an inefficient government (Cozzens and Thakur, 2014). The solutions should encompass strategies involving socioeconomic, political and environmental approaches. Moreover, it is important to determine people's perceptions of different technologies, illnesses and treatments when crafting solutions.

Case studies by Frost and Reich (2009) show that it is difficult to formulate strategies that produce unanimous acceptance of a technology at either a national or global level. Creating access therefore requires the time and resources to develop carefully designed strategies, together with end-users, for dealing with the manifold impediments along the

pathways to access. With South Africa's NHI Bill still being deliberated, the unequal structure of the nation's healthcare system and issues such as access to and adoption of healthcare technologies are essential for both the implementation of an NHI as well as of a 4IR strategy.

The next section of the chapter explores interventions that can be implemented to ensure that the benefits from healthcare technological innovations are equitably disseminated among all population groups, particularly poor and marginalised communities. The chapter draws on the conceptual framework for value co-creation introduced by Prahalad and Ramaswamy (2000), which discusses the *active participation* of consumers in the many phases of the invention process as opposed to the generic concept of partaking, or *passive participation*. Voorberg et al. (2014) speak of the importance of citizen engagement in social innovation, which requires that the conditions under which citizens co-create be well understood.

Co-creation for healthcare technologies

Co-creation entails a paradigm shift away from simply consulting end-users to actively working together with them in order to determine the issues at hand and create solutions. This concept was initially applied to the private sector (businesses working together with customers). However, it has gradually been explored in the public sector where citizens have predominantly been categorised as passive users of public services, to thinking of them as co-creators (Voorberg et al., 2017). In this setting, opportunities are created for citizens to partake in identifying which are the services and outcomes that are important to them, and how these should be coordinated. The co-creation concept encourages governments and public officials to take into account alternative knowledge systems, different sources of information and unique experiences (Voorberg et al., 2017).

The advent of the internet and other digital technologies has made it viable for consumers to participate at various points of innovation (Sawhney et al., 2005), which results in an enhanced product and consumers being satisfied with the quality of the innovation. In healthcare, the concept of co-creation speaks to the inclusion of patients as collaborators in innovation and value creation. This

results in healthcare providers being able to offer patients enhanced experiences through the provision of innovative healthcare services at more affordable costs.

Nambisan and Nambisan (2017) identify three themes that can be adopted to ensure equitable access to technological innovations in healthcare: educate, engage, evolve.

First, under 'educate' they recognise that what is known about healthcare challenges and solutions is substantial, always developing and shared among various stakeholders, including diverse patients. Patients may have unique knowledge about what they need from their digital technology, such as more detailed information on what the data it produces means, and how potential solutions may work (or not) in their exceptional context (Nambisan and Nambisan, 2017). Therefore, knowledge must be bidirectional – healthcare institutions need to educate patients on the technological innovations, and, at the same time, patients need to inform and educate healthcare institutions on the context of their routine experience of the technological innovation. This is crucial for improving the development and adoption of technological innovation.

Second, 'engage' entails patients being active players in the redesigning of sociotechnical systems[4] that involve infusion and adoption of new technological innovations. Nambisan and Nambisan (2017) provide an analysis of how healthcare consumers have established online forums to review issues related to the use of wearable devices. These reviews and discussions among healthcare consumers help advance and provide unrestricted solutions to some of these challenges. In a setting like one in rural South Africa, this engagement would need to take a different form. Perhaps through a communication platform easily accessible to most or, in communities where internet and data is an issue, meetings or focus groups could be utilised. Dynamic and effective patient participation in the multiple stages of innovation may result in healthcare providers being more active in creating space for improved innovation.

4 Sociotechnical theory has at its core the idea that the design and performance of any organisational system can only be understood and improved if both 'social' and 'technical' aspects are brought together and treated as interdependent parts of a complex system.

Third, under 'evolve', the authors examine wearable devices and how the health data they provide has been used to create data portals. Furthermore, these devices have fuelled an analysis by healthcare institutions of how healthcare practitioners can use such consumer-owned data in diagnosis and treatment. This is an indication of how new technological innovations generate changes in sociotechnical structures and how these changes sequentially alter how new technologies are advanced, understood or applied by healthcare institutions and patients. As such, co-creation could persist through the lifespan of the innovation; healthcare institutions need to be mindful of these subtleties and adjust their approaches and procedures accordingly.

eHealth interventions in African countries

eHealth is the use of ICT to improve a flow of information, using electronic devices, thus supporting the delivery of health services and the management of health systems (WHO and ITU, 2012). eHealth has been lauded as a viable solution to equitable distribution of healthcare to the marginalised and vulnerable population groups, particularly across African healthcare systems. What is encompassed in eHealth has been debated for a few years as the term has been used to describe ICT technologies used for healthcare in similar but subtly different ways. A qualitative study on what constitutes eHealth was conducted to establish a conceptual framework of eHealth that sufficiently describes its intricacy and possible areas of intersection (Shaw et al., 2017). The study, which entailed obtaining perspectives from professionals in healthcare delivery, research, education, practice, governance and policy, revealed that there are three distinct but intersecting domains of eHealth (see Table 9.1). The researchers in this study argued that there was a need for a model of eHealth that provided an opportunity for shared discourse and for eHealth implementation and operationalisation (Shaw et al., 2017).

These domains are respectively defined as 1) the use of digital technologies to monitor, track, and inform; 2) the use of digital technologies to facilitate communicative encounters between health stakeholders; and 3) the use of data to improve health and health services. In a systematic review of published research, Cohen et al. (2015) examined the use and

Table 9.1: eHealth domains and subcategories

Domain	Subcategories
Health in our hands: the use of eHealth technologies to monitor, track and inform health	• Health, not just healthcare • Consumer-driven and -controlled health • Health via social media and the internet
Interacting for health: the use of technologies to communicate between stakeholders in health	• Connecting for real-time health • Social discourses and storytelling • New ways of interacting to personalise care • Supporting health professionals
Data enabling health: the collection, management and use of health data sources	• Data management systems and data repositories • Data for precision health • Data enabling quality

Source: Shaw et al. (2017)

impacts of eHealth in community-based health facilities in developing countries. The review found numerous studies referring to eHealth initiatives. However, upon further investigation the authors concluded that there may be limited diffusion of these eHealth technologies within community-based facilities in developing country contexts. The authors also established that several eHealth technologies are aimed at data collection for reporting purposes rather than for patient care.

One of the most common eHealth platforms used across Africa is mobile health, or mHealth in short, which is the use of mobile devices for healthcare delivery. Mobile connectivity has been a driver of transformation for millions of people across Africa, through facilitating the distribution of basic resources and services, including education, healthcare and financial inclusion. Mobile devices have allowed for the circumvention of some of the challenges brought on by considerable gaps in infrastructure and funding. The number of smartphone connections in the sub-Saharan African region reached 302 million in 2018, and this number is forecast to

reach approximately 700 million by 2025, an adoption rate of 66 per cent (GSMA, 2019). Populations in developing or low-income countries have been able to take advantage of the availability of low-cost smartphones that have overcome the barrier to affordable access (Wood et al., 2019). These low-cost smartphones provide data sensing and processing capabilities comparable to more expensive mobile devices (Wood et al., 2019).

The proliferation of mobile technologies across the African continent has given rise to interventions that use mobile devices for healthcare delivery. Approximately 98 per cent of all internet experiences in Africa happen on mobile smartphones (GSMA, 2019). In Kenya, the accessibility of smartphones has been used advantageously in several eHealth projects implemented in an attempt to offer cost-effective solutions to health and healthcare system challenges (Njoroge et al., 2017). Although there has been a mixture of the types of eHealth platforms used, the majority of these were facilitated by mobile devices. This finding is supported by a report that revealed that most of the East African eHealth start-ups use mobile devices, with 64 per cent of Kenyan start-ups relying on mobile devices (High-Tech Health, 2017).

The use of mHealth in South Africa is also expanding. GSMA indicates there were 83 mHealth services in South Africa in 2013, with the majority focusing on HIV/AIDs and women and children (Cargo, 2013). In 2016, the most common mHealth applications were the registration of users and vital event tracking, data collection and reporting, and the creation and updating of electronic health records (Botha et al., 2016). As the technical barriers to using mHealth applications need to be as low as possible to increase reach, these services mostly utilise SMS (Botha et al., 2016).

Table 9.2 shows a few mHealth programmes that have been implemented in countries on the continent using different platforms.

The sustainability of many mHealth interventions over long periods of time, however, is a cause for concern. The reliance on donor funding means the services are discontinued after some time. Thus, there is a need for a more viable solution to mHealth implementation. Botha et al. (2016: 145) argue for:

> an integrated mHealth & Wellness Innovation Ecosystem as opposed to the development of additional free-standing

Table 9.2: Health programmes in a few African countries

Project	Platform used	Purpose
MomConnect[5] Since 2014 (South Africa)	• SMS • Unstructured Supplementary Services Data (USSD) • Mobile website	• Platform allows pregnant women to reach out with pressing questions and get feedback. • Was used as a platform to improve service at healthcare facilities.
Project[6] Masilukeke Since 2008 (South Africa)	• SMS	• Health education and awareness programme (one million messages per day to subscribers to encourage HIV/AIDS testing).
MSos[7] Since 2013 (Kenya)	• SMS • Web portal	• Text message facility that allows real-time communication between health facility workers and disease surveillance coordinators at sub-county, county and national levels.
Safer Mom[8] Since 2014 (Nigeria)	• Web App • Mobile App • SMS • Voice service	• Platform that monitors and tracks pregnancy and babies' development.
MTrac[9] (Uganda)	• Toll free MTrac SMS hotline 8200	• SMS based technology connecting hospitals to the national drug chain.

Source: Njoroge et al. (2017)

5 MomConnect http://www.health.gov.za/index.php/mom-connect
6 Project Masilukeke https://www.innovations.harvard.edu/project-masiluleke
7 MSos http://www.africanstrategies4health.org/uploads/1/3/5/3/13538666/msos.pdf
8 Safer Mom https://www.changemakers.com/makingmorehealth/entries/safermom
9 MTrac http://www.mtrac.ug/

> mobile applications and services. mHealth in South Africa is not only about improving the availability, access and delivery of healthcare services, but is also about enhancing the country's strategic capabilities to create, adapt and implement novel mHealth solutions within, and by, the public and private sector, towards enhancing the country's overall innovation capacity.

Importantly, collaboration between stakeholders in the public sector, the private sector and broader civil society is required to overcome barriers to successful mHealth implementation and so to unlock its full potential. The capacity for mHealth to contribute towards improved health equality and ultimately to pave the way for successful implementation of even more advanced ICT systems should be harnessed. The lack of readily available and sufficient evidence on the impacts of eHealth on healthcare delivery and patient outcomes (Cohen et al., 2015) is a missed opportunity to determine the usefulness of mHealth applications and to establish areas for improvement. It also means there is lack of sufficient evidence to conduct studies examining readiness for emerging technologies.

This section has highlighted that, in a developing context, mHealth is a more readily available technology to improve healthcare and make it more equitable. The importance of taking cognisance of the context in which technological innovations are intended to operate cannot be overstated. Essentially, the design and development of healthcare systems and technologies should be mindful of a nation's needs and available resources. Furthermore, co-creation should be at the centre of the development of mHealth solutions to increase the chances of uptake.

CURRENT ADVANCES IN 4IR TECHNOLOGIES IN THE SOUTH AFRICAN HEALTH SECTOR

Even with the country's unfavourable state of healthcare and sometimes ineffective implementation of health technologies, there are small pockets where advanced 4IR technologies are being employed in South Africa's healthcare sector. A few examples are provided below in Table 9.3.

Table 9.3: Examples of 4IR technology advancement in South Africa

4IR Technology	Application	Example
Artificial Intelligence	Diagnosis and triage of patients	To streamline and improve medical imaging diagnosis for radiologists. With this technology, radiologists are empowered to prioritise urgent cases and, in that way, present a more patient-centric model of health service delivery (Envisionit, 2020)
Artificial Intelligence	Automated triaging	Reduces patient waiting time at clinics, and ensures records are always accessible (Phulukisa, 2020)
Artificial Intelligence	Enhanced communication with patients	Multilingual chatbot service for self-diagnosis (doctor on your smartphone). Additionally, the app connects healthcare workers and patients in real-time (Datawizzards, 2020).
Artificial Intelligence	Counselling services	An app providing counselling and tackling GBV and mental health (AI for Good, 2018)
Big Data	Clinical decision-making support	Vantage technology integrates data immediately from a large range of sources to analyse service delivery. It then makes recommendations for step-by-step action, directing staff to take the right action at the right time, rather than make decisions based on gut instinct, habit or anecdotal evidence (BroadReach, 2019).

4IR Technology	Application	Example
Biotechnology	Advanced genetic engineering and synthetic biology to develop human therapeutic proteins	Using plant cells to express human recombinant proteins with increased safety, production speed, clinical efficacy, cost and scalability (Arzagen, 2019)
Drones	Deliver blood and medical supplies	The South African National Blood Service (SANBS) partnered with the Western Cape Blood Service to introduce a nationwide blood delivery drone service (Malinga, 2020).

Furthermore, COVID-19 has led to various private-sector and academic institutions producing face shields for frontline health workers using 3D printing (3D community, 2020). 3D printing requires little human interaction and can even be done in the manufacturer's home. Additionally, algorithms have been used for data modelling (Covid19sa, 2020) to assist in decision-making during the COVID-19 pandemic. The models are able to show and predict factors such as hotspots, numbers of infections and deaths, and available functional hospital beds. They have been valuable in navigating through the uncertainty presented by this novel virus.

While these exciting technological innovations are impressive and have the capacity to transform healthcare, there is a low probability of their benefits being widespread and inclusive without a concurrent strengthening of the healthcare system and socioeconomic redress.

WAY FORWARD: A MULTI-LAYERED, SYNDEMICS APPROACH TO HEALTHCARE

As described above, the issues in the South African healthcare system are multifaceted, historical and systemic. It then follows that efforts

to strengthen the healthcare system should take a comprehensive approach. The use of AI and other digital technologies in under-resourced settings requires a firm understanding of socioeconomic, healthcare and political conditions, infrastructure constraints and further associated infrastructure requirements, such as IT, communications systems and programmes for delivering primary health services. In addition, several AI technologies rely on robust electronic health record systems.

Technological innovations are a crucial aspect of healthcare reforms, but they require complementary and supportive interventions for their benefit to be experienced by all. Some areas that policymakers could consider include the following:

- Systemic issues in the country that need to be addressed. The South African government has drafted numerous policies that aim to redress inequalities, but many of those challenges persist. These systemic challenges are a barrier to realising the full potential of 4IR technologies, particularly for communities that bear the brunt of a defunct system.
- The South African healthcare system relies heavily on community healthcare workers (CHW). They play a pivotal role in the management of diseases in healthcare delivery and can be used extensively in the process of technology co-creation and/or diffusion. They have unique knowledge of communities, and this can be used to forge partnerships between healthcare providers and patients. However, CHWs need to be fairly compensated for the work they do – and their employment formalised. In this way, they will be incentivised and will have an enabling environment to work optimally.
- A national, widespread intervention for healthcare infrastructure development is required, including ensuring water and sanitation facilities are up to standard. Such an infrastructure plays a major role in health outcomes.
- A healthcare-focused 4IR strategy tailored to the South African healthcare system should be drafted.
- Priority should be given to the training and upskilling of healthcare workers in technologies introduced into the healthcare system.

- Electronic health records (and any other ICT systems) need to be maintained by skilled personnel.
- Lastly, adequate resources are required to plan for and effectively meet the health needs of the whole population. The NHI should, therefore, be prioritised to aid in redressing the fragmented healthcare system, while providing quality healthcare and access to health technologies to all, regardless of socioeconomic factors, geographical location or ability to pay.

CONCLUSION

This chapter has explored the benefits of 4IR technologies and shown how these are currently being enjoyed by high-income countries. The issue of access to technological innovations for marginalised communities was shown to be a possible barrier to equitable distribution of the benefits of 4IR technologies. Solutions to healthcare in the South African context, and more broadly the African context, require a syndemic approach (MISTRA, 2019). Technology alone will not be the panacea to healthcare system challenges in the country, and on the continent at large. Rather, parallel strategies and policies need to be in place, such as programmes that ensure that healthcare workers are upskilled, and that patients are included in the development of technologies meant for them. These are some of the various factors that impact on health outcomes, including socioeconomic, environmental and political factors, which need to be addressed, with technological advances as enablers of solutions. Health inequalities will continue being entrenched and the majority of the population will be left out of the so-called revolution if 4IR technologies are treated as a blanket solution, and a comprehensive, transdisciplinary approach is neglected.

These concerns have been brought to the fore with the race for a COVID-19 vaccine. There is a danger that in the urgency to have a vaccine, questions about access to and distribution of the vaccine will be neglected. Will developed, wealthier countries be the first to gain access to the vaccine? And within both developed and developing countries, will privileged groups have better and quicker access? The need for an equitable, fair strategy for a potential vaccine

underscores the importance of the central issue raised in this chapter: The technologies of the Fourth Industrial Revolution hold exciting potential for transformation but their benefits are greatly dependant on the context in which they are implemented. In South Africa, one of the most unequal countries in the world, failure to discuss what 4IR technologies will mean for its marginalised groups, and their access to healthcare, runs the risk of entrenching inequalities. In exploring 4IR technologies and their potential for transformation, researchers need to keep at the forefront the question of who these innovations are for.

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