Digital Health:

A Framework for Healthcare Transformation

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Introduction

Global health systems are at a crossroads, facing exponential growth in healthcare costs that are far outpacing the growth rates in the GDP to support health system sustainability. Stretched budgets, coupled with aging populations and the rapidly growing prevalence of chronic illness, are collectively exerting strain on health systems that are already struggling to cope with demands for services.

Health systems have relied on well-established disease management pathways and evidence-based care approaches in an effort to manage care demands and standardize practices to improve quality and safety. Yet, the prevalence of chronic illness continues to grow; 60% of adults in the U.S. have a chronic illness and 40% have two or more chronic conditions (Centers for Disease Control and Prevention, 2019), accounting for $3.3 trillion in health system costs annually.

Chronic illness is now responsible for 75% of total health system costs in North America, and evidence indicates that current care delivery models are not well constructed to effectively manage the growing demands chronic illness is placing on today's healthcare systems (Milani, R. et al, 2017). Healthcare costs are expected to continue to grow as new therapies (e.g. genomics, personalized medicines) emerge and will place additional cost burden on health systems. Blue Cross Blue Shield Association has now reimbursed, for the first time in its history, new therapy for one patient in the amount of $2 million (Serota, 2019).

Current funding models and cost pressures will make such life-changing therapies unaffordable and inaccessible, until health systems can transform care delivery, and new business models are developed to support access to life-saving therapies — made available to all people and populations. The current reimbursement models and care pathways focused on disease management will continue to escalate, placing health systems in an impossible position as they continue to struggle to meet the demands for health services from populations they are mandated to serve (Marvasti, F. & Stafford, R, 2012).
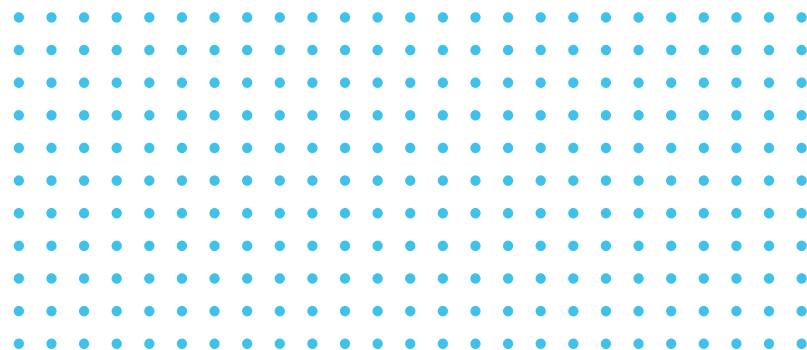
While health systems struggle to manage growing demands for care and financial sustainability, consumers and populations are placing new expectations on health systems for greater personalization of care focused on health and wellness (Statista, 2019).

Over 57% of the world's population are now connected through the World Wide Web, easily accessible through an expanding set of technologies including wearables, smartphones, computers, sensors and tablets (Statista, 2019). The availability and affordability of internet access enables information to flow freely across global borders, connecting people and populations to health experts, health teams and organizations anywhere in the world. Global populations are emerging as informed consumers of healthcare, striving to make health decisions autonomously, with the support of provider teams, rather than relying on prescribed care pathways which may not be aligned with personal health needs and goals. One has only to look at the 318,000 health applications in the consumer market to understand the drive toward health and wellness enabled by the many consumer devices and technologies in this rapidly growing market (IQVIA, 2017).

Consumer motivations are shifting as the rapid evolution of digital technologies has increased consumer demand for care personalized to the unique values, needs and life circumstances of people and populations (Snowdon, A., Schnarr, K. & Alessi, C, 2014). Although many health systems aspire to deliver "patient-centered care," the existing care pathways and care models rely on prescriptive approaches of health professionals who assess and direct care and treatment for patients, rather than creating care models designed and informed by patients to achieve personal goals and health outcomes (Snowdon, A. et al, 2014).

Consumers can now connect virtually to global experts and health organizations and have access to a wide range of health information through internet-based technologies. The "consumer" role is emerging rapidly as individuals are empowered to make health decisions and lifestyle choices fueled and enabled by the growing market of digital tools, technologies and health "apps" in the consumer market. Yet, there is a disconnect between the health and wellness tools consumers are using, and current healthcare systems which have not engaged people digitally to meaningfully connect to them in a way that supports and enables achievement of their personal health goals.

Care pathways, although evidence-based, have not been structured to enable patients to personalize care strategies to fit with their unique needs and life circumstances, nor have disease management pathways included, or enabled, self-management tools and technologies to help people support their health and wellness.

It is widely acknowledged that the key to closing the gap between people and their health systems to advance and strengthen health and wellness is transformation of today's healthcare system toward the future, digitally enabled health system focused on health and wellness.

Digital health remains underdeveloped with very few global jurisdictions having advanced to offering digital care environments that engage and support people to manage their health and wellness. Although digital health holds tremendous potential for health systems to engage people and populations more meaningfully, a number of critical questions remain unanswered. Including, what exactly is digital health and what does digital health achieve?

What is the impact and value of digital health for people and populations? How can digital health transform health systems to engage people more meaningfully to support and sustain health and wellness?

Digitizing care delivery of today's health system to optimize disease management is commonly viewed as adding significant expense to the current system, which has not achieved sustainable high-quality outcomes to date.

Leveraging digital technologies to transform care delivery to reimagine the future health system that reaches out to connect with individuals and populations meaningfully is the promise of digital health.

The goal of this whitepaper is to define digital health, and propose a digital health framework and measurement strategy — the Digital Health Indicator — to guide and inform digital health system progress and strategy, as care delivery is transformed to engage and connect to people and populations meaningfully, while also strengthening system performance and sustainability.

The proposed digital health framework and indicator is informed by, and builds upon, the existing theoretical and empirical evidence of digital health concepts and frameworks.

Evolution of Digital Health

To begin to answer the question of "what is digital health?" one must first consider the evolutionary change in information technology in health systems to understand the context and starting point for digital health and the opportunity digital health offers to fuel transformational change in health systems.

Digital health has been described as an era (Rowlands, 2019), a progression along the evolutionary path of information and communication technologies (ICT) in healthcare, one that constitutes a great leap forward and transcending technologies rather than just the next technological step. Digital health as an "era" is embedded in what is widely accepted as the fourth industrial revolution — the use of big data, analytics, and artificial intelligence, all of which are evolving across virtually every business sector (Figure 1). While the fourth industrial revolution is well underway in many sectors — finance, travel, online retail, communications — it has not evolved as quickly in the health sector.

Health Sector has progressed here

The Four Industrial Revolutions

| 1750 | 1800 | 1850 | 1900 | 1950 | 2000 |

1

2

3

4

First (1784)
Mechanical production, railroads, and steam power

Second(1870)
Mass production,electrical power, and the advent of the assembly line

Third(1969)
Automated production, electronics, and computers

Fourth(Now)
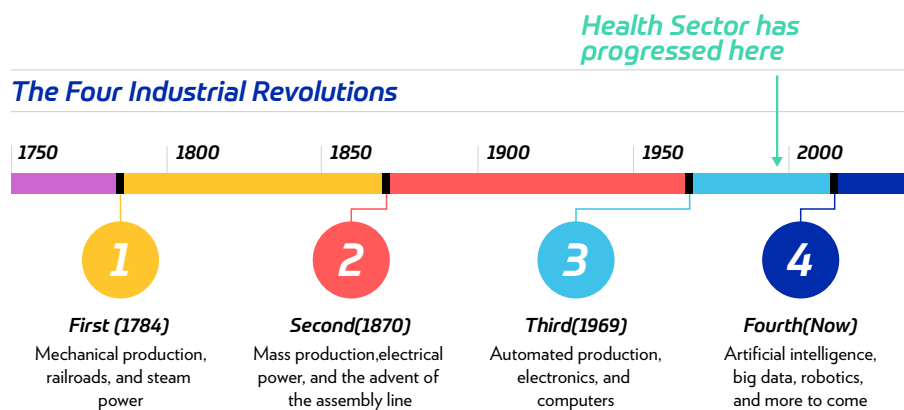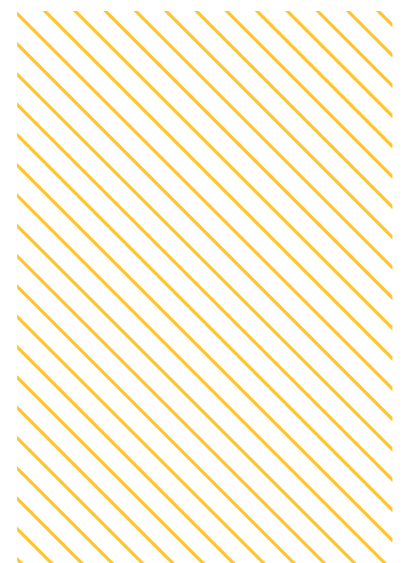Artificial intelligence, big data, robotics, and more to come

Figure 1: The Four Industrial Revolutions and Progress of Health Systems

ADAPTED FROM (MURRAY, 2016) (TOPOL, E. 2019)

Healthcare is widely viewed as a laggard in adopting new technologies compared to nearly all other industries such as transportation, finance, retail, and manufacturing. The evolution of ICT in healthcare is summarized in Table 1 (Rowlands, 2019) to document the context within which digital health can be more fully examined across global health systems.

1950-1960	1970-2000	2000-2020	2020+
Mainframe Computers	Health IT	E-Health	Digital Health
Mainframe computers are introduced into business sectors.	Health informatics as a discipline emerges. Problem oriented health record is implemented.	Growth in chronic illness rates, need for data given quality and safety challenges.	Analytics, AI, robotics, machine learning, Internet of Things, health apps, virtual reality.
Mainframe computers were agnostic to all sectors.	Personal computers on the market for consumers.	Consumerism emerges with use of personal computers and access to information via internet. Public funders invest in interoperability.	Pervasive use of ICT in "digital" societies.
Code written in machine and assembly language.	Health IT departments in hospitals deploy IT enterprise systems.		Wellness focused.
Relatively limited impact on healthcare.		E-commerce emerges. Enterprise wide shared health record (EMR) implementation underway.	Consumers demand health services that are responsive when and where needed, digitally,
Focus: Limited focus on corporate support functions only.	Focus: Logistics and organizational functions a major focus, performance is prioritized. Management systems software focus.	Focus: Health IT focus on patient care delivery, digital technologies focus on provider directed and controlled care processes.	Focus: Consumer and person-centric — care that aligns with lifestyle. New data sources (e.g. wearables, sensors, social network data) connect to health systems.

Table 1: Summary of the Evolution of Health Information Technology

Digital health is now emerging in health systems, building on the strengths of the eHealth era where an enterprise approach to digital technologies has created the necessary foundational infrastructure. Key themes evident in the evolution of information technology in health systems show important features of digital health that are clearly emerging:

a. **The emergence of consumerism** started in the eHealth era when personal computers became readily available to consumers along with a multitude of digital technologies which continue to emerge. Transformation in the role of patients to consumers continues to unfold, where consumers are now choosing how they prefer care to be delivered that is consistent with their lifestyle, values, and "life flow" of daily activities in digital societies. The emerging role of the consumer signals new expectations and demands of health systems to offer choice, fueled by empowerment as people and populations demand access to digitally-enabled health services, which they have grown accustomed to in virtually every other business sector (Rowlands, 2019).

b. **Expansion and reach of personalized health data,** beyond formal health systems, now engages multiple and varied sources of data, within and across social systems, health systems and digital communities. It was only when enterprise IT infrastructure became mainstream that data began to be mobilized in formalized health systems. A wide range of devices and technologies including social networks, wearables, telemonitoring, genomics analysis (both private and public sector) and health applications can be personalized to capture outcomes to track health and wellness. This places new urgency on interoperability across health systems and communities to enable the safe and secure flow of data from multiple and varied sources to people and populations. Personalization of data that is accessible and meaningful to the day-to-day lives of individuals is a key feature of digital health.

c. **The emergence of advanced analytics and algorithms** (e.g. AI, machine learning, deep learning, neural networks) are prominent in digital health, which further advances the transformation from the current disease management focus, to a more proactive and predictive strategy focused on keeping people healthy and well. Analytics are the new currency of digital health, able to transform data into knowledge, insights, evidence of value and impact that informs new models of care within a digitally-enabled environment. Digital care delivery models also offer great opportunity to streamline operational processes to strengthen efficiency, productivity, responsiveness and access to care within a more automated and integrated digital health ecosystem.

In order to advance digital health transformation, the key dimension of consumerism in health systems will be examined more fully to identify the key feature of a person-enabled health system.

The "Empowered" Consumer

Currently, there is a poor fit between what formal health systems have to offer (i.e. dominant disease management focus), and what empowered consumers value and are seeking to achieve (i.e. health and wellness).

This "disconnect" has evolved for two reasons:

01 Health systems focus primarily on managing illness and disease using prescribed care pathways, rather than focusing on individual health and wellness goals where care pathways are adapted and personalized to person's health, wellness and quality of life goals (Snowdon, A. et al, 2014).

02 The majority of digital tools and platforms available online to consumers are not connected or interoperable with information infrastructure in formalized health systems, making it nearly impossible for consumers to reach out and connect, digitally, to health teams.

Essentially, what has now emerged are two, distinct and separate healthcare systems: the traditional system, which is institution-centric and prioritizes disease management; and, the consumer-based approach, where people select and engage online tools, wearables, and resources to create their own personalized strategy to manage their health and wellness, custom-designed to the needs, values, and goals of the individual (Snowdon, A. et al, 2014).

If digital health is to advance and progress toward a system that prioritizes health and wellness of people and populations, then one must first examine the motivations of people as consumers of health services to better understand what drives consumers toward these personalized approaches to health and wellness.

In a 2014 study, seven key motivations or "drivers" were documented that fuel the empowered consumer in health systems (Snowdon, A. et al, 2014), described in the following.

01
Drive to learn and manage health and wellness.

People do not want to wait to get sick before they are able to seek healthcare services, they are driven to learn health behaviors and strategies that achieve health and wellness goals. Access to health information and the explosion in the use of health applications ("apps") is a clear indication of the thirst for health and wellness tools and technologies sought after by consumers the world over.

02
Drive to engage and connect to other consumers ("like me").

People are actively engaging others via online "communities," composed of people who are experiencing similar health challenges, experiences, or sharing common health interests. Online peer-to-peer support is offering consumers the opportunity to learn from "people like me," which not only supports meaningful relationships and social support, engagement, but also encourages achieving health goals they share or strive to achieve. While the validity of the medical information provided through these social networks may not be considered "evidence-based," these are powerful networks that inform, influence, and share health behaviors and experiences.

03
Drive to "take control."

People inherently strive for, and value, self-determination. What is most important and what matters in terms of their individual health and wellness journey, all fuel the drive toward autonomy, control of their own destiny and self-determination to achieve personal goals. People are no longer waiting for health education from providers; they are now taking initiative, accessing information online that is deemed relevant to their individual needs and health circumstances.

04
Drive to self-manage health information.

People today are seeking health information that is relevant to them, is easily understood, and is actionable. Consumers are demanding access to information that is relevant to their personal needs and health outcomes. Consumers want to fully understand all of the possible treatment or health program options, the associated risks and benefits for each, so that they can make informed decisions about their health and wellness. There is an emerging trend toward using technologies to provide people personalized health information through online access to their health records and lab results that also connect with physicians or healthcare teams. Providing people with their personal information about their medical data increases health literacy and at the same time enables consumers to better understand their health status as it changes over time.

05
Drive to ensure accuracy.

People who have access to, and manage, their own health information are more likely to recognize the risk of adverse events, or errors. Confidence in quality and safety of care delivery is a growing challenge given that medical error is now the third leading cause of death in health systems (Makary, M. & Daniel, M, 2016). Just one of many examples is that seven percent of abnormal lab results are not communicated to patients, which precludes appropriate follow-up and may result in inappropriate or delayed diagnoses (Callen, J., Westbrooke, J., Georgiou, A. & Li, J, 2012). The growing rate of errors has eroded confidence in health systems with 1 in 10 people globally experiencing medical error (World Health Organization, 2019). Access to health records is a growing trend that will be particularly important for engaging people to have the confidence in ensuring questions can be asked, and outcomes and progress are fully understood.

06
Drive to collaborate with health providers, not be simply recipients of care.

Empowered with access to information from both the consumer and the provider creates an opportunity for greater connectivity and engagement with health providers, creating the conditions for shared decision-making. Digital technologies offer the potential to transform the traditional "in-person" visits with providers, toward a more digitally-enabled care environment that offers convenience, choice, and opportunity for personalization.

07
Drive toward consumer engagement.

Consumer engagement is closely linked to growing health literacy as consumers can now go online to access expertise and health information from around the globe, with many opportunities for accessing health services online. The phenomenon of "Dr. Google" is more than just the availability of, and access to, online technology. Responding to the trend of the empowered consumer is challenging for health systems as it undermines the hegemony of the medical model of health, where there are established traditions of professional judgments of clinical 'need' be considered above the 'wants', 'preferences' or 'choices' of patients. Healthcare consumerism is about enabling people to self manage their health, fueled by the fundamental value of self-determination of what it means to be human.

To further examine concepts that are relevant to the empowered consumer, a critical appraisal of the literature included a review of concepts such as patient experience, patient engagement, consumer-centered care, patient-centered care, consumer-enabled care, personomics, and digital health frameworks or models.

A number of common themes were evident in this literature. First, patient engagement is considered as a crucial element of a more "patient-centric" health system and much work has focused on finding new ways to engage patients to strengthen their experiences in health systems. Despite significant attention to engaging patients in their care, findings suggest that patients continue to be viewed as "recipients" of care, and patient "engagement" efforts focus primarily on encouraging patient feedback on their experiences. Acknowledgement of individuals as the primary decision-maker and manager of their health and wellness is much less clearly defined in the literature to date. Other notable gaps in this patient engagement literature, include:

THE FOLLOWING MODELS WERE INCLUDED IN THIS REVIEW:

- PAM (Patient Activation Measurement)

- World Health Organization: Global Strategy on Integrated People-Centered Health Services (IPCHS)

- Value +

- Warwick - Edinburgh Mental Wellbeing Scale

- Consumer Assessment of Healthcare Providers and Systems (CAHPS or HCAHPS)

- Patient Reported Outcome Measures (PROM)/Patient Reported Experience Measures (PREM)

- National Institute for Health and Care Excellence (NICE) reports and literature

- No focus on digital connectivity or social network engagement to support health literacy, enable and inform self-management of health and wellness.

- Limited focus on the importance of access to health data and literacy tools to support and inform individual-level decisions.

- Little or no acknowledgement of the fundamental drive toward autonomy, based on personal needs, values and life circumstances.

- Technologies that connect, automate, engage, and track outcomes and data informed risk management are not described in current frameworks and measurement tools.

Digital technologies offer the potential to shift care environments to being more open and flexible, enabling much greater involvement of consumers in managing their own healthcare (Baumann, 2015) (Iyawa, G., Herselman, M. & Botha, A, 2016) (Kotskova, 2015). However, there remains limited evidence that documents consumer engagement approaches, outcomes, or care delivery strategies at the system level.

Current Themes Emerging in the Literature:

The Opportunity for Digital Health Outcomes

Academic literature, as well as current institution-based documents and frameworks, were examined to understand the current state of the science describing and defining "digital health."

This critical analysis provides an overview of the strengths and gaps in published literature to identify the current state of the science, knowledge and empirical evidence related to digital health. The following summarizes the key themes evident in this literature.

The Challenge of Digital Infrastructure and Legacy Systems

As more technology is adopted, the coordination between organizations and information systems becomes increasingly challenging. Many healthcare organizations have outdated systems and struggle with the merging of different legacy technologies, often created at different times for different uses (Henfridsson, O. & Bygstad, B, 2013). Having the right infrastructure, either through hardware or software, was a key theme throughout the literature (Ullah, F., Asif Habib, M., Farhan, M., Khalid, S., Yahya Durrani, M. & Jabbar, S, 2017). (Raghupathi, W. & Raghupathi, V, 2014). There has been an emphasis on the need for the right infrastructure system, that connects the many

different applications in healthcare, from Enterprise Resource Program (ERP) data to patient care data in EHR systems (Snowdon, A. & Wright, A, 2017) (Henfridsson, O. & Bygstad, B, 2013).

The expanded use of healthcare information is considered essential to improving and expanding healthcare and advancing science, but raises issues of policy, accountability, and security (Rosenbaum, 2010) (Knoppers, B. & Thorogood, A, 2017) (Ullah, F. et al. 2017). Enhanced and connected networks of data sources and digital infrastructure is seen as a critical enabler for the data-driven advances in digital healthcare, but is a key part that is missing from most global healthcare systems (HealthCareCan, 2019). Having the right infrastructure in place can reduce silos of information and create "visibility" throughout the healthcare system (the ability to see not only a person's information, but the products used in their care, healthcare decisions, and if they have seen different healthcare professionals or specialists from different organizations).

Transformation from the "Internet of Things" (IOT) to the "Intelligence of Things"

Data is constantly being collected by health organizations such as hospitals (EHR utilization data), consumers (wearables, Fitbits, apps), and social networks (e.g. special interest groups, consumer groups, communities and populations) (Ziegelstein, 2017).

Connecting the data sets from formalized health systems with the large and growing health data emerging from consumer health devices and applications, creates the opportunity for predictive tools to inform care delivery strategies that proactively identify and then mitigate risk to support health and wellness. Digital health tools offer consumers the potential for greater connectivity to health systems, and offer new strategies for more robust data collection of outcomes across the journey of care, making way for more personalized approaches to care delivery (Ziegelstein, 2017).

Data infrastructure that collects and harvests data from multiple sources can enable "learning" health systems, which is a system that aims to improve (learn) from the data it acquires (from user experience, research evidence, or analysis of large data sets) (Hu, J., Perer, A. & Wang, F, 2016). What has been widely described as the Internet of Things, is now incorporating new technologies such as Artificial Intelligence and machine learning into digital technologies used by the consumer. As Artificial Intelligence and machine learning is adopted more widely in health systems, the Internet of Things is anticipated to transform into the Intelligence of Things; how we use the data collected to change our processes and in turn, shift culture and behavior (Koenig, 2020) (Wallace, 2015).

It is the integration of the rapidly progressing world of digital technologies into health systems that sets the stage for the future digital health system, one that is informed by evidence and real-world data to proactively support and strengthen health and wellness of people and populations. Currently, significant challenges include privacy, data sharing and connectivity across organizations, the storage of data, and tracking data and outcomes at the level of the individual (Manogaran, G. Vartharajan, R, Lopez, D., Kumar, P., Sundarasekar, R. & Thota, C, 2018).

The Shift Toward: Health and Wellness Outcomes for Populations

Mobilizing data across communities and health systems enables clinician teams and health leaders to examine the opportunity for health and wellness outcomes as healthcare services evolve and transform from the reactive disease management approach to a proactive population health approach where population health data is used to inform personalized medicine as a way to reduce chronic disease(Pritchard, D., Moeckel, F., Villa, MS., Housman, LT., McCarthy, CA. & McLeod, HL, 2017).

The literature described segmentation of populations (i.e., splitting the population into different population groups) based on health and wellness indicators, health risks, and health outcomes whereby analytics, inform clinician teams of priority populations at risk. This creates the opportunity to proactively intervene, then track the value of interventions on health and wellness outcomes associated with care delivery (Rumsfeld, J. Joynt, K. Maddox, T., 2016) (Lynn, J., Straube, B., Bell, K., Jencks, S. & Kambric, R, 2007). Population segments enable targeted, personalized and prioritized care delivery, which can be tracked and tailored to consumer health goals, values, and individual life circumstances (Bates, D., Saria, S., Ohno-Machado, L., Shah, A. & Escobar, G, 2014)

The Value of Self-Management in Health and Wellness

People and populations are ready to manage their own health and wellness and are actively seeking strategies and tools to take charge of their health and to change the way they access health services. Online connectivity offers digital tools, online resources, access to genomics and DNA services, and communications technologies that are most often disconnected from the formalized health system (Snowdon et al, 2014).

Although consumers are actively using personal health tools, such as wearables, sensors, or digitally enabled devices (e.g. insulin pumps, pacemakers), there are few opportunities, if any, for consumers to link their personalized health tools to the formalized patient data (EHR) embedded in health systems. Evidence indicates that when people are actively managing their personal health and wellness, health system costs are reduced and quality outcomes, such as reduced error and adverse events, improve (Milani, R., et al, 2017).

The concept of "patient activation" has been described as a model that leverages a variety of digital tools and technologies to engage individuals in their care, connecting them in new ways to their health teams, and offering them choices for how, when, and where care is delivered. It focuses on supporting individuals to be "active" in managing their chronic illness, having the tools to enable them to do so, supported by health teams when and where help is needed. To date, there is evidence that patient activation has been shown to improve medication adherence, and align with best practice care pathways, which has demonstrated significant reductions in adverse outcomes and reduced total healthcare costs (Milani, R., et al, 2017).

What is unique in this literature is the role of digital technologies in shifting care environments to being more open and flexible, enabling much greater involvement of individuals in managing their own healthcare (Iyawa, G., Herselman, M. & Botha, A, 2016) (Baumann, 2015) (Kotskova, 2015). Although there are many models of consumer engagement, there remains limited evidence that documents outcomes at the system level. The concept of patient activation has been described by some health systems, such as NHS and Ochsner (Milani, R., et al, 2017) (Hibbard, J. H., Stockard, J., Mahoney, E. R. & Tusler, M, 2004). However, scalability of consumer-engaged care delivery remains limited in both scope and evidence of impact and value at the system level.

The most compelling finding from this review of digital health literature is the opportunity for health system transformation — enabled by digital health technologies that can achieve transformation of care models, whereby individuals are empowered, connected and informed, and care delivery prioritizes health and wellness.

To further examine the concept of digital health, the following section documents how digital health is defined, and how digital health frameworks and models have been described.

What is Digital Health?

"Digital health" has been discussed widely, yet an agreed upon definition of digital health remains elusive.

A variety of terms and concepts are used interchangeably in reference to digital health, including "mHealth" (mobile health), "eHealth" (e.g. technology and digital applications to assist patients in their health), virtual care, and telehealth, to name just a few. A search of digital health definitions in both empirical literature and grey literature (e.g. online sources) was completed to fully examine current definitions of digital health to identify themes and concepts. Appendix 1 includes a summary of the published definitions of digital health included in this analysis.

Three types of digital health definitions, emerged from this analysis, described in the following:

Digital health defined in terms of type and use of digital technologies.

The most prevalent focus of digital health definitions is on the type and use of digital technologies (Gardiner, 2019; Canada Health Infoway, 2020; Lupton, 2014; Robinson, L., Griffiths, M., Wray, J., Ure, CM. & Stein-Hodgins, J, 2015; Scotland Digital Health Institute, 2018; WHO, 2019). For example, "Digital Health is a term that is frequently adopted to encompass a wide range of technologies related to health and medicine" (Lupton, 2014).

Similarly, "digital health refers to the use of information technology/electronic communication tools, services, and processes to deliver health care services" (Canada Health Infoway, 2020). Finally, the WHO definition of digital health is a "broad umbrella term encompassing eHealth (mHealth), as well as emerging areas such as [the] use of advanced computing sciences in 'big data', genomics, and artificial intelligence."
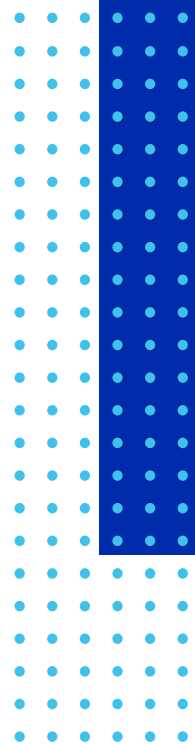
Digital health definitions focused on improvement of healthcare delivery.

A number of definitions focus on the use of digital technologies to improve the delivery of healthcare, such as improving the holistic view of patients (FDA); "achieving health objectives" (UNICEF); upgrading the practice of medicine (Steinhubl, S. & Topol, E, 2018); delivering evidence-based therapeutic interventions to prevent, manage, or treat a disease or disorder (Goldsack, J., Coder, M., Fitzgerald, C., Navar-Mattingly, N., Corvos, A. & Atreja, A, 2019); monitor, and improve wellbeing and health of patients (Iyawa, et al. 2016); measure and intervene to support human health (Best, 2019); improve health system performance and capacity to deliver care, treat patients, track diseases and monitor public health (Deloitte, 2019) (European Society of Cardiology, 2019) (Swiss Tropical and Public Health Institute, 2020). These definitions infer the use of digital technologies can optimize current health system priorities of delivering care to manage or treat diseases and/or monitoring outcomes such as public health.

Digital health as a strategy for health system transformation.

Less common, but very compelling are a number of more recent definitions of digital health focusing on the concept of health system transformation toward patient-centric, democratization of care. Specifically, Trono (2016) defines digital health as a revolution that enables medicine to transform from a "reactive and often empirical discipline" into a "precise, preventive, personalized and participatory endeavor." Mesko (2017) describes the "cultural transformation of how disruptive technologies provide digital and objective data accessible to both caregivers and patients, leading to an equal level of doctor-patient relationship with shared decision-making and democratization of care." And Rowland (2019) defines digital health within the context of digital societies whereby "data is harvested in real-time across all societal activities, sophisticated analyses distill knowledge from these data to encourage better health and better value by including a wide range of economic activities and technologies, and is citizen-centric , decentralized and requires health providers to participate, not control". Similarly, the theme of citizen-centric and the empowerment of individuals has been prioritized by a number of organizations (FDA, 2018) (Iyawa, et al. 2016) (DiMe Society, 2019) (Goldsack, et al, 2019).

In each of these definitions, there is a central focus on transformation of health systems toward a strong focus and prioritization of health and wellness that is achieved by enabling and empowering people and populations to manage and control their health and wellness journey of care.

These definitions highlight the high degree of variability of digital health concepts and perspectives. There is a distinct difference in definitions that focus on digital health as a strategy to augment or improve health system performance and optimizing or advancing disease management.

These digital health definitions offer a glimpse into digital health as an opportunity to transform healthcare systems from a provider-centric model where patients are recipients of care, to digital health ecosystems that empower people by leveraging the digital infrastructure and technology to support and enable self-management of their health and wellness, supported by care teams as partners.

These definitions are consistent with concepts emerging in the literature which support the view of digital health as transformational, whereby new models of care delivery increase access to care for individuals (Jamieson, T., Wallace, R., Armstrong, K., Agarwal, P., Griffin, B., Wong, I. & Bhatia, S, 2015), by providing more direct connectivity with provider teams and specialists to improve convenience and cost-effectiveness (Vimalandanda, V., Gupte, G., Seraj, S., Orlander,
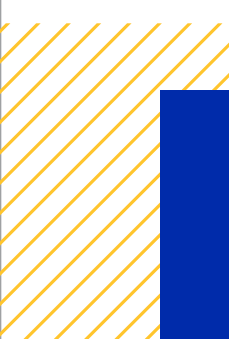
J., Berlowitz, D., Fincke, B. & Simon, S, 2015). According to Chang and West (2006), digital ecosystems transform the traditional, rigid health environment to one that is open, flexible, demand-driven and interactive (Chang, E. & West, M, 2006).

Digital health, also referred to as an ecosystem, is a new architecture and collaborative environment that extends beyond traditional human reach, provides an interactive community, rich data and information, value-add customer and agent services, high connectivity, cross-disciplinary learning and flexibility, and orients around self-empowerment of users (Chang, E. & West, M, 2006) (Janjua, N. Huddain, M. Afzal, M. Ahmad, H, 2009) (Heintzman, 2015).

Digital Health Frameworks and Models

A critical analysis of digital health frameworks and models was completed to identify the key concepts described as relevant features of digital health.

Documents and reports from global agencies and institutions were included in this review and analysis.

A concept analysis of the published frameworks and models was completed, and then further analyzed qualitatively to identify common themes across the models and frameworks. Table 2 summarizes and conceptually groups the key themes across all of the models and frameworks to further delineate the key features of digital health. A complete listing of the frameworks and models reviewed in this analysis is summarized in Appendix 2.

Table 2: Concept Analysis of Digital Health Models and Frameworks

Theme	Concepts Associated with Digital Health Themes	Model/Framework
Governance and Leadership	• Coordination with eHealth at the national level, align health goals with political support. • Promoting awareness and engaging stakeholders. • Using expertise, partnership and coordination to develop and adopt eHealth components. • Support and empower required change and monitoring of results for delivering best results.	WORLD HEALTH ORGANIZATION NATIONAL EHEALTH TOOL KIT (WHO, 2012); WHO GLOBAL STRATEGY ON DIGITAL HEALTH 2020-2024 (WHO, 2019); GLOBAL DIGITAL HEALTH INDEX (MECHAEL, P. ET AL, 2019)
	Strategy and Investment • A responsive strategy for monitoring eHealth. • Involvement, and taking lead, of major stakeholders and sectors. • Financing is aligned with priorities (government, private, public).	WORLD HEALTH ORGANIZATION NATIONAL EHEALTH TOOL KIT (WHO, 2012); WHO GLOBAL STRATEGY ON DIGITAL HEALTH 2020-2024 (WHO, 2019); GLOBAL DIGITAL HEALTH INDEX (MECHAEL, P. ET AL, 2019)
	Legislation, Policy, Regulation are Established • National policies and legislation in priority areas, including sector policies. • Legal and enforced regulation for privacy and trust for consumers and industry in eHealth practice and systems.	WORLD HEALTH ORGANIZATION NATIONAL EHEALTH TOOL KIT (WHO, 2012); WHO GLOBAL STRATEGY ON DIGITAL HEALTH 2020-2024 (WHO, 2019); GLOBAL DIGITAL HEALTH INDEX (MECHAEL, P. ET AL, 2019)
	Workforce • Make eHealth knowledge and skills available through internal expertise, technical cooperation or use of the private sector. • Build national, regional, and specialized networks for eHealth. • Establish eHealth training programs for healthcare capacity building.	WORLD HEALTH ORGANIZATION NATIONAL EHEALTH TOOL KIT (WHO, 2012); WHO GLOBAL STRATEGY ON DIGITAL HEALTH 2020-2024 (WHO 2019); GLOBAL DIGITAL HEALTH INDEX (MECHAEL, P. ET AL, 2019)
	Collaboration/ Strategic Partnerships • Defined objectives, goals and roles are needed; the team needs to understand the objective of the program, and work with external vendors to implement digital programs, with the ability to analyze the results. • Partnerships and collaborations are between varying levels of government, public, and private organizations.	(EVANS, H., AGARWAL, A. & BAZOS C, 2017)

Theme	Concepts Associated with Digital Health Themes	Model/Framework
Data Infrastructure and Interoperability	**Services and Applications** • A means for enabling services and systems, access, and exchanging and management of information (users include the general public, private and public partnerships).	WORLD HEALTH ORGANIZATION NATIONAL EHEALTH TOOL KIT (WHO, 2012); WHO GLOBAL STRATEGY ON DIGITAL HEALTH 2020-2024 (WHO, 2019); GLOBAL DIGITAL HEALTH INDEX (MECHAEL, P. ET AL, 2019)
	Data Standards • Standards that enable consistent and accurate collection of data and exchange of health information.	WORLD HEALTH ORGANIZATION NATIONAL EHEALTH TOOL KIT (WHO, 2012); WHO GLOBAL STRATEGY ON DIGITAL HEALTH 2020-2024 (WHO, 2019); GLOBAL DIGITAL HEALTH INDEX (MECHAEL, P. ET AL, 2019)
	Data Infrastructure • Forming the foundation for information exchange across all health sector boundaries. Including physical infrastructure (networks), services, and applications.	WORLD HEALTH ORGANIZATION NATIONAL EHEALTH TOOL KIT (WHO, 2012); WHO GLOBAL STRATEGY ON DIGITAL HEALTH 2020-2024 (WHO, 2019); GLOBAL DIGITAL HEALTH INDEX (MECHAEL, P., ET AL, 2019)
	Privacy and Security • Prioritizing privacy and security of health information where a secure "enclave" for health information enables data sharing. • Data is de-identified and used to improve programs and services.	(EVANS ET AL, 2017)
Analytics	**Predictive Analytics using Small Data Sets** • Digital health data can be limited, but to get the most out of the data, insights can be drawn from smaller citizen populations and the findings applied to a larger citizen population.	(EVANS ET AL, 2017) (INSTITUTE OF MEDICINE, 2011)

Theme	Concepts Associated with Digital Health Themes	Model/Framework
Person-Enabled Healthcare	**Personomics** • The use of personal characteristics, defined by personalized medicine, that takes into account the person's lifestyle, goals, beliefs, resources, support network, and data to understand current and future health conditions and how they will respond to treatment. • Putting the person at the center of their own healthcare, including being informed, making decisions, giving multiple options, and becoming "partners" in the healthcare system.	(INSTITUTE OF MEDICINE, 2011) (ZIEGELSTEIN, 2017)
	Citizen-Centric Data Ecosystem • A "data ecosystem" integrates multiple sources of data: digital health data, claims data, EHR data and third-party data, all at the citizen level; A citizen data ecosystem provides a complete data set for every person across the journey of care.	(INSTITUTE OF MEDICINE, 2011) (EVANS ET AL, 2017)
Outcomes	**Health Quality** • Health quality has three main goals: improving individual experience of care, improving the health of the population, and reducing per capita cost of healthcare.	(INSTITUTE FOR HEALTHCARE IMPROVEMENT, 2020) (BODENHEIMER, T. & SINSKY, C, 2014)
	Learning Health System • Science, informatics, incentives, and culture are aligned for continuous improvement and innovation, with best practices seamlessly embedded in the delivery process and new knowledge captured as an integral by-product of the delivery experience.	(INSTITUTE OF MEDICINE, 2011)

This analysis profiles the key themes related to digital health — including governance and leadership, data infrastructure, analytics, person-enabled healthcare, and a focus on outcomes at the system level. The analysis resulted in the consolidation of concepts and themes into four key dimensions that define digital health, described as follows:

01 **Person-enabled healthcare** is the prioritization of healthcare services that support people and populations to manage their health and wellness within the context of their personal values, needs, and unique life circumstances. Person-enabled health is a hallmark feature of digital health described across a number of models and frameworks, which places the individual at the center of health and wellness care. The unique life circumstances of every individual are considered and accounted for — including their lifestyle, goals, beliefs, resources, social network, and health data — to understand and manage health conditions and wellness, and identify future risks to health and wellness. Person-enabled health offers strategies for how an individual can manage risks to support their health and wellness within their unique values and life circumstances to promote overall quality of life.

02 **Predictive analytics** is the transformation of data into information, knowledge, and insights, to create real-world evidence to inform decisions. Health systems generate massive amounts of data. However, unless — and until — data is mobilized, exchanged and analyzed to reveal insights, information and knowledge, then it cannot adequately inform stakeholder decisions (e.g. individual decisions and provider decisions) to achieve health and wellness. A central feature of predictive analytics contributes to what is described as "learning" health systems, whereby robust analytics track health outcomes to enable systems to learn and define the care delivery strategies that achieve best outcomes and the conditions under which best outcomes are achieved for every individual and population.

03 **Governance and workforce** is the vision and system level strategy to guide implementation of digital health across global health systems. Governance ensures the policy and regulatory environment of health systems guards privacy, security, stewardship and accountability. Strongly linked to performance and strategy is the integrity, capacity, and sustainability of the health workforce, which is critical to ensuring people and populations have secure connectivity to care teams, and data is accessible across the journey of care.

04 **Interoperability** is the digital infrastructure strategy that makes data accessible to stakeholders, ensuring data standards, data structure, and semantics make data exchange possible in a manner that is private and secure, flowing seamlessly from multiple sources of data to stakeholders who are approved to access the data. Interoperability is foundational for data to be accessible to individuals and providers, enabled by digital technologies to translate data into information, knowledge and insights to inform decisions.

These four dimensions of digital health emerged repeatedly from the critical analysis of the literature and the analysis of current digital health definitions, models and frameworks.

The consistency in the patterns of concepts emerging in the literature serve to validate these four dimensions which are proposed as the foundation for a digital health framework. In much of the literature to date, digital health is conceptualized as empowering people and populations to have power and voice in defining their health goals and managing their health and wellness journey to achieve the quality of life that is meaningful and of value to every person and population.

It is particularly clear in the literature that authors distinguish the role of "patients" as recipients of care, in today's healthcare systems, from the role of person, is a role defined by choice, expectation, and empowerment (Rowlands, 2019) that reflects the future digital health system. The role of consumer is one of many roles that an individual may assume in digital health systems.

The HIMSS Digital Health Framework

While digital health is widely viewed as the future of sustainable and high performing healthcare, until now, digital health has been defined from a wide variety of perspectives and viewpoints. To advance and inform the progress of digital health across global health systems, the following definition of digital health is proposed, informed by the critical analysis of literature and digital health models and frameworks:

Digital health connects and empowers people and populations to manage health and wellness, augmented by accessible and supportive provider teams working within flexible, integrated, interoperable, and digitally-enabled care environments that strategically leverage digital tools, technologies and services to transform care delivery.

Most notable in this definition is the central focus on how digital technologies are leveraged to transform health systems of today, to enable digital health systems of tomorrow — systems where care delivery can happen anywhere and anytime (e.g. mobile care, virtual care, intuitive "smart" community care) by connecting and empowering people and populations to manage their health and wellness.

The role of provider teams shifts toward partners in care that support and inform an individual's decisions, rather than to direct and encourage compliance with provider driven care pathways. Digital health means that digital technologies are seamlessly embedded into everyday routines and environments to offer "high touch" care delivery, personalized to the unique life circumstances and values of every person and population.

Grounded in this definition, the HIMSS Digital Health Framework centers on three objectives:

01
Achieve sustainability of global health systems.

Digital health infrastructure is seamless and intuitive to optimize care anywhere for people and populations, by automating operations and care delivery to achieve quality and safety outcomes. High performing digital health systems track outcomes, predict risks for populations to cue clinician teams to proactively intervene to reduce risk and keep people well. The automation of care processes within digital environments, and the prioritization of care delivery focused on keeping people well, collectively advances health system sustainability from financial, workforce, and population health perspectives.

02
Transform health systems toward proactive systems focused on health and wellness.

Digital health systems transform care delivery to provide access to care within robust digital environments that support people and populations to self-manage their health and wellness proactively, fueled by digital technologies that seamlessly interface with care teams who offer "high touch," dynamic, and data-informed partnerships between people and providers, anywhere and anytime care is needed.

03
Enable learning health systems to optimize quality and safety outcomes.

A digital health strategy enables the flow of data in a secure and private ecosystem approach that is easily accessed by all stakeholders (e.g. individuals seeking care, provider teams, leadership) in order to inform decisions. Transparency and traceability of data and outcomes, in real-time across the journey of care, provides real-world evidence of the value of care delivery outcomes, and measures that value in terms of outcomes a person defines from their unique values, perspectives, and life circumstances. Digital health creates the capacity for health systems to learn what care processes, programs and approaches offer the best outcomes, for who, and under what conditions those best outcomes are achieved; this informs operational and clinical decisions. Figure 2 illustrates the digital learning health system.

Implement new models of care/innovations in pilot test sites, examine value and impact

Analyze outcomes and predict risk to inform new care models and innovations

Evaluate evidence of impact, value, and relevance across populations

Mobilize Data to track population outcomes across the system

Scale new models of care/innovation across health system

Predictive Proactive

Flow of Data in Real time

Digital Health Learning System

Populations

Interoperable Connected Data Network

Governance & Workforce

Figure 2: Digital Health Learning System

The proposed HIMSS Digital Health Framework is designed to guide health system transformation that enables people to stay well leveraging digital technologies to redesign how care is delivered and how value is achieved, building on the knowledge, science and theoretical development to date (Greene, S., Tuzzio, L. & Cherkin, D, 2012) (Hibbard, J. H., Stockard, J., Mahoney, E. R., & Tusler, M, 2004) (Carman, K., Dardess, P., Maurer, M., Sofaer, S., Adams, K., Bechtel, C. & Sweeney, J, 2013).

Each of the four dimensions of digital health are described in the following sections.

01

Person-Enabled Healthcare

Person-enabled health is defined as a health system focused on meeting and delivering on individual needs, values, and personalized health goals. It recognizes the value and importance of connectivity between people and their care teams, creating a partnership based on individual needs and choice. It leverages digital options (such as online tools, handheld devices for "care anywhere" approaches, or apps that enable on-demand health and wellness care), to support self-management of personal health and wellness goals, shaped by the unique life circumstances, preferences, health needs and choices of the individual.

The HIMSS Digital Health Framework advances the concept of person-enabled health and wellness, aided and supported by digital tools and technologies to track progress and outcomes toward defined goals, to achieve value for people and populations. Digital tools and technologies engage and support people to manage their health and wellness, connecting them in meaningful ways to their health teams, and offering them choices for how, when, and where care is delivered. To date, there is emerging evidence that person-enabled digital health engages people in managing their health, leveraging care pathways that can be personalized to individual needs and circumstances. Outcomes of this approach that have been documented include improved medication adherence, health behaviors that are aligned with best practice care pathways, which has demonstrated significant reductions in adverse outcomes and reduced total healthcare costs (Milani, R., Lavie, C., Bober, R., Milani, A., & Ventura, H., 2017).

Building on the work of Milani, R. et al (2017) and Hibbard. et al. (2004), the following graphic illustrates a care delivery strategy whereby populations are segmented based on levels of engagement in their care, and the complexity of their health conditions and health status (Figure 3). This care delivery strategy profiles how health services can be personalized to unique population segments based on engagement in managing their health and wellness and the complexity of health status.

Person-Enabled Activation

High Activation Low Complexity

Population: Healthy, active population who are supported to inform health goals and decisions with evidence

Online/Virtual Home, Community, Social Network Engagement to Support Health Literacy

Care Delivery Focus: Inform and track health goals, provide analytics tools to inform decisions, track wellness outcomes

High Activation High Complexity

Population: Actively managing health and wellness, has one or multiple chronic conditions, self manages health to achieve health goals and stay well

Localized Health Hubs, Specialist Care Virtual and Online at Consumer's Choice

Care Delivery Focus: Health and wellness coaching, health navigation tools, track outcomes, proactively manage risk

Low Activation Low Complexity

Population: At-risk of chronic illness and multi-comorbidities, limited activation in managing health

Virtual "Home and Community" Programs Support Self Management, Navigation, Case Management to Reduce Risk

Care Delivery Focus: Navigation, health and wellness coaches, online tools/wearables to guide self management and proactively reducing risk, to keep people well

Low Activation High Complexity

Population: Multi-comorbidities, medically fragile, reliant on acute hospital care, high cost, end of life care

Specialty Care Clinics, Hospital; Integrated Care Proactively Tracking Outcomes

Care Delivery Focus: High risk of acute illness, requires intensive case management, track outcomes to identify risk, support self management

Complexity & Cost

Figure 3: Person-Enabled Healthcare Delivery Model

Digital health systems focus centrally on enabling people to manage their health and wellness, informed by their personal needs and values, defined by the following three sub-dimensions:

01
Personalized Care Delivery

Person-enabled health is the personalization of care, whereby indiviuals are the primary decision-maker in managing their health and wellness. People choose the digital tools and technologies (e.g. personal digital tools, mobile devices, wearables) that best suit their unique life circumstances and personalized approaches to healthcare.

02
Proactive Risk Management

Focuses on care delivery that proactively identifies risks to health and wellness, cues individuals and their provider team partners of the risks and strategies to proactively intervene to prevent risk and sustain or strengthen progress toward health goals. Proactive care delivery requires a transformational shift from the siloed, disease management approach of today, to one where seamlessly integrating services and enabling care delivery in digital ecosystem environments enable personalized care delivery to individuals and populations. Proactive care delivery means anticipating and identifying populations who are at risk for deterioration in health and proactively intervening to support and strengthen health to keep people well.

03
Predictive Population Health

Health system data is mobilized and robust analytics tools track population health outcomes to anticipate risks (e.g., gaps in health screening, risks of chronic illness, risk of medical error) and prescribe and inform program level strategies to manage and reduce risks to population segments, focused on health and wellness. Predictive population health is informed by a robust analytics infrastructure that mobilizes digital tools, dashboards, and public reporting strategies to strengthen population health outcomes.

The person-enabled health dimension guides health systems to consider digitally enabled care delivery models that meaningfully connect people with their provider teams to support and enable self management of health and wellness, and proactively manage risk to keep people and populations well. Person-enabled care is a hallmark feature of digital health systems.

02

Predictive Analytics

Predictive analytics is defined as the transformation of data into knowledge and real-world insights that inform decisions for individuals, health teams, and health system leaders. Predictive analytics brings together health system data, along with digital tools and population data, to inform care delivery and operations, creating personalized healthcare, prediction of risk to optimize outcomes, and the tracking of population health proactively to support health and wellness.

Data and analytics have a foundational role in digital health systems. Rowlands (2019) describes the role of "sophisticated" analytics that is central to digital health:

"Digital health harvests data, information and knowledge in real-time from all societal activities, not just interactions with the health system and/or data traditionally regarded as 'health' data; uses sophisticated analytics to distill knowledge from these data; intervenes in the widest possible range of societal and economic activities and technologies to encourage and generate better health and better value for health investments; and is

citizen-centric, decentralized and requires health service providers to participate, not control." (Rowlands, 2019)

Health systems today are generating massive amounts of data, which is growing exponentially, as over 12 billion devices are now connected to the internet and is expected to increase to 75 billion by 2025 (Rowlands, 2019).

Yet, in order for data to offer value to people, populations and health systems, data must be captured and then analyzed effectively so that it can be translated into knowledge, information and insights.

Predictive analytics makes it possible for systems to learn what care works best, for who, and under what conditions best outcomes are achieved. Predictive analytics tracks data across the journey of care to enable people, populations and their provider teams to track, monitor, and fully understand progress toward personalized health and wellness goals.

Data mobilized at the system-level informs every care delivery strategy and tracks operational performance to ensure every person receives the best possible care, personalized to their unique goals and life circumstances.

Toward Achieving Predictive Analytics

With rapidly expanding sources and volumes of data come new opportunities to process and analyze data to generate knowledge, insights and information (Carvalho, J., Rocha, A., Vasconcelos, J. & Abreu, A, 2019). New analytic technologies (e.g. AI, machine learning) shift the role of analytics in healthcare from descriptive analytics that analyze retrospective data, toward predictive tools that leverage existing data to predict outcomes. This includes elements such as risk and anticipated future health outcomes used to inform proactive interventions that reduce risk and support health and wellness.

Analytics in a person-enabled health system are defined as, predictive analytics that focus on mobilizing data, to create real-world evidence by transforming data into knowledge and insights to inform decisions for individuals, health teams, and health system leaders. Data in digital health systems, can inform care delivery and operations only when analytics tools and care processes create the evidence and knowledge to inform strategies to personalize care delivery for every individual and tailor care to unique population segments. Predicting risk accurately affords health systems the capacity to optimize outcomes and track population health to indentify opportunities to proactively intervene to sustain and stregthen population health and wellness. Analytics not only strengthen health system performance, but most importantly underpin and make possible the transformation toward predictive, proactive digital health systems of the future where individuals are supported and enabled to manage their health and wellness.

Prescriptive and predictive analytics inform personalized care strategies by tracking and tracing outcomes across the journey of care for every individual. Analytics then identify risk of poor outcomes proactively to cue clinician teams and individuals to intervene and prevent deterioration in health and wellness. Analytics also segment populations based on outcomes to identify strategies for strengthening quality and safety outcomes for populations health systems serve. Personalized analytics collect individual data from multiple sources (e.g. personal digital tools, mobile devices, wearables) and include "progressive" data sources (e.g. genomic and biometric). Personalized analytics enable the flow of data between individuals, their care network, and provider teams to track and report outcomes, track side effects and adverse events that are then analyzed to examine progress toward health and wellness goals, and track population-level health outcomes.

As digital health evolves, sophisticated analytics focused on predictive and prescriptive outcomes will enable personalized care that is proactive to keep people well. The predictive analytics dimension of digital health systems has three sub-dimensions:

01
Personalized Analytics

Personalized analytics collects individual health and wellness data from multiple sources (e.g. personal digital tools, mobile devices, wearables), including "progressive" data sources (e.g. social, genomic and biometric), to enable individuals and their provider teams to track progress toward health and wellness goals.
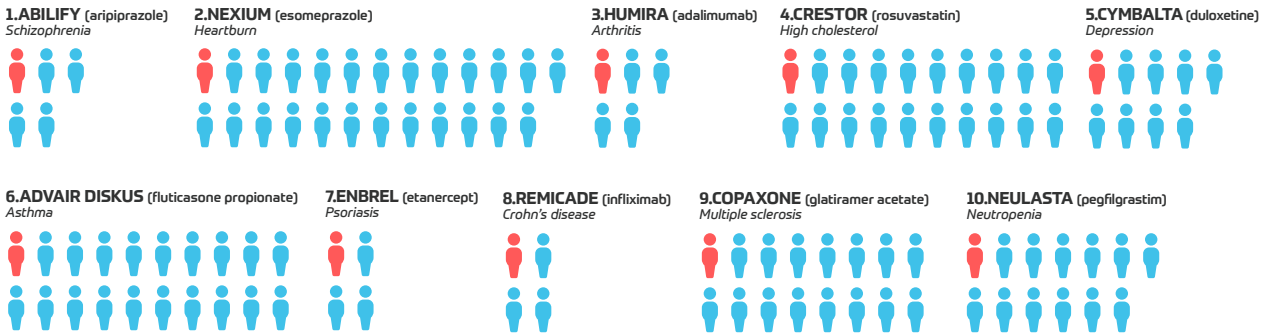
Personalized analytics connects people to health teams and enable them to report data through the use of wearables, sensors, or other digital tools that track outcomes, identify side effects, adverse events and progress toward health goals. A variety of analytics tools are offered so that individuals choose digital tools and technologies that best suit their needs. Individuals use these tools to support and learn (e.g. strengthen health literacy), and also report outcomes and health indicators to track progress toward personal goals.

A key feature of personalized analytics is the focus on precision in care delivery enabled by automated tracking and traceability of outcomes for every individual to determine what works best for who, and under what circumstances best outcomes are achieved. The emergence of precision medicine and genomics enabled therapies will require health systems to have the digital infrastructure to track health outcomes at the individual level to identify which therapies offer the greatest value for specific population segments. Today's health systems prescribe therapies on the premise of "one size fits all", informed by best evidence (e.g. care pathways) whereby all individuals with a specific disease or diagnosis follow the prescribed care pathway. To date, health systems have not had the digital infrastructure to track the effectiveness of every health treatment or therapy, hence little is known about health outcomes of treatments or therapies at the individual level.

More recently, the precision of care pathways has come into question relative to the high degree of variability in outcomes of care. The following graphic illustrates emerging evidence of lack of precision in today's therapies (Figure 4).

IMPRECISION MEDICINE
For every person they do help (orange), the ten highest-grossing drugs In the
United States fail to improve the conditions of between 3 and 24 people (blue)

1.ABILIFY (aripiprazole)
Schizophrenia

2.NEXIUM (esomeprazole)
Heartburn

3.HUMIRA (adalimumab)
Arthritis

4.CRESTOR (rosuvastatin)
High cholesterol

5.CYMBALTA (duloxetine)
Depression

6.ADVAIR DISKUS (fluticasone propionate)
Asthma

7.ENBREL (etanercept)
Psoriasis

8.REMICADE (infliximab)
Crohn's disease

9.COPAXONE (glatiramer acetate)
Multiple sclerosis

10.NEULASTA (pegfilgrastim)
Neutropenia

Based on published number needed to treat (NNT) figures. For a full list of references, see Supplementary Information at go.nature.com/4dr78f.

Figure 4: The Imprecision of Medicines
ADAPTED FROM (SCHORK, 2015)

Drug therapies vary in the level of effectiveness for individuals, based on clinical trial outcomes of medicines available today, which offer a limited degree of precision in treating the most prevalent chronic illnesses in the US population (Schork, 2015). For every person these drugs offer help or value, there are between 3 and 24 people who achieve no value, or perhaps even experience harm.

The cost of drug therapies globally is rising, so too is the prevalence of chronic conditions which will continue to require multiple therapies. Personalized care delivery in a digital health system overcomes this significant challenge by tracking every therapy, every care procedure, product and health team, for every individual consumer and links that data to outcomes data captured in electronic medical records.

This digital infrastructure and analytics capacity enables digital health systems to measure the value and outcomes of therapies more precisely for every person and for population segments to personalize care delivery to the unique needs and outcomes for every individual and every unique population segment.

Predictive analytics makes it possible for health systems to predict which therapies will offer value for an individual (e.g. identify the red people; fig. 4), and which will offer no value (e.g. the blue people; fig. 4) who can then avoid harm and cost of therapies that are not effective. Personalized analytics are the fuel for digital health systems — which has the capacity to track every therapy to health, wellness, and quality-of-life outcomes for every individual and for population segments.

02
Predictive Analytics

Predictive analytics track and trace outcomes across the journey of care for every individual patient, to identify outcomes that work best for every individual and the conditions under which best outcomes are achieved. Predictive analytics also track program and population level outcomes to identify risk for potential harm or poor outcomes to inform quality and safety strategies, and proactively alert clinician teams and individuals to strategies to keep people well.

Predictive analytics employ algorithms and artificial intelligence tools to proactively identify outcomes and predict risk to health and wellness, at both the individual and population level. Predictive analytics capacity leverages the personalized data of every individual over time to track program and population-level outcomes for health organizations and health systems.

The goal of predictive analytics is to identify the risk for potential harm or poor outcomes before those outcomes occur, which enables provider and program teams to respond proactively to mitigate the risk of harm or decline in health of population segments and individuals who are at risk.

One example emerging in health systems is the use of algorithms to predict which patients admitted to hospital are at the greatest risk for sepsis, a life-threatening infection which has high mortality rates and which adds significant cost due to prolonged lengths of stay in hospital. Outcomes to date have demonstrated remarkable reductions in sepsis for hospitalized patients, saving lives, reducing length of stay and health system costs (Saryeddine & Brimacombe, 2009). Predictive analytics make it possible to identify people at greatest risk for changes to their health, so that informed interventions can be implemented to mitigate risk and prevent decline in health status.

Predictive analytics make it possible for health systems to prioritize health and wellness, using preventive strategies that cue clinician teams when risk is increasing, and prescribe or recommend preventive interventions to manage risk. Predictive analytics make transformation possible, from today's "reactive" health system, focused on disease management once an individual becomes ill or deteriorates, toward the future digital health system which proactively identifies and tracks people and population segments at greatest risk, intervenes and partners with consumers to mitigate risks to health, and then tracks progress toward health goals in real-time to ensure health and wellness is sustained and strengthened over time. Predictive analytics tools and algorithms also examine program-level outcomes to inform quality and safety decisions to strengthen population health outcomes. Prescriptive tools make recommendations based on best evidence to guide care delivery to achieve best outcomes for every individual and population, which is foundational to digital health systems.

03
Operational Analytics

Operational analytics mobilize data to track health system performance outcomes including, but not limited to, efficiency, productivity, workflow, safety, quality, workforce capacity and sustainability, supply and logistics outcomes, financial and adverse events. Operational analytics use digital tools and dashboards to track operational outcomes such as efficiency, productivity, quality, safety, access, equity and cost.

Operational analytics use digital tools and dashboards to inform leadership decisions, based on real-time flow of data across organizations and health systems. Decision-makers and leaders track operational outcomes such as efficiency, productivity, quality, safety, access, equity, and cost, using analytics tools on handheld devices such as smart phones, tablets or online tools to support proactive decisions based on accurate and complete, real-time data. Operational analytics enable leaders and decision-makers to assess value, system learning, and sustainability (e.g. workforce sustainability, financial sustainability). Aggregate performance outcomes are reported publicly to inform individuals, product manufacturers, suppliers, government and funders of performance progress and outcomes. Analytics tools also offer leaders real-time data to inform key decisions in day to day operations to optimize processes in real-time.

A key feature of analytics is the seamless flow of data, that is analyzed to identify outcomes at the individual and population level. For example, one US health system was able to track the progress and outcomes of patients infected with C. Difficile over a six-month period following introduction of a new care protocol which demonstrated a decline in desired outcomes for these patients. Clinicians strengthened the care protocol, informed by these analytics, and within three months patient outcomes had improved significantly. This hospital system scaled the new protocol across the entire health system and continued to track outcomes in these patients, and track provider adherence to the care protocol, to ensure the new protocol continued to offer strong quality outcomes.

This example demonstrates the power of predictive analytics in identifying patients at risk, implementing new care approaches and documenting the value of those approaches to enable system learning.

In digital health systems, analytics create the evidence of value for health systems to identify care processes and programs that offer best outcomes for every individual and population segment. Analytics offer continuous feedback in real-time to monitor and create transparency of outcomes, such as quality and safety, to inform decisions based on knowledge and insights. This transparency of outcomes demonstrates how care delivery can be personalized to individual needs and inform health system leaders how best to optimize operational processes to ensure digital health systems are high performing and financially sustainable to ensure access to care for every individual. Predictive and prescriptive analytics capacity creates the evidence of value-based healthcare, defined as:

$$\textbf{Value=} \quad \frac{\text{Health outcomes that matter to patients}}{\text{Cost of delivering these outcomes}}$$

(PORTER, M, 2010)

Analytics in a digital health system mobilizes data across multiple sources and analytics create the evidence of outcomes, particularly outcomes reported and defined by individuals. As consumers use wearables, and other devices to report outcomes, analytics will serve a critical role to link consumer-generated data to formal health systems to track those outcomes and transform data into knowledge and insights to inform decisions and the value of outcomes . This knowledge helps to identify risk to future health outcomes and inform decisions by individuals and their care partners.

Data infrastructure in health systems today is rarely able to track and trace every care transaction, every product used in care, and the outcomes care achieves for individual consumers. Thus, if value is the goal of health systems, as Porter (2010) suggests, then the ability to capture health outcomes using robust analytics infrastructure across health systems will be required to measure value accurately. This has yet to be fully realized in health systems today.

03

Governance and Workforce

Governance and Workforce is defined as the strategic leadership and oversight of digital health systems that ensures the policy and regulatory environment of health systems guards privacy, security, stewardship and accountability. Governance puts priority focus on a sustainable, high-performing workforce that is prepared to deliver digitally-enabled health services. The future of sustainable, high-performing digital health ecosystems requires unique governance structures to transform workplace environments. These digitally-enabled environments, in turn, enable care delivery models that are informed by data analytics, and guided by robust data stewardship, policy and decision making processes.

Governance and workforce capacity of digital health systems is crucial to providing the digital leadership and accountability required for robust, high-performing health systems. In this dimension, workforce is combined with governance to reflect the highly integrated relationship between governance, leadership and a robust and sustainable digital health workforce.
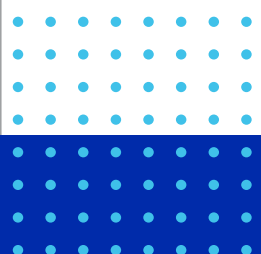
Governance creates the oversight and stewardship of digital health systems. The flow of personal health data across health organizations and provider teams connected digitally to individuals present new ethical considerations and challenges that must be considered, and regulated, by policy frameworks. Effective governance frameworks must recognize that the policy frameworks of today's health system will not be effective for the future digital health system.

Current policies and governance frameworks are lagging significantly behind technology development creating substantive challenges in advancing digital health systems. Barriers include the inconsistent use of standards (e.g. FHIR, HL7), inconsistent application of policies, siloed health information systems, digital platforms and technologies that are not interoperable, and IT systems that do not interface or work together (Health Care Can, 2019). As digital health evolves, leaders can expect to experience employee and professional pushback as digital competencies are required, clinician roles change, and there is lack of appropriate organization and system-wide digital health strategy. Pushback may also come where there is a lack of expertise or experience in digital leadership, there is rigid organizational structures and policy settings, or where traditional funding models are used that are not equipped to manage health in a digital society (Rowlands, 2019). A clear and well-defined digital health strategy focused on transformation of care requires new governance structures and tools to support and incentivize progress toward a robust digital health system.

Governance in Digital Health Systems

Digital health begins with the recognition and acknowledgement that the governance frameworks and solutions of current health systems are no longer effective or adequate for digital health systems of the future. To date, digital health has focused predominantly on the digitization of today's health system data, including digital enterprise infrastructure such as Electronic Medical Records (EMR). While these digital infrastructures have been important, efforts, to date, have not examined the transformation of care delivery to person-enabled models of care focused on managing health and wellness, connected meaningfully to provider teams when and where needed.

Key requirements of digital health systems that governance policy must support and enable, include the following:

- Reimbursement models that incentivize outcomes, not transactions.

- Focus on value of outcomes, defined by people and populations.

- Care delivery processes and pathways that prioritize health and wellness.

- Provider roles that support self-management where providers are care partners.

- Data that is secure, private, and used to proactively identify risk and track outcomes to inform care decisions.

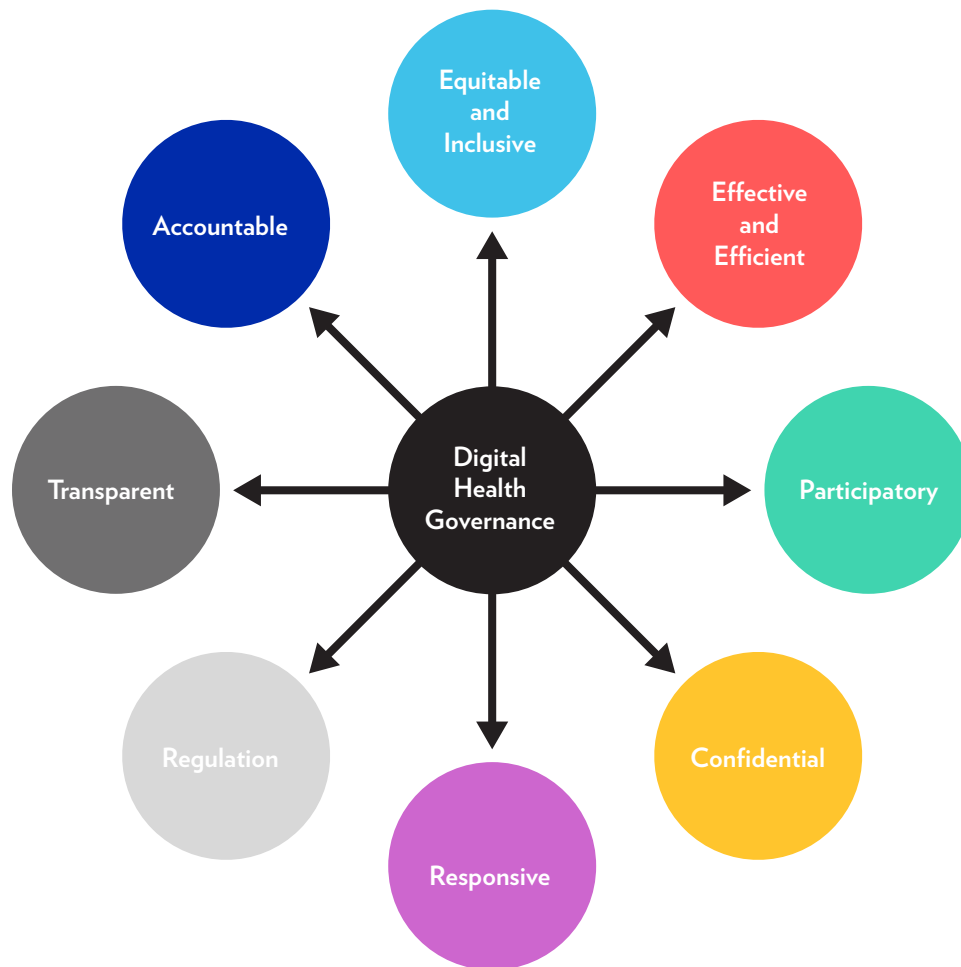## *Principals of Good Digital Health Governance*

Figure 5: Principles of Digital Health Governance

Governance of digital health systems has been examined in a number of key reports, including: Transforming Health Systems Through Good Digital Health Governance (2018) by the Asian Development Bank (Marcelo, A., Medeiros, D., Ramesh, K., Roth, S., & Wyatt, P, 2017), Information Governance Principals for Healthcare (2014) by the American Health Information Management (2014) the work of Benedict and Schlieter (2015) and by Feretti, F. et al. (2018) in their work on governance in digital health. Principals of good governance that support digital health (Marchelo, A. et al, 2018), are summarized in Figure 5.

Principles of digital health governance have informed the design and development of the key sub-dimensions of a digital health system. Data stewardship is guided by principles of confidentiality, and accountability, transparency is guided by principles of accountability, policy and decision-making processes are informed by principles of accountability, equity and inclusiveness, and mobilizing individual engagement with health systems and teams is based on principles such as responsiveness, participatory, equitable and inclusive principles. Each of these sub-dimensions are described in the following section.

a. **Data Stewardship:** Stewardship describes the leadership, culture, vision and objectives required to support digital health. It includes the accountability frameworks and management processes such as the responsibility of planning, building, running, and monitoring digital health as well as the resources and expertise to evaluate and use new technologies. The adoption of new digital tools is informed by evidence and best practices to support system-wide adoption and utilization at scale. Criteria aligned with the use of data and digital technologies are guided by, and inform, best-practice decision-making to improve quality of care.

The concept of "data stewardship" has been defined as the processes by which data is managed, and gathered, and how it can mobilize individual-level data while protecting this data safely and securely (Rosenbaum, 2010). Data stewardship assumes a critical role in creating trust between the leadership team accountable for the management of data, and the individuals or sources of data, ensuring all data is stored properly and used anonymously (Rosenbaum, 2010). Data stewardship is one of several key accountabilities of digital health governance to ensure data stewardship roles and responsibilities are captured, and implemented, within an environment of "gold standard" policies to highly effective and responsive data stewardship (Rosenbaum, 2010).

b. **Policy and Decision-Making Processes:** Policy and decision-making processes describe the measurement, learning and feedback, resource allocation, and coordination used for governance processes that encompass policy and decision-making required to support digital health transformation. Policy and decision-making processes include evidence informed digital health strategy, alignment of digital processes, value-based health system incentives and frameworks focused on outcomes. The impact of digital transformation requires policy frameworks that support and incentivize performance (e.g. efficiency, productivity, quality and cost) outcomes, and enable health system stakeholders to build and sustain meaningful relationships with the people and populations health systems serve.

Policy frameworks become critically important for digital health systems to enable and encourage staff, clinicians, physicians, managers and leaders to have clear lines of accountability to make decisions. Digital health systems necessarily reach and connect to people and populations in digital societies, which requires clear and robust policy frameworks to support decision-making. Accountability frameworks that extend from individuals managing their health and care, to senior leadership, supports and sustains trust, confidence, and transparency. In turn, leadership decisions are guided by the appropriate use of data, information, and knowledge to inform care processes and solutions focused on personalized and proactive health and wellness. In digital health systems, value is defined and determined by individuals based on what they deem meaningful and valued. The dynamic flow of data will require razor sharp attention to decision-making policies and accountability frameworks that demonstrate and support accountability of health systems to the individual and populations they are mandated to serve.

c. **Transparency:** Digital health systems support connectivity and relationships with people and populations, including digitally-enabled communication and transparency of quality, safety, and performance outcomes. Every person is considered a partner in healthcare whereby governance and oversight ensures transparent access to personal health information and health system level performance outcomes, as well as equity in access to healthcare services, data, and digitally enabled care delivery.

Key features of transparency in digital health include access to data and information, and access to supportive provider partnerships characterized by clear and open communication, trust, confidence, and acknowledgement of personal values, culture, and needs. Individual relationships with health teams are supported by digital tools and technologies to ensure meaningful and timely connectivity to providers, when and where it is needed. Personal choice in the use of digital tools, or not, supports personalized health and wellness care models that enable self-management. Health literacy, knowledge about digital technologies, equity and accessibility are prioritized by governance frameworks to advance digital health strategies that ensure access to health services for every citizen.

d. **Workforce Capacity and Competency:** The rapid evolution of digital health ecosystems requires knowledge, skills and abilities across the workforce to support and enable adoption of digital health strategies that support person-enabled care focused on health and wellness. Workforce policies support and retain a high-performing workforce that is incentivized to design, adopt and scale digitally-enabled care processes and operational strategies focused on outcomes, value and impact for people, populations and operational performance that advances health system sustainability.

Digital health requires unique governance structures and workplace environments, to transform current care delivery models toward digitally-enabled care approaches that mobilize and meaningfully engage every individual (Topol, E. 2019). The rise of genomics, digital medicine, and AI are all changing the landscape of healthcare and with new emerging technologies there is a need for a new type of workforce (Topol, E. 2019). Genomics and other technologies have the potential to transform models of care delivery, therapeutics, diagnostics, and precision medicines. However, the opportunity these new technologies offer can only achieve value if the workforce has the knowledge and competency to adopt these new technologies into practice. Digital technologies have been categorized based on both the type and intended use of digital technologies (Goldstack, 2019):

- Digital health includes technologies, platforms, and systems that engage individuals for lifestyle, wellness and health-related purposes: to capture, store, or transmit health data, and/or support life science and clinical operations.
- Digital medicine includes evidence-based software and/or hardware products that measure and/or intervene in the service of human health.
- Digital therapeutic products deliver evidence-based therapeutic interventions to prevent, manage, or treat a medical disorder or disease.

Each of these digital health technologies requires new workflows, new skills and competencies to implement and scale across health systems successfully.

Smartphone apps can help a person self-manage their health, while clinicians can offer treatments and prescribe therapies remotely. Yet, such digital care processes require the necessary privacy and security for clinicians and individuals to connect using digital technologies. Reimbursement models, policies and accountability frameworks must be designed to support and enable the required changes to clinician workflows, competencies in managing digital models of care, and expertise in the use of advanced analytics to inform and guide care delivery. The emergence of new ways to collect and consume data means there needs to be a rise in data literacy for both the individual and the workforce (Topol, E. 2019). As data becomes more plentiful and complex, there is a need for improved understanding of its use while ensuring security and privacy measures are robust and access to data is appropriately managed.

The following findings of The Topol Review (2019) offer key principles for health system leaders to consider when advancing digital health strategies:

- Patients need to be included as partners and informed about health technologies, with a focus on how access and use of such technologies must be considered to support vulnerable populations.

- The healthcare workforce requires expertise and guidance to evaluate new technologies, using processes grounded in real-world evidence.

- Digital technologies can provide solutions to health workforce challenges, such as reducing the workload related to time spent on administration by clinicians, which allows them more time with the patient, assisting with diagnostic skills, improving the clinician-patient relationship, and providing more equitable means of providing healthcare.

In order for a health workforce to thrive in a digital health system, one must consider the key features of digital leadership. According to Kraemmergaard (2019), one of the most important features of digital leadership is having a digital mindset, which means that value must be continuously created for the individuals, provider teams, staff, operational managers and leaders, and all those using and engaging with digital technologies. The critical relationship between the individual, the health system teams, and competencies or skillsets that a digital health workforce must develop and sustain to be successful are as follows: (Kraemmergaard, 2019)

- **Ambidextrous:** Ability for a workforce to optimize while exploring and balancing innovative models of care delivery with the required structures and allocation of resources.

- **Agile:** Ability to adapt to consumer demands and expectations while also prototyping and testing new approaches or strategies to meet individual health needs.

- **Meaningful Frameworks:** Importance of frameworks to serve as a guide to inform and enable, while at the same time supporting innovative new workflows and use of technologies.

- **Competency Pipeline:** Importance of the organization or health system to recruit, retain and develop the workforce skills, knowledge and competency required to support a digital health system.

Digital leadership is described as follows:

"Leadership in the future is not about having all the right answers. It is about asking the right questions, empowering and inspiring questions, that motivate the team or group to learn, to work toward meaningful goals that are aspirational."

(KANE, G., PHILLIPS, A., COPULSKY, J. & ANDRUS, G, 2019)

A strong and robust digital health workforce is a critical factor in leading digital health transformation across global health systems and sustaining a robust and well-prepared workforce to support and enable transformation of global health systems toward digital health systems of the future.

04

Interoperability

> **Interoperability is defined as "The ability of different information systems, devices and applications to access, exchange, integrate and cooperatively use data in a coordinated manner, within and across organizational, regional and national boundaries, to provide timely and seamless portability of information and optimize the health of individuals and populations globally. Health data exchange architectures, application interfaces and standards enable data to be accessed and shared appropriately and securely across the complete spectrum of care, within all applicable settings and with relevant stakeholders, including by the individual."**
>
> (ACCESSED AT: HTTPS://WWW.HIMSS.ORG/WHAT-INTEROPERABILITY).

Meaningfully connecting people, populations and health teams when, where and how it is needed, to optimize health and wellness is a key outcome of the interoperability dimension of digital health systems. Interoperability has long been considered a critical infrastructure capacity of health systems to enable data to be seamlessly mobilized across multiple sources. This makes it possible to connect individual consumer's health ecosystems, with formalized health system teams when and where connectivity is needed.

Connectivity means internally connecting stakeholders within health organizations (e.g. between departments of a hospital, clinic, provider teams, lab, pharmacy, data repositories), and enabling this same feature externally across separate, autonomous organizations (e.g. from one healthcare system to another, one jurisdiction to another, from primary care to community care to hospital care) (Global Digital Health Partnership, 2019).

To date, there is evidence of progress among some health systems in advancing internal interoperability. However, external interoperability remains elusive, as a number of challenges and barriers have limited progress toward seamless interoperability across global jurisdictions. External interoperability that transcends global borders and offers access to people and populations, remains vastly under-developed in the health sector.

The challenge of interoperability is described in the following:

"Although every nation has a different healthcare system, all nations use health data standards. Countries and territories are at different stages of adoption and implementation of these standards. Thus, harmonization is crucial in promoting the interoperability of electronic health records (EHRs) and empowering patients with their data across the globe."

(GLOBAL DIGITAL HEALTH PARTNERSHIP, 2019)

The key barriers to interoperability include the following (Global Digital Health Partnership, 2019):

- Lack of EHR capability to take action based on exchanged data.
- Poor usability of EHRs and negative impact on provider workflows.
- Lack of universal adoption of standards-based EHRs.
- Increasing cost due to interoperability infrastructure that is unaffordable.
- Challenges managing coordinated action among and across multiple organizations.
- Economic incentives that do not encourage data exchange.

Additional barriers described by global leaders include: limited attention to engage people and populations to control or inform interoperability; interoperability engaging with or informed by clinicians; variation in infrastructure capacity in low income areas; lack of metrics to document success; evidence of market failure of interoperability; and lack of knowledge and skills informing governance frameworks and approaches (Global Digital Health Partnership, 2019). Notably, the access, engagement, control and contribution to health information and individual-level data was identified as a key barrier that has yet to be overcome by health systems (Global Digital Health Partnership, 2019). The lack of progress toward highly interoperable, accessible and person-enabled health systems is a key challenge to overcome the growing "disconnect" between people and health systems.

Features of Interoperability

The seamless flow of data requires connected, integrated, safe and secure coordination and oversight to ensure information systems are interoperable and data access is easily accessible. The capture and mobilization of data across multiple sources, from clinician teams and health services to people and populations, must be connected, accessible, and seamlessly interoperable. Interoperability requires exceptional data processes, structures and platforms to connect, exchange data, track outcomes and communicate with stakeholders, accessible when and where needed. To achieve interoperability, four unique sub-dimensions must be considered.

01   **Foundational Interoperability:** Establishes the inter-connectivity requirements needed for one system or application to securely communicate data to, and receive data from, another. It is defined as the exchange of data at the individual level, which is accessible across clinical, social, and community settings. Foundational features of interoperability include: data and information capture, capacity for data storage and data management, access to data to inform communication between individuals and clinicians, teams, and organizations, capacity for wireless and multimedia data exchange, and virtual/remote information exchange to communicate information.

Currently, many healthcare organizations have legacy systems that are outdated, often created at different times for different uses, which may not merge or integrate with different technologies (Henfridsson, O. & Bygstad, B, 2013). Having the right foundation, either through hardware or software, is a key feature of a highly interoperable system (Ullah, F. et al, 2017) (Raghupathi, W. et al, 2014). The exchange and mobilization of data across various EHR platforms is one of the most significant challenges to overcome to achieve interoperability (Global Digital Health Partnership, 2019).

The lack of EHR platform capacity to take action based on exchanged data was highlighted as a major barrier by experts in seven countries, ranking greater than any other barrier (Global Digital Health Partnership, 2019). In today's health systems, EHRs enable a provider to view data, but the data cannot be imported, reconciled or integrated with other digital tools to update the corresponding information in patient records. Not surprisingly, providers are challenged to work within environments where data has yet to be mobilized meaningfully, resulting in clinicians often questioning the value of EHR data, given they are unable to do anything with it (Global Digital Health Partnership, 2019).

Information and data have been collected by health systems for decades, yet much of that data has been inaccessible, siloed, and restricted in access, resulting in limited access to data to inform decisions that advance health system strategy and performance. Foundational features of interoperability make it possible to democratize and support data exchange, making it possible for providers to work with that health data, share it with appropriate stakeholders when and where needed. Most importantly, foundational interoperability facilitates the use of analytic tools to transform data into knowledge and insights to support and enable individuals to self-manage their health and wellness. Foundational interoperability overcomes the two challenges related to foundational data exchange — the lack of structure or standard terminologies in the content of exchanged data, and the lack of functionality within and across EHR platforms.

Experts in interoperability describe this challenge as follows:

"Even if the data are structured; there is also a lack of mature or widely adopted standards and guidelines for interoperability functions such as data reconciliation. In the United States, despite 80% of physicians using interoperable EHRs that generate structured documents, only 10% could find, send, receive, and integrate patient summary records from outside their health system."

(GLOBAL DIGITAL HEALTH PARTNERSHIP, 2019)

The lack of progress of foundational interoperability to date is noteworthy, whereby clinicians remain challenged to access and use data within formalized health systems. EHR functionality and "limited usability" of EHR capabilities result in provider teams underutilizing data, either due to lack of time, or due to complex user interface.

Interoperability in digital health systems reaches beyond EHR data, enabling access and usability of personal health data from multiple and varied sources. By reaching across organizations, social networks, and health applications, individual level data is accessible to all within each person's unique personalized, health ecosystems.

Connectivity with individuals to enable them to report their progress and outcomes relative to their personal health goals, is foundational to digital health systems that support seamless, integrated care for every individual, when and where support is needed.

02 **Structural Interoperability:** Defines the format, syntax, and organization of data exchange including at the data field level for interpretation. It describes the flow of data and information that is automated and integrated across multiple and varied sources of data, data reporting and access functions, data center structure, data integrity, and information exchange across multiple and varied platforms.

Structural interoperability reduces the silos of data and information to create "visibility" of data across health systems that enables the capture of personal health data, outcomes, decisions, engagement of care providers and social networks across organizations and global jurisdictions. Big data has been identified as integral to the future of healthcare, but without the ability to access, use, and see that data, health systems will not achieve seamless interoperability. Poor or fragmented system design in EHRs and how they integrate with other health IT (HIT) systems or technologies, remains a key barrier. This must be overcome in order for interoperability to advance, to enable digital health systems and digital tools and technologies employed by people and populations to manage their health and wellness (Global Digital Health Partnership, 2019).

03 **Semantic Interoperability:** Provides for common underlying models and codification of the data, including the use of data elements with standardized definitions from publicly available value sets and coding vocabularies, providing shared understanding and meaning to the user.

Interoperability across the multiple and varied sources of data that individuals may engage for health services (e.g. primary care, home care, acute care, long term care, communities, personal technologies-wearables, sensors, virtual care) requires agreement among many stakeholders, commencing with consent and agreement by individual citizens on how, when, and for what purpose their data can be accessed. At the system level, interoperability requires all participants to agree upon certain rules and policies in order to work together to exchange information, which requires agreement and resources to implement such agreements (Global Digital Health Partnership, 2019). Governments, payers, providers, health professionals and leaders all need to collaborate to set the course together, to achieve meaningful impact for people and populations. Specifically, decisions must be made for each participant in the data exchange regarding: transaction types, purposes (acceptable uses), transport standards, format standards, vocabulary standards, access management, security levels, and consequences for violating the rules (Global Digital Health Partnership, 2019). Semantic interoperability is complex and aspires to not only achieve interoperability within global health systems, but aspires to achieve interoperability across global borders. A global framework to advance interoperability, particularly semantic interoperability, has not yet been established to guide and inform progress.

04 **Organizational Interoperability:** Includes governance, policy, social, legal and organizational considerations to facilitate the secure, seamless and timely communication and use of data both within and between organizations, entities and individuals. These components enable shared consent, trust and integrated end-user processes and workflows.

Organizational interoperability seeks to overcome the challenges of policy, security, privacy frameworks and legacy technologies to support and incentivize interoperability worldwide. Organizational level interoperability means people and their provider partners have access to data at the point of care, when it is needed to make informed decisions, with seamless ability to see all of a person's data (e.g. from other providers, organization teams, and jurisdictions) (Global Digital Health Partnership, 2019). Privacy and security challenges are dynamic and complex but are critical in order to support and enable data exchange when and where it is needed. Standardized terminology and taxonomy ensure every provider and every individual is able to view and comprehend the exchanged data, and software can accurately understand and interpret the data's meaning, using analytics, in a standardized way. The engagement and collaboration of all stakeholders in strengthening the use of current and future digital technologies must be supported and incentivized by senior leadership and governance policies.

Today, there are few countries which have achieved national interoperability platforms to enable data exchange and data sharing meaningfully between a person and their health provider teams across organizations, communities and jurisdictions. But there is progress in some jurisdictions. The National Health Information Infrastructure (NHII) has been a healthcare standardization initiative for an interoperable healthcare information system in the US (National Committee on Vital and Health Statistics, 2011). It is a knowledge-based network of interoperable systems of clinical, public and personal health data which offers information flow across three dimensions: personal health, clinical healthcare providers, and the public (National Committee on Vital and Health Statistics, 2011). Much work remains to be done to accelerate progress toward achieving interoperability, connecting people and populations to digital health systems that are intuitive and seamlessly embedded in global digital societies.

As data is democratized and technology continues to develop rapidly, interoperability is a critical dimension necessary to meaningfully connect people to providers or caregivers virtually, online, or via digital tools and platforms. Digital health ecosystems must reach far beyond formal health organizations to engage people, their social networks, health ecosystems and health applications to support health and wellness. Interoperability has been described as a "radical" approach to enable individuals to source data from a variety of organizations, stakeholders, and global expertise to mobilize and track data, and seamlessly flow that data within digital communities.

Interoperability is a key dimension of digital health that creates the "end-to-end" visibility across the spectrum of data sources, supporting and enabling a person's health journey. The importance of visibility and transparency in a healthcare system has been described, from its creation, distribution, delivery to the customer and customer experience, all to benefit the health of people and populations (Musa, A., Gunasekaran, A. & Yusuf, Y, 2014) .

The Digital Health Indicator

In order to support health system strategy to advance digital health transformation, a measurement tool — the Digital health Indicator (DHI) – was developed to measure and document progress toward a digital health system.

"The Digital Health Indicator measures progress toward a digital health ecosystem. An ecosystem that connects clinicians and provider teams with people, enabling them to manage their health and wellness using digital tools in a secure and private environment whenever and wherever care is needed. Operational and care delivery processes are outcomes-driven, informed by data and real-world evidence to achieve exceptional quality, safety and performance that is sustainable."

The DHI measures both operational features of digital health systems, as well as transformation of digital care delivery that is focused on outcomes, informed by data and real-world evidence. The methodology supporting the development of the DHI is described in the following section, followed by the design and structure of the Digital Health Indicator.

Methodology

To design the DHI, the operational definitions for each of the four dimensions of the Digital Health Indicator were developed, informed by the critical analysis of the literature, and review of digital health definitions, frameworks and models described in previous sections.

Digital Health indicators were then designed for each of the four dimensions and respective sub-dimensions to construct the DHI measurement tool. Indicator design and structure was informed by the findings of the critical analysis of the literature and review of digital health models and frameworks published to date (Appendix 2). The indicators for each dimension and sub-dimension were further analyzed for conceptual clarity and alignment with concepts and operational definitions of each dimension and sub-dimension of the DHI – interoperability, governance and workforce, person-enabled health, and predictive analytics.

A second review of indicators across the four dimensions identified areas of overlap, redundancy, and balance in the number of indicators for each dimension. Digital health indicators were further refined for each dimension and sub-dimension to ensure each accurately reflected concepts and evidence that emerged from the critical analysis of the literature to construct the first complete version of the Digital Health Indicator. The next methodological step was a concept analysis of all DHI indicators in order to examine relationships between concepts within and across the four dimensions and sub-dimensions of the DHI. The outcome of this analysis informed the design of a conceptual framework to map the conceptual relationships across each of the dimensions of the DHI, illustrated in figure 6.

POPULATION HEALTH & WELLNESS

DIGITAL CAPACITY

Individuals are meaningfully connected to providers to manage health

ANALYTICS & TRACEABILITY: *Outcomes*

INTEROPERABILITY: *Democratization of Data*
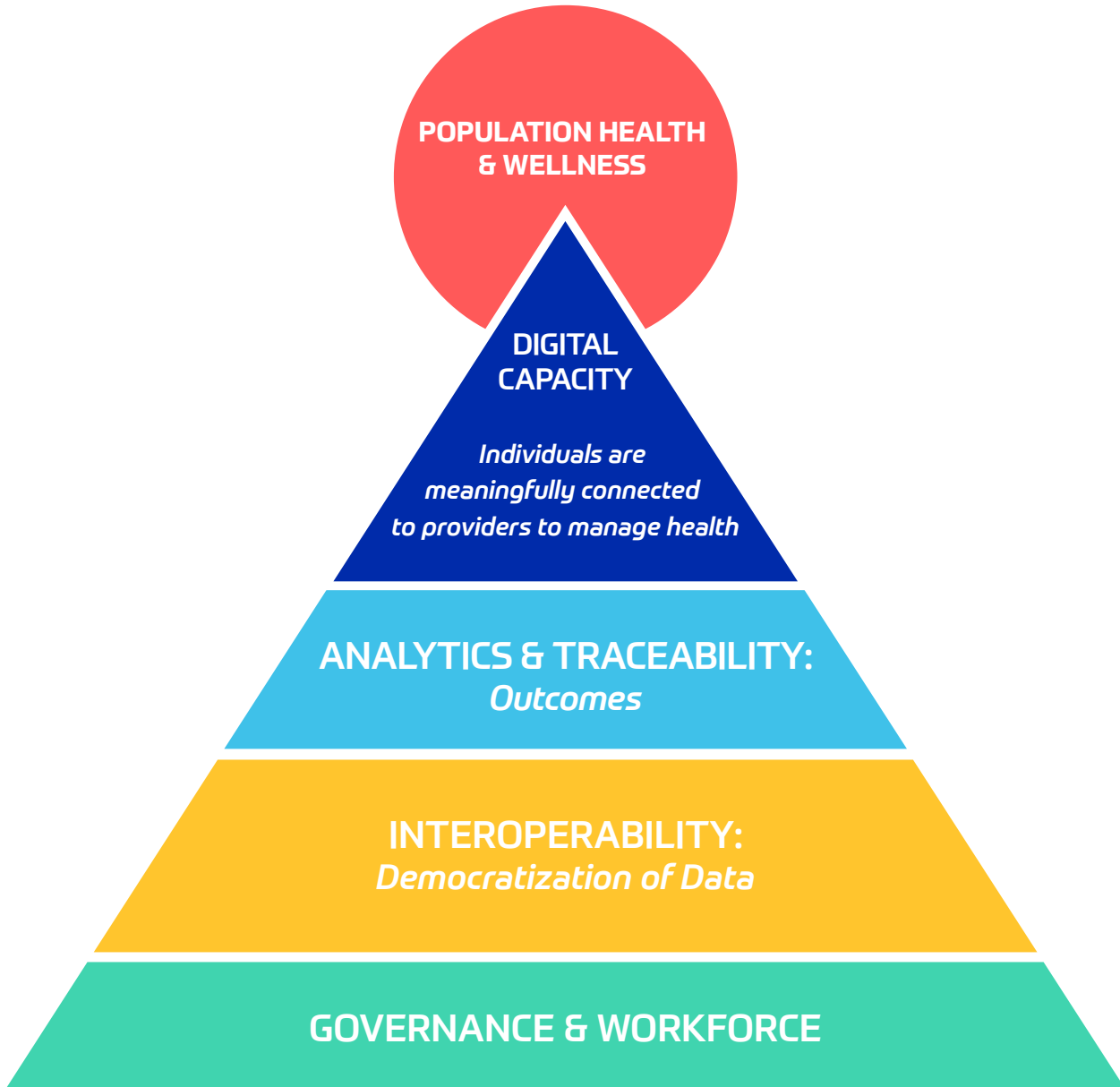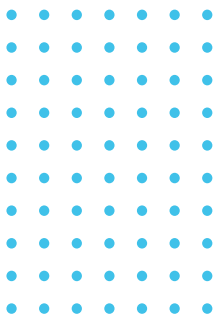
GOVERNANCE & WORKFORCE

Figure 6: Conceptual Framework of Digital Health

Specifically, the foundation for a digital health ecosystem is strong governance and workforce to ensure policy frameworks support digital health and the workforce has the competencies and support to operationalize and deliver digitally enabled models of care to people and populations. Health data is mobilized and democratized across the health organization or system in an interoperable data network, accessible within and across organizations that are part of health systems. The democratization and interoperability of data is foundational to digital health systems, whereby data is mobilized to inform or connect every stakeholder across the health system. Building on this foundation is the second "layer" of the digital health framework which leverages predictive analytics and traceability of outcomes to enable digital health systems to transform data into knowledge and insights, that enable tracking and traceability of outcomes for individuals and populations, as well as system level outcomes which inform care delivery and operational decisions.   Analytics and traceability of outcomes creates transparency across health systems by communicating outcomes, insights and knowledge system wide. This conceptual model illustrates how the key dimensions of digital health are measured, and how data is mobilized and democratized across the system to enable advanced analytics to track outcomes, proactively identify risk, and then cue provider and program teams to inform prevention efforts that mitigate risk and keep people and populations healthy and well. The apex of the graphic denotes the hallmark feature of digital health systems, the capacity to digitally engage people and populations to support health, wellness and ultimately quality of life.

To further examine the face validity of the four dimensions of digital health, a qualitative content analysis of maturity model indicators was completed.

Over the past two decades, HIMSS, a global non-profit organization, has established a portfolio of seven digital maturity models that have been adopted by health organizations in 50 countries to date. The suite of maturity models are unique in the world, and offer a measurement strategy to assess a specific aspect of digital maturity to guide and inform strategic decisions to advance digital maturity. The maturity tools are well established in the global health system market, some for as long as 14 years, to measure the digital maturity of key areas including, digital health records (EMRAM, O-EMRAM), analytics (AMAM), clinically integrated supply outcomes (CISOM), diagnostic imaging (DIAM), coordination of care (CCMM), and infrastructure (INFRAM). The HIMSS maturity tools are summarized in Table 3.

Table 3. HIMSS Suite of Maturity Models

Maturity Model	Digital Maturity Measure
Electronic Medical Record Adoption Model (EMRAM)	The EMRAM documents the key concepts related to the digital infrastructure required for a fully functional electronic medical record. Clinical documentation of care processes is transformed into a digitized medical record data source, integrated and stored in a data repository. The data repository enables clinical decision support to inform care decisions and track progress of care, offering continuity of clinical documentation across all healthcare services, primarily in hospital settings.
Outpatient Electronic Medical Record Adoption Model (O-EMRAM)	The O-EMRAM builds on the EMRAM and includes a portal to engage people in their care by providing access to their health information. The data repository enables clinical decision making and mobilizes data to support and inform disease registries, with analytics tools used to track population health.
Adoption Model for Analytics Maturity (AMAM)	The AMAM focuses on the analytics tools required to advance an organization's analytics capability, with the aim to optimize system performance and improve cost, efficiency and productivity of care delivery.
Continuity of Care Maturity Model (CCMM)	The CCMM is a digital strategy to connect data infrastructure tools across provider organizations, where an integrated data repository mobilizes health system data across organizations and provides visibility to health provider teams. Both individuals and clinician teams are able to access the data, while analytics offer decision support tools to inform decisions and advance the continuity of care along the journey of care.
Digital Imaging Adoption Model (DIAM)	The DIAM provides digital imaging and IT experts a roadmap to hospital imaging maturity, allowing healthcare organizations to improve their digital strategy regarding medical imaging and ensure better outcomes for patients.
Infrastructure Maturity Model (INFRAM)	The INFRAM focuses on the digital infrastructure of health organizations to provide a high-level overview of the key features of the data network in organizations, and the access to data within a secure and private digital environment. The INFRAM includes mobile connectivity for people and population and "end-to-end" visibility of data in real time.
Clinically Integrated Supply Outcomes Maturity Model (CISOM)	The CISOM mobilizes data to enable tracking and traceability of care delivery processes, the products used in care, and the provider teams delivering care, all linked to individual outcomes including health and wellness outcomes, quality, safety and cost outcomes to track system performance and value.

All seven models measure digital maturity using a number of measurement indicators, organized into levels of maturity from level 0 to 7.

The global market prominence of these maturity models and real world adoption of these maturity models offer a unique opportunity to validate the concepts and indicators measured by these maturity models, with the concepts and indicator measures of the Digital Health Indicator. To complete this analysis of content validity, a qualitative analysis of the 1,103 indicators, across all seven maturity models, was completed to identify the conceptual themes and concepts measured by the maturity model indicators. The content analysis of maturity model indicators was then compared to the concept analysis of the DHI, to identify and cross reference the concepts measured by the maturity models and the DHI.

The outcome emerging from this analysis revealed strong content validity for concepts measured by the Digital Health Indicator. Notably, there were conceptual gaps in the maturity model indicators where no maturity model was found to measure the concept of workforce competencies and capacity which is foundational to digital health systems. In addition, there were very few indicators in the maturity models, that measured the dimension concepts of person-enabled health. Less than 5% of maturity model indicators, measure how health systems are engaging people and populations to manage their health and wellness.

This analysis offered strong content validity and conceptual clarity for the majority of DHI indicators, and identified strong conceptual alignment between the key concepts measured by the maturity models, and the dimensions and sub-dimensions of the DHI. Digital health indicators were further refined for each dimension and sub-dimension to complete the design and validation of the Digital Health Indicator. Table 4 provides the rapid assessment version of the Digital Health Indicator. Pilot testing of the Digital Health Indicator is currently underway in three jurisdictions - Canada, Europe and the USA.

Table 4: Digital Health Indicator (Short Version)

Dimension	Indicator
Interoperability	People have access to their personal health records, health system services, educational tools and health navigation tools to support health decisions and navigate access to care and services from their own homes. Includes fully integrated virtual care and remote patient monitoring with intervention.
	Clinicians use secure devices in daily practice routines, to enable collaboration with other clinicians including secure messaging, consultations, and real-time access to patient data that is securely managed to protect privacy.
	Security breaches and alerts are tracked using machine learning technologies to identify accuracy and risk of alerts, cost to manage breaches, and track compliance with security legislation.
Person Enabled-Health	Data is mobilized to track population health outcomes to inform personalized care strategies that support and sustain population health and wellness.
	Care delivery focuses on keeping people well by proactively intervening to reduce risk using predictive analytic tools.
	Individuals are the primary decision-makers and use digital tools to self-manage their health and wellness.
Predictive Analytics	Analytic tools at the point of care track individual outcomes to inform care decisions that mitigate health risks and optimize health outcomes.
	Predictive analytic tools segment the population, based on risks and outcomes for population segments, to identify the conditions under which best outcomes are achieved to inform proactive interventions that strengthen population health.
	Analytic tools track operational performance in real-time to inform leadership decisions to strengthen quality, safety, and cost outcomes across the organization/system.
Governance and Workforce	Staff are accountable for supporting person-enabled care that is personalized to the unique needs, circumstances, and choices of the individual informed by evidence of value and person reported outcomes.
	Organizational strategy and performance outcomes are shared publicly to inform the community of impact and value achieved by the organization or health system.
	Organizational polices are responsive to value for patients, informed by patient participation at all levels of governance, to inform and support digital healthcare systems.

Summary

The proposed Digital Health Framework offers a measurement tool for advancing digital health for global health systems. Each of the four dimensions identify and measure the progress toward advancing the four dimensions of digital health.

To date, many countries and territories have adopted EMRs and associated digital technologies, but progress toward transformation of health systems toward proactive, predictive, high performing digital health systems focused on supporting population health and wellness has been limited.

Digital health is emerging as a priority for many public and private healthcare systems as a way forward to drive value for every global citizen, to ensure healthcare is accessible and equitable, and high performing.

The HIMSS Digital Health Framework builds on the strategic pathways of the maturity models to offer an evidence-based conceptual model designed to guide and inform health system strategy to advance digital health globally.

The proposed Digital Health Framework and Digital Health Indicator (DHI) is anticipated to evolve and develop as pilot-phase testing is completed and adoption by global health systems inform and contribute to further refinement of the framework as digital health advances progress.

The Digital Health Framework and DHI tool are anticipated to serve as a strategic guide to advance transformation of current health systems, toward digital health systems which prioritize health and wellness for people and populations.

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Appendix 1. Digital Health Concepts

Digital Health	Source	Definition of Digital Health Term
Academic Literature		
Digitally Engaged Patient	SOCIAL THEORY & HEALTH VOLUME (LUPTON, D., 2014)	"The discourses of the **digitally engaged patient** suggest that 'empowerment' may be achieved by using sophisticated **digital technologies for self-monitoring and self-care.** These discourses suggest that control over one's recalcitrant body and its ills can be better achieved via technological means. Lay people are expected and encouraged to develop routines to regularly assess these physiological markers and thus to develop the type of expertise in monitoring their bodies that was once the preserve of healthcare providers."
Digital Health	SOCIOLOGY COMPASS (LUPTON D. , 2014)	"**Digital health** is a term that is becoming frequently adopted to encompass a wide range of technologies related to health and medicine."
The Person-Based "Digital" Approach	JOURNAL OF MEDICAL INTERNET RESEARCH (YARDLEY, L., MORRISON L., BRADBURY, K., & MULLER, I., 2015)	"The person-based approach provides a process that enables developers to gain vital insights into **how different people experience and implement interventions,** and a framework to help developers identify the key characteristics that will make an intervention more meaningful, attractive, and useful to those who engage with it."
Digital Health	DIGITAL MAMMOGRAPHY: A DIGITAL APPROACH (ROBINSON, L., ET AL., 2015)	"The use of **digital media** to transform the way healthcare provision is conceived and delivered."
Digital Health	PROCEDIA COMPUTER SCIENCE (IYAWA, ET AL., 2016)	"An improvement in the way healthcare provision is conceived and delivered **by healthcare providers** through the use of information and communication technologies to **monitor and improve the wellbeing and health of patients** and to empower patients in the management of their health and that of their families."
Digital Health Revolution	DIGITAL HEALTH REVOLUTION (TRONO, 2016)	"**New technologies** in life sciences, engineering, informatics, and communication stand to revolutionize health management by opening the door to the establishment of connections between an individual's genotype (i.e. genetic make-up) and phenotype (i.e. the sum of traits that can be observed or measured), while **integrating the influence of the environment** (e.g. diet, exercise, exposure to chemicals, sunlight, viruses or bacteria). Medicine can thus ambition to **morph from an essentially reactive and often empirical discipline into a precise, preventive, personalized** and participatory endeavor. Individual risk factors will be identified to assess probability of developing diseases and design appropriate prophylactic measures, and ills such as cancer will be dealt with through highly specific and individualized treatments based on their precise molecular fingerprinting, rather than by their assignment to overly general classes of pathologies." *
Digital Health	MHEALTH (MESKO, B., ET AL, 2017)	"The cultural transformation of how disruptive technologies that provide digital and objective data accessible to both caregivers and patients leads to an equal level doctor-patient relationship with shared decision-making and the democratization of care."
Digital Health	NPJ DIGITAL MEDICINE (STEINHUBL, S.T., ET AL. 2018)	"Using **digital tools to upgrade the practice of medicine** to one that is high-definition and far more individualized."

Digital Health	Source	Definition of Digital Health Term
Digital Health Institutes		
Digital Health	DIGITAL HEALTH INSTITUTE SCOTLAND (DIGITAL HEALTH AND CARE INSTITUTE, 2018)	"Defining digital health and care is a complex task as, globally, **we are still to decide on a universal definition.** Digital health applications consist of certain essential elements such as wireless devices, hardware and software sensors, microprocessors and integrated circuits, the internet, social networking mobile and body area networks, health IT, genomics, and personal genetic information. Because of the varied nature of these elements the term **digital health forms an umbrella term for: big data, cloud computing, connected health, eHealth, gamification, epatients, Health 2.0, health information technology, mobile health, personalized medicine, quantified self, telehealth, telemedicine, wireless health.**"
Digital Health	THE US FDA (FDA, 2018)	"The broad scope of digital health includes categories such as mobile health (mHealth), health information technology (IT), wearable devices, telehealth and telemedicine, and personalized medicine. These technologies can empower consumers to make better-informed decisions about their own health and provide new options for facilitating prevention, early diagnosis of life-threatening diseases, and management of chronic conditions outside of traditional care settings. From mobile medical apps and software that support the clinical decisions doctors make every day, to artificial intelligence and machine learning, digital technology has been driving a revolution in health care. Digital health tools have the vast potential to improve our ability to accurately diagnose and treat disease and to enhance the delivery of health care for the individual. Digital tools are giving providers a more holistic view of patient health through access to data and giving patients more control over their health. Digital health offers real opportunities to improve medical outcomes and enhance efficiency."
Digital Health	UNICEF (UNICEF, 2018)	The term 'digital health', which includes both mHealth and eHealth, describes the general use of ICTs (digital, mobile and wireless) to support the achievement of health objectives.
Digital Health	WORLD HEALTH ORGANIZATION (WORLD HEALTH ORGANIZATION, 2019)	The term digital health is rooted in eHealth, which is defined as "the use of information and communications technology in support of health and health-related fields." Mobile health (mHealth) is a subset of eHealth and is defined as "the use of mobile wireless technologies for health." More recently, the term digital health was introduced as **"a broad umbrella term encompassing eHealth (which includes mHealth), as well as emerging areas, such as the use of advanced computing sciences in 'big data', genomics and artificial intelligence."**
Digital Health	EUROPEAN SOCIETY OF CARDIOLOGY (EUROPEAN SOCIETY OF CARDIOLOGY., 2019)	Digital Health is **the use of information and communication technologies** (ICT) to treat patients, conduct research, educate healthcare professionals, track diseases and monitor public health.

Digital Health	Source	Definition of Digital Health Term
Digital Health	DIGITAL MEDICINE SOCIETY (DIME), DIGITAL THERAPEUTICS ALLIANCE (DTA), HEALTHXL, AND NODE.HEALTH (GOLDSACK, ET AL. 2019)	"Digital health includes technologies, platforms, and systems that **engage consumers** for lifestyle, wellness and health-related purposes: capture, store, or transmit health data, and/or support life science and clinical operations."
Digital Medicine	DIGITAL MEDICINE SOCIETY (DIME), DIGITAL THERAPEUTICS ALLIANCE (DTA), HEALTHXL, AND NODE.HEALTH (GOLDSACK, ET AL. 2019)	"Digital medicine includes **evidence-based software** and/or hardware products that measure and/or intervene in the **service of human health."**
Digital Therapy	DIGITAL MEDICINE SOCIETY (DIME), DIGITAL THERAPEUTICS ALLIANCE (DTA), HEALTHXL, AND NODE.HEALTH (GOLDSACK, ET AL. 2019)	"Digital therapeutic products deliver **evidence-based therapeutic interventions** to prevent, manage, or treat a medical disorder or disease."
Digital Health	CANADA INFOWAY (CANADA HEALTH INFOWAY, 2020)	"Digital health refers to the **use of information technology**/ electronic communication tools, services and processes to deliver health care services or to facilitate better health."
Healthcare Systems		
NHS Adoption of Digital Technologies (Deloitte Centre for Health Solutions, 2019)	DELOITTE (DELOITTE CENTRE FOR HEALTH SOLUTIONS, 2019)	The use of "digital technologies" to tackle some of healthcare's problems. "The importance of technology in bridging the gap between demand for healthcare and the capacity of healthcare services to meet that demand and provides an objective view of the current state of NHS digitalisation and what the future of healthcare might look like." *Includes: safety (privacy and data security) and interoperability (technologies interoperable with systems and services).
Digital Health	DIGITAL HEALTH INFORMATICS SOCIETY OF AUSTRALIA (ROWLANDS, 2019)	Digital health as **health and healthcare in the context of digital societies.** Digital health harvests data, information and knowledge in real-time from all societal activities, not just interactions with the health system and/or data traditionally regarded as 'health' data; uses sophisticated analytics to distill knowledge from these data; intervenes in the widest possible range of societal and economic activities and technologies to encourage and generate better health and better value for health investments; and **is citizen-centric, decentralised and requires health service providers to participate, not control.** "What is Digital Health and Why does it Matter" https://www.hisa.org.au/wp-content/uploads/2019/12/What_is_Digital_Health.pdf?x97063
eHealth	DIGITAL HEALTH SWISS TROPICAL AND PUBLIC HEALTH INSTITUTE (SWISS TPH, 2020)	The significance of Information and Communication Technologies (ICT) as a means to improve the performance of health systems and population health is increasingly recognised. In this respect, the term 'eHealth' is widely used.*

Digital Health	Source	Definition of Digital Health Term
Online Sources		
Digital Health	ZD NET (BEST, 2019)	"Using technology to help improve individuals' health and wellness."
Digital Health	LSX, THE NETWORK FOR LIFE SCIENCE EXECUTIVE LEADERS (GARDINER, 2019)	"Digital health is the application of new technology in a healthcare setting. Whether this be telemedicine, mHealth, or wearable technology, digital health is changing the life sciences and healthcare industry from being in the hands of the practitioners to being in the hands of the patient."

*Not an exact definition, stated as "defined as" but taken from the document as an assumed definition.

Appendix 2: Concept Analysis of Digital Health Models and Frameworks

Theme	Concepts Associated with Digital Health Themes	Model/Framework
Governance and Leadership	• Coordination with eHealth at the national level, aligning health goals with political support • Promoting awareness and engaging stakeholders • Using expertise, partnership and coordination to develop and adopt eHealth components • Support and empower health system change including monitoring results and outcomes.	WORLD HEALTH ORGANIZATION NATIONAL EHEALTH TOOL KIT (WHO 2012); WHO GLOBAL STRATEGY ON DIGITAL HEALTH 2020-2024 (WHO 2019); GLOBAL DIGITAL HEALTH INDEX (MECHAEL, 2019).
	Strategy and Investment • A responsive strategy for monitoring eHealth • Involvement, and taking lead, of major stakeholders and sectors • Financing is aligned with priorities (government, private, public)	WORLD HEALTH ORGANIZATION NATIONAL EHEALTH TOOL KIT (WHO 2012); WHO GLOBAL STRATEGY ON DIGITAL HEALTH 2020-2024 (WHO 2019); GLOBAL DIGITAL HEALTH INDEX (MECHAEL, 2019).
	Legislation, Policy, Regulation • National policies and legislation in priority areas, including sector policies • Legal and enforced regulation for privacy and trust for consumers and industry in eHealth practice and systems	WORLD HEALTH ORGANIZATION NATIONAL EHEALTH TOOL KIT (WHO 2012); WHO GLOBAL STRATEGY ON DIGITAL HEALTH 2020-2024 (WHO 2019); GLOBAL DIGITAL HEALTH INDEX (MECHAEL, 2019).
	Workforce • Make eHealth knowledge and skills available through internal expertise, technical cooperation or use of the private sector • Build national, regional and specialized networks for eHealth • Establish eHealth training programs for healthcare capacity building	WORLD HEALTH ORGANIZATION NATIONAL EHEALTH TOOL KIT (WHO 2012); WHO GLOBAL STRATEGY ON DIGITAL HEALTH 2020-2024 (WHO 2019); GLOBAL DIGITAL HEALTH INDEX (MECHAEL, 2019).
	Collaboration/ Strategic Partnerships • There needs to be defined objectives, goals and roles; the team needs to understand the objective of the program, and work with external vendors to implement digital programs, with the ability to analyze the results • Partnerships and collaborations are made between varying levels of government, public and private organizations	(EVANS, 2017)

Theme	Concepts Associated with Digital Health Themes	Model/Framework
Data Infrastructure and Interoperability	**Services and Applications** • Provide means for enabling services and systems, access, and exchanging and management of information (users include the general public, private and public partnerships)	WORLD HEALTH ORGANIZATION NATIONAL EHEALTH TOOL KIT (WHO 2012); WHO GLOBAL STRATEGY ON DIGITAL HEALTH 2020-2024 (WHO 2019); GLOBAL DIGITAL HEALTH INDEX (MECHAEL, 2019).
	Data Standards • Standards that enable consistent and accurate collection of data and exchange of health information	WORLD HEALTH ORGANIZATION NATIONAL EHEALTH TOOL KIT (WHO 2012); WHO GLOBAL STRATEGY ON DIGITAL HEALTH 2020-2024 (WHO 2019); GLOBAL DIGITAL HEALTH INDEX (MECHAEL, 2019).
	Data Infrastructure • Forming the foundation for information exchange across all health sector boundaries. Including physical infrastructure (networks), services, and applications	WORLD HEALTH ORGANIZATION NATIONAL EHEALTH TOOL KIT (WHO 2012); WHO GLOBAL STRATEGY ON DIGITAL HEALTH 2020-2024 (WHO 2019); GLOBAL DIGITAL HEALTH INDEX (MECHAEL, 2019).
	Privacy and Security • Prioritizing privacy and security of health information where a secure "enclave" for health information enables data sharing • Data is de-identified and used to improve programs and services	(EVANS, 2017)
Analytics	**Predictive Analytics using Small Data Sets** • Digital health data can be thin, but to get the most out of the data, insights can be drawn from smaller citizen populations and the findings applied to a larger citizen population	(EVANS, 2017) (INSTITUTE OF MEDICINE, 2011)
Outcomes	**Health Quality** • Health quality has three main goals: improving individual experience of care, improving the health of the population, and reducing per capital cost of healthcare	(INSITUTE FOR HEALTHCARE IMPROVEMENT, 2020) (BODENHEIMER, 2014)
	• **Learning Health System** "Science, informatics, incentives, and culture are aligned for continuous improvement and innovation, with best practices seamlessly embedded in the delivery process and new knowledge captured as an integral by-product of the delivery experience"	(INSTITUTE OF MEDICINE, 2011)

Theme	Concepts Associated with Digital Health Themes	Model/Framework
Person-Centric Healthcare	**Personomics** • The use of personal characteristics, defined by personalized medicine, that takes into account the person's lifestyle, goals, beliefs, resources, support network, and data to understand current and future health conditions and how they will respond to treatment • Putting the citizen at the center of their own healthcare, including being informed, making decisions, giving multiple options, and becoming "partners" in the healthcare system	(INSTITUTE OF MEDICINE, 2011)
	Person-Centric Data Ecosystem • "data ecosystem" integrates multiple sources of data: digital health data, claims data, EHR data and third-party data, all at the citizen level; A citizen data ecosystem provides a complete data set for every person across the journey of care.	WHO PATIENT HEALTH ENGAGEMENT MODEL (GRAFFIGNA, 2018)
	Patient Engagement • "Patients' motivation, knowledge, skills and confidence to make effective decisions to manage their health". (Hibbard JH, 2010)	VALUE+ (EUROPEANS PATIENT'S FORUM, 2012) IMI U-BIOPRED (U-BIOPRED PIP, 2016) PAM (NHS, 2018)
	Patient Empowerment • "a process through which people gain greater control over decisions and actions affecting their health" and should be seen as both an individual and a community process." (WHO, 2009)	WHO PATIENT HEALTH ENGAGEMENT MODEL (GRAFFIGNA, 2018)
	Patient Activation • "Patient activation' describes the knowledge, skills and confidence a person has in managing their own health and care." (NHS, 2018)	PAM (NHS, 2018)
	Patient Experience • "Patient experience encompasses the range of interactions that patients have with the health care system, including their care from health plans, and from doctors, nurses, and staff in hospitals, physician practices, and other health care facilities." (Agency for Healthcare Research and Quality, 2017)	CAHPS (OR HCAHPS) HOSPITAL SURVEY (GIORDANO, 2009) PROMS AND PREMS (CIHI, 2020) NICE (NATIONAL INSITUTUE FOR HEALTH AND CARE EXCELLENCE, 2014)
	Patient Satisfaction • A variety of different definitions with an emphasis on patient attitudes, and feelings towards care	SHORT ASSESSMENT OF PATIENT SATISFACTION (SAPS) (HAWTHORNE, 2014)