Positive disruption

Health and education in a digital age

Pathways for Prosperity Commission
Technology & Inclusive Development

Blavatnik School of Government
University of Oxford

Cover Image, 12-year-old Basanti uses an
online education tool, Udaipur, Rajasthan, India.
Photograph: Ishan Tankha, Pathways Commission 2018.

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Foreword

In this era marked by a growing uncertainty of what technology will mean for humanity's future — how we work, how we connect with each other, and how our economies grow — this new Pathways for Prosperity report, *Positive disruption: health and education in a digital age*, makes the case that technology, if properly harnessed, can be a transformative force for the poorest and most marginalised.

Technology has the potential to revolutionise patient health and the way students learn. For the poorest, most marginalised people living in the farthest regions of the world, technology could mean faster communication with healthcare professionals, more education opportunities for remote students, and more efficient services — thanks to tools that monitor disease outbreaks and track whether teachers are showing up for work.

But these positive outcomes are not an inevitable by-product of innovation. Technology is not a silver bullet, and cautionary tales are abundant. *Positive disruption: health and education in a digital age* argues that realising the full potential of innovation in the areas of health and education requires policymakers and practitioners to enshrine inclusion as a core goal up front as they design and scale new technologies in these areas.

Positive disruption: health and education in a digital age builds on previous reports from the Pathways for Prosperity Commission. Developing countries have an important window of opportunity to design policies that ensure technology in their countries advances in a way that improves the lives of all their people. This will require smart investments in human capital, forward-looking approaches to innovation and regulation, and a willingness to understand innovation as part of broader social and economic systems.

This report sets out a number of practical considerations for governments, industry, and civil society to consider as they work to embrace technology in a way that will drive the greatest gains in inclusivity, human well-being, and more equitable growth. We hope this report contributes to a vital and vibrant dialogue on these topics.

Melinda Gates **Sri Mulyani Indrawati** **Strive Masiyiwa**

Acknowledgements

The co-chairs and commissioners would like to extend their thanks and acknowledge the dedicated people that made this report possible. It was drafted by a team led by the Commission's academic directors Professor Stefan Dercon and Professor Benno Ndulu, and the secretariat's head of research and policy, Toby Phillips. Invaluable contributions to this report were made by the Commission's executive director Elizabeth Stuart, and researchers Raluca David, Sophie Ochmann, Andrea Tartakowsky Pezoa, Francesca Walker, Chris Eleftheriades, Kate Samuelson, and Cole Scanlon.

Communications and production of this report were led by Meena Bhandari, the Commission's head of communications and events, with Philippa King, Emily Cracknell, Rose Marsh, and Liliana Resende.

The team greatly benefited from the advice of the Dean of the Blavatnik School of Government, University of Oxford, Ngaire Woods, together with the school's faculty and staff.

For their helpful and stimulating conversations the team would like to thank the people who participated in our workshops on fintech (Nairobi), edtech (New Delhi and Oxford), primary healthcare (Kigali), Digital ID (New Delhi), systems management (Oxford) and service delivery policymaking (Washington DC). For further conversation and comments, the team would particularly like to thank Alice Albright, Noam Angrist, Ralph Arnold, Girindre Beeharry, Jean Boulton, Liliana Chamas, Christopher Elias, Mike English, Roberta Gatti, Gargee Ghosh, Amanda Glassman, Stephane Guimbert, Rachel Hinton, Ari Johnson, Priya Balasubramaniam Kakkar, Kim Kerr, Dan Kress, Ju-Ho Lee, Ruth Levine, Richard Meredith, Calum Miller, Susanna Moorehead, John Norris, Shantanu Nundy, Alex Palacios, Chris Paton, Jamie Proctor, John-Arne Rottingen, Jaime Saavedra, Justin Sandefur, Siddarth Shetty, Mike Trucano, Pramod Varma, Ken Warman, Tim Wilson, and Rob Yates.

The depth of the report is thanks in part to independent research and analysis conducted for the Commission by Karishma Banga, Olly Buston, Areeq Chowdhury, Jonathan Dolan, Matthew Homer, Diwakar Kishore, Zahra Mansoor, Kay McGowan, Prakhar Misra, Naomi Muinga, Bernard Naughton, Chris Paton, Anna Pick, Dhwani Shah, Dirk Willem te Velde, and Priya Vora.

About the Pathways Commission

The Pathways for Prosperity Commission on Technology and Inclusive Development is proud to work with a talented and diverse group of commissioners who are global leaders from government, the private sector and academia.

The Commission is based at Oxford University's Blavatnik School of Government. We collaborate with international development partners, developing country governments, private sector leaders, entrepreneurs, and civil society to produce cutting-edge research.

The Commission aims to catalyse new conversations and to encourage the co-design of country-level solutions aimed at making frontier technologies work for the benefit of the world's poorest and most marginalised men and women.

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Pupils in Udaipur, Rajasthan, India, wait to enter a Mindspark computer lab at school. Photograph: Ishan Tankha, Pathways for Prosperity Commission, 2018.

Executive summary

This report sets out a vision for how developing countries can significantly improve their health and education systems by making effective use of data-driven technology. It examines the potential benefits of these technologies, and offers guidance on how to achieve change. Service delivery in developing countries is notoriously complex, and this report does not shy away from the many failures of technology. But with this dose of realism, we maintain that digitally enabled technology has the potential to create more effective, efficient and equitable health and education systems by looking beyond the clinic and the classroom, to transform the underlying decision-making, management and administrative apparatus. This report describes the necessary digital building blocks to realise this vision, and provides a set of principles to help make digital technology a positive disruptor, rather than just a distraction to policymakers.

The opportunity

Digital technologies have led to progress in both health and education, setting out clear examples of what is possible. In Uganda, for example, the web-based application Mobile VRS has recently helped increase birth registration rates in the country from 28% to 70%, at the very low cost of $0.03 per registration – thus helping decision-makers track health outcomes and improve access to services.[1] In Kenya many school children perform at learning levels more than two years lower than their grade would suggest. A new technology-aided programme, Tusome, is boosting outcomes. This national literacy programme, introduced by the Kenyan Ministry of Education, includes digitised teaching materials and a tablet-enabled teacher feedback system. If implemented effectively at national scale, programmes like Tusome can close the learning gap in early grades for under $150 per child.[2] In India, a study of a free, after-school programme that introduced Mindspark, a digital personalised-learning software, showed improvements in mathematics assessment scores of up to 38% in less than five months, thereby dramatically reducing students' learning gaps.[3] The Delhi-based programme could be rolled out at scale at a fraction of the cost of current per-pupil spending in schools.

Digital solutions that are *embedded* in health and education systems can improve service delivery in three ways. They can boost productivity at the point of delivery, improve interconnectivity within the system, and allow for more effective organisational designs. For example, digital monitoring tools can address motivational gaps that lead to absenteeism of workers – so long as incentives of actors within the wider system are acknowledged and addressed.

Digital data collection can improve weak management structures by supporting decision-making, improving interconnectivity, streamlining supply chains, and recording integrated data from test scores to attendance. Curated digital libraries can bridge the knowledge gaps of frontline workers. Finally, SMS reminders can increase appointment attendance, improve interconnectivity within the system, and lead to greater uptake of services by citizens.

Such progress is happening today. But in the near future, digital technologies will offer the possibility of something more: the potential to completely reimagine the delivery of health and education services. Pioneering examples already exist in developing countries which demonstrate the viability of this transformative potential. Moreover, these leading efforts suggest that with deliberately designed implementation, such approaches can be cost-effective and inclusive. In this report, we set out five visions of how technology-driven tools and the data underpinning them can improve the delivery of health and education services in the future. These visions are all interrelated: they draw on the potential of data and of technologies such as machine-learning, algorithms and communication technologies, and they reflect the consequences for both how students and patients will learn and be treated, and the associated changes in how services will be delivered and systems will be managed.
The five visions are:

1. **Creating responsive learning systems.** In a *learning system,* data-driven technologies could enable feedback loops at all levels, informing decisions and continuously advising on best clinical or teaching practices by bridging the current gap between research and practice. Pockets of such systems are already taking shape, powered by digital technology such as India's Mobile-based Surveillance Quest using IT (MoSQuIT), a smartphone-based platform for malaria surveillance that enables better outbreak monitoring and real-time responses.

2. **Targeting at-risk people in health and education.** Systems could also be made *proactive* to ensure services get to the people who need them most. In the health sector, this is starting to emerge in programmes that use community data to identify high-risk patients for active outreach. In education, it will allow more precise targeting of pupils whose learning is lagging.

3. **Tailoring health and education services to individual needs.** *Personalised health and education* hold great potential to revolutionise effectiveness, efficiency and equity. For example, digital personalised learning software greatly improves test scores by tailoring content based on an individual student's proficiency level, rather than that of the rest of the class.

4. **Redefining the roles of educators and health care workers.** With digital technologies, the *roles of teachers and health workers will change.* Digital technologies including machine learning may lead to the automation of certain tasks, especially routine or codifiable parts

of the job. Consequently, frontline workers' skills will change markedly. Frontline workers will remain a crucial part of the system, but will spend less time on routine tasks and place greater focus on core strengths such as judgement, initiative, and the socio-emotional "human touch".

5. **Bringing quality healthcare and education to remote areas.** In the future, we may also see *virtual systems* which break down the walls of clinics and classrooms, including remote diagnosis via telehealth technologies, remote clinics and reaching out to students in the most remote areas to provide quality education through videoconferencing.

The challenge

Technological solutions cannot guarantee success. Too often, they fail to deliver impact, or to work at scale. To date, most innovation has been focused on the point of delivery: clinics and classrooms. This model has repeatedly failed when technological innovations ignore constraints across the wider system. For example, the One Laptop per Child programme in Peru had little effect on maths and reading test scores, and other similar programmes succeeded *only when integrated with broader changes to teaching*. Effective service delivery addresses the complexity of systems, and involves a variety of actors and end users who have different roles and motivations.

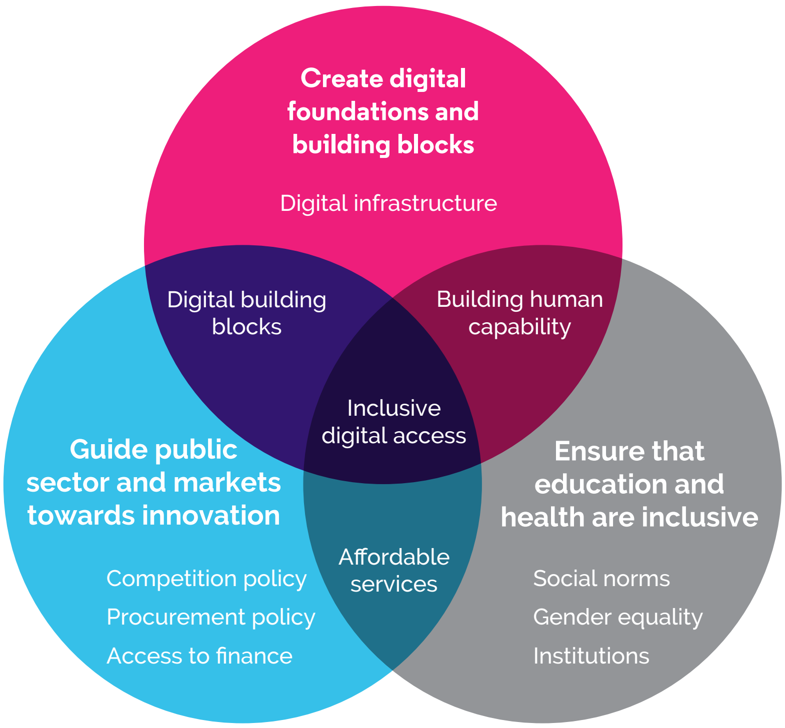
Policymakers need to take a systems approach both to better understand where the problems within health and education lie, and to better predict how the system is likely to respond to new technologies. The value of this approach is clear. New technologies – even the most advanced ones – only work well when the broader enabling environment is right. Success in adoption will depend on the system as a whole: the various actors, connections among these actors, organisational norms, and the local and national political contexts. The absence of such an enabling environment, however, should not serve as a reason to wait to introduce reforms. Indeed, even when specific elements of the system are not working perfectly, reforms made in a joined-up manner can enhance outcomes, challenging the status quo. For example, digital payrolls can stymie corruption, feedback systems can boost motivation and thereby tackle absenteeism, and data-systems can create incentives for more transparency in decision-making. And, in the process, such initial steps can start the redesign of systems.

What to do next?

The time is ripe to plan for scale, and to bring digital technologies into health and education systems. Many recent attempts towards innovation still need to prove their success. Even those with careful evaluations are typically no more than pilot studies, at relatively small scales. The potential is nevertheless clear, and the next step is to start using digital technologies to deliver at scale. This is a critical moment. Decisions made by funders and policymakers today will determine whether the roll-out of digital technologies will be a costly way to exacerbate failings and inequalities in existing systems, and a distraction for policymakers, or a force of positive disruption towards more effective, efficient and equitable systems.

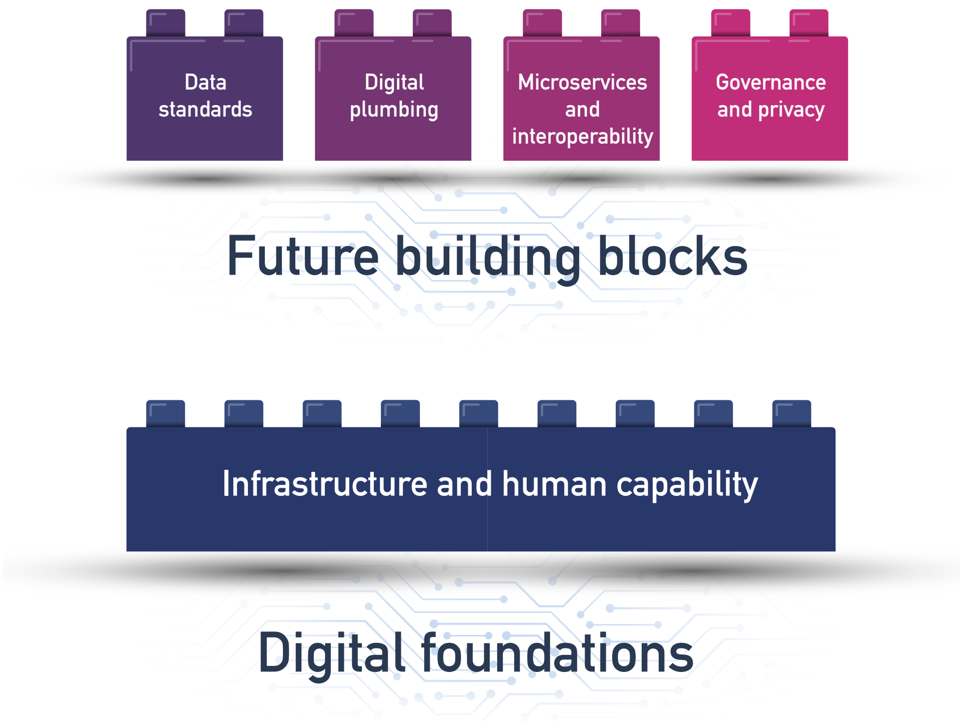
For implementation at scale, the focus will need to be on promoting innovation in the private and public sectors, ensuring that progress is inclusive, and, especially, creating the right digital foundations for scale. In Figure ES1, below, we have adapted a framework from our previous report, *Charting Pathways for Inclusive Growth*, which outlined policy priorities for technology-enabled growth.[4] The same priorities are valid for innovation in health and education service delivery. The key driver for success in using digital technologies in service delivery – the effective use of data – requires a focus on creating the right enabling digital foundations and digital building blocks (explored further below). In addition, governments must create space for innovation in service delivery, both in the public sector and with private actors. Finally, ensuring that education and health are inclusive will require special attention to issues such as access, affordability and digital literacy. This report, alongside our previous work, argues that in the absence of such an explicit focus, existing inequalities by wealth or gender will be exacerbated.[5]

Figure ES1. **A policy framework for health and education for all through digital technology**



Data will be the fuel that powers future digital systems. The five future visions put forward in this report all rely on data to reimagine the design and architecture of these systems. However, many countries are working from a low existing baseline in effectively capturing and using data. Countries must ensure the right *digital foundations* are in place: even the simplest digital services require digital infrastructure, including access to electricity and internet, and digital skills. When setting up such digital foundations, inclusive access must be considered. Furthermore, truly harnessing data will require establishing the *building blocks for future digital systems*. Clear rules around data governance and privacy must be established: these future visions require significant centralisation of data about citizens, and while the potential upside is large, so, too, is the potential for harm. New regulations, protocols and rules must be established to guard against privacy violations, data misuse, and algorithmic bias. From there, data standardisation will be key to breaking down silos between programmes, and ensuring information can be compared across regions and between organisations. Likewise, countries will need to develop "digital plumbing" – metaphorical pipes that collect and transport information for data aggregation – and open digital services to ensure that the insights and value from data can be harnessed by innovators, incumbent providers, and ordinary people.

Figure ES2. **Foundations and building blocks for future service delivery systems**



How to do it?

This report offers four principles that can help everyone – citizens, workers, policymakers, funders and entrepreneurs – harness the opportunities of the digital age for better health and education, and avoid some of the previously experienced pitfalls of inappropriate adoption and poor implementation of technological innovations at scale.

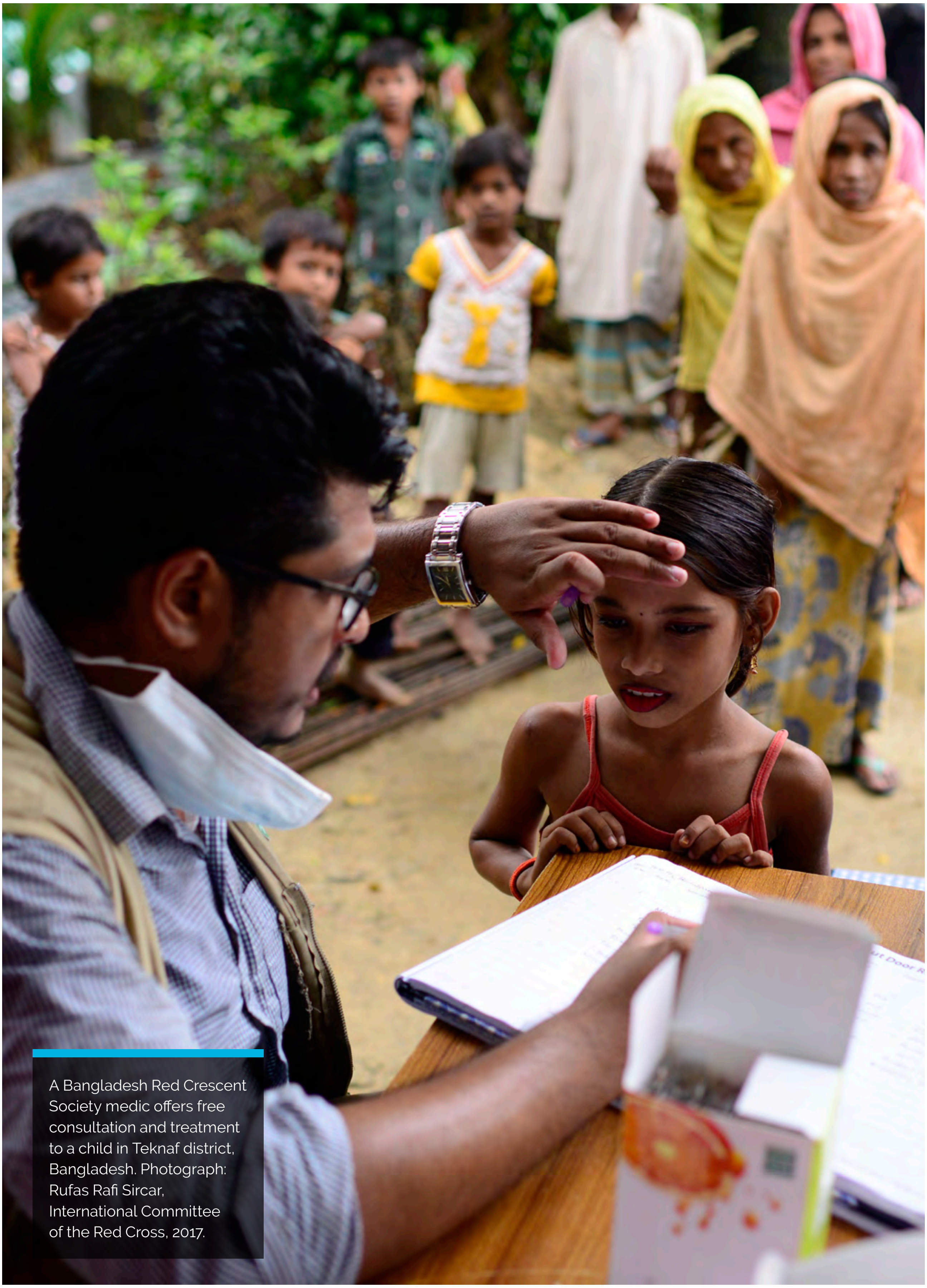
1. **Deploy technology only when it offers an appropriate and cost-effective solution to an actual problem.** Policymakers and funders should invest time and effort in identifying the specific problems holding back their health and education systems, and they should only decide to use a digital solution if it is the best solution on offer. They also should be confident that an intervention will work in the local and national contexts, and be cognisant of the local political or organisational culture. Moreover, efficacy at a small scale does not fully inform impact at scale, let alone affordability. Rather, impact and costs of scaling need to be monitored carefully.

2. **Focus on the content, data sharing, and system-wide connections enabled by digital technology, not exclusively on hardware.** All too often, when policymakers look to deploy technological solutions to health and education, the focus is on procuring pieces of hardware. However, digital solutions will only have impact if they are used by everyone - frontline workers, citizens, and officials. This means that people must have access to the right inclusive digital foundations (infrastructure and skills), and that software and digital components must be crafted to serve the end users.

3. **Invest in digital building blocks, not just the bulk collection of raw data, in order to move towards the systems of the future.** Good data can inform decision-making, fuel active feedback loops in a learning system, and offer personalised services. In practice, digital building blocks provide a way to build the required domestic capability as well. These data frameworks enable system managers to learn from experience, compare interventions, and set standardised criteria for success – boosting their ability to understand their system and implement solutions at scale.

4. **Ensure that the technology genuinely works for all by making deliberate efforts to engage with and build solutions for people who are typically left behind.** This should start with explicit attempts to understand the specific wants, needs and priorities of marginalised communities. Resulting actions can be as simple as providing SMS reminders to attend clinic appointments, or as complex as a targeted outreach programme, such as the Muso community health worker programme in Mali, which uses data to improve performance and a digital supervision tool to increase impact.

Decisions made today by funders and policymakers will determine whether digital technologies can truly change education and health delivery for all. By deploying new tools, and by following the principles outlined in this report, developing countries can enhance and change the functioning of their health and education systems. They should critically monitor progress in terms of scale, impact and cost. If done carefully and judiciously, positive disruption is possible, and digital services will bring developing countries closer to the ambition of offering better health and education for all.



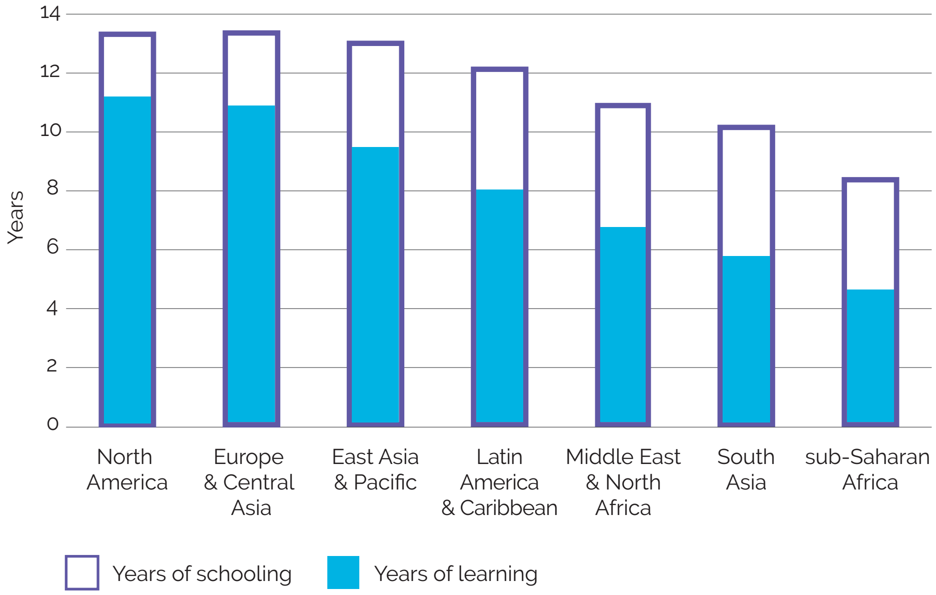
A Bangladesh Red Crescent Society medic offers free consultation and treatment to a child in Teknaf district, Bangladesh. Photograph: Rufas Rafi Sircar, International Committee of the Red Cross, 2017.

Chapter 1
Introduction

With fast technological change, the contribution of human capital to individual and national progress will become more – not less – important. In a previous report, the Pathways for Prosperity Commission suggested ways in which the potential risks of technological disruption can be turned into opportunities for inclusive development. That report, *Charting Pathways for Inclusive Growth*, identified five possible pathways that could be unlocked by digital technologies, providing developing countries with new engines for growth, better jobs and livelihoods.[6] It argued that these pathways can only be realised with commensurate investments in human and institutional capabilities. Periods of rapid technological change – such as the current one – require societies to invest in the right skills, both to take best advantage of its potential, and to avoid further entrenching the exclusion of the poor, vulnerable groups, and women. The World Bank's 2019 World Development Report on the future of work echoed this with a call for developing countries to "invest in their people with a fierce sense of urgency – especially in health and education, which are the building blocks of human capital – to harness the benefits of technology and to blunt its worst disruptions".[7]

This report asks whether and how current technological change can be harnessed to deliver improved human capital for all. Huge sums are spent on health and education worldwide to improve human capital, and more careful investment could enable great savings. This report focuses on how learning and healthcare services can be more *effective*; how such services can achieve these goals more *efficiently;* and how such services can boost *equity* in access and outcomes, targeting those typically left behind. As in previous reports of the Commission, the emphasis is on the opportunities from digital, digitally enabled, and related new technologies, as progress in these avenues is particularly promising at present.[8] The report sets out a vision for data-driven health and education systems underpinned by technology used in smart ways; it analyses what the benefits could be, and how countries can chart a course to achieve these benefits.

Figure 1. **Children in less-developed world regions spend less time in school and learn less per school year**

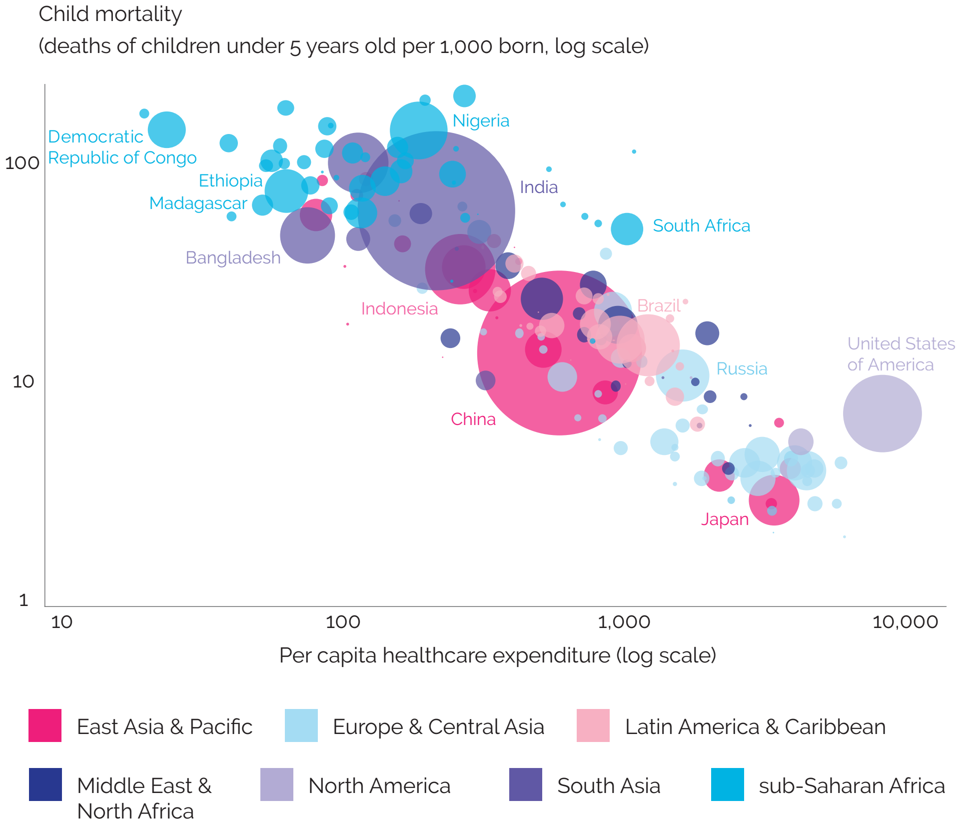


Source: Angrist et al. (2019a), Pathways Commission analysis.

Note: These are technical statistical metrics called "*expected* years of schooling" and "learning-adjusted years of schooling."[9]

People across the developing world live longer, healthier lives than they once did, and benefit from more education than even a few decades ago, but they still remain behind those who live in richer nations.[10] On average, the learning outcomes, in terms of learning-adjusted years of schooling, for children in sub-Saharan Africa are just under a third of those of children in North America (see Figure 1).[11] Moreover, there is considerable variability between countries in terms of how *efficiently* they use resources for health and education.[12] For instance, in countries with around 8 years of schooling, learning outcomes vary from 4.3 learning-adjusted years (Angola) to 6 learning-adjusted years (Gabon).[13] The unevenness of this performance suggests this is not simply an issue of financing. For example, Madagascar, Bangladesh and South Africa all have similar child mortality rates, but South Africa spends 19 times more than Madagascar and 13 times more than Bangladesh on healthcare (Figure 2).[14] These differences in efficiency also tend to translate into large equity gaps. Resources are often used ineffectively, suggesting serious failings in health and education systems and the broader structures within which they are embedded. Serious issues of exclusion remain; the poor, marginalised groups, and women are all too often left behind.

Figure 2. **Health outcomes generally improve with health expenditure, but this can mask significant variance**



Source: World Bank (2019d), Gapminder (2019), Pathways Commission analysis.

Note: This figure uses data from 2013. Expenditure is adjusted for purchasing power parity, and is reported as 2011 international dollars. The size of a circle represents a country's population.

Successful technological change in health and education systems cannot be taken for granted, as historical and recent experiences show. For example, the development of vaccines for smallpox and other diseases indisputably made enormous contributions to human health. But success stemmed from more than the invention of new vaccines; it was achieved through a *system* developed for more effective monitoring and to distribute resources, people, and new clinical products to the places they were most needed.[15] These systems were then adapted and changed in response to feedback from operations on the ground. Recent attempts to eradicate polio have shown not only the potential for change, but also the difficulties. Eradication efforts in a wide range of countries met with success as a result of deliberate system-wide action, but elsewhere there were considerable setbacks in hard-to-reach areas and target groups.[16] Even for successful technological innovations, adoption can be slow and uneven, and can hit constraints of both supply and demand.

However, as we argue in this report, if implemented carefully, digital, digitally enabled, and related new technologies hold great promise for health and education systems. In Chapter 2, we assess the state of global health and education. Chapter 3 examines emerging digital solutions to four common system constraints, often predicated on increasing connectivity between citizens, providers, governments, funders and suppliers. Indeed, with new technologies, new organisational models for service delivery may well become feasible – potentially allowing systems to be redesigned to be lower-cost and more effective. Possible near-future visions for health and education service delivery are discussed in Chapter 4, and Chapter 5 describes the digital foundations and building blocks required to translate these visions into reality, from electricity infrastructure, to digital standards and regulations. Chapter 6 concludes by offering a set of principles to guide policymakers keen to start implementing these visions.

If a single lesson may be drawn from our analysis, it is this: silver bullets rarely deliver without a clear understanding of, and appreciation for, the broader operating environment. Consider an example: GeneXpert, a state-of-the-art test for tuberculosis diagnosis, has no effect when patients fail to return to the clinic to get their medication.[17] This is not to say that better diagnostic technology is not important, but merely that it may be rendered impotent if another part of the system is broken. Technology alone is not a cure; it can be a vital part of efforts to improve outcomes, but it must be deployed alongside a genuine desire to understand and solve broader system constraints. **It is for this reason that we emphasise health and education *systems*, and how technology can improve them.**


Graduating class 2019
8 years of schooling
4.2 years
Madagascar
4.8 years
Pakistan
6 years
Gabon
4.7 years
Papua New Guinea
4.1 years
Angola
Equivalent years of learning
Data from World Bank (2019c)
Note: This is a comparison of learning outcomes ("learning adjusted school years") from countries where the average student is expected to get 8 years of schooling.

The manager of the village pharmacy accounts for her stock in Sindian village, Ziguinchor region, Senegal. Photograph: Bruno Deméocq, International Committee of the Red Cross, 2010.

Chapter 2
Understanding health and education systems

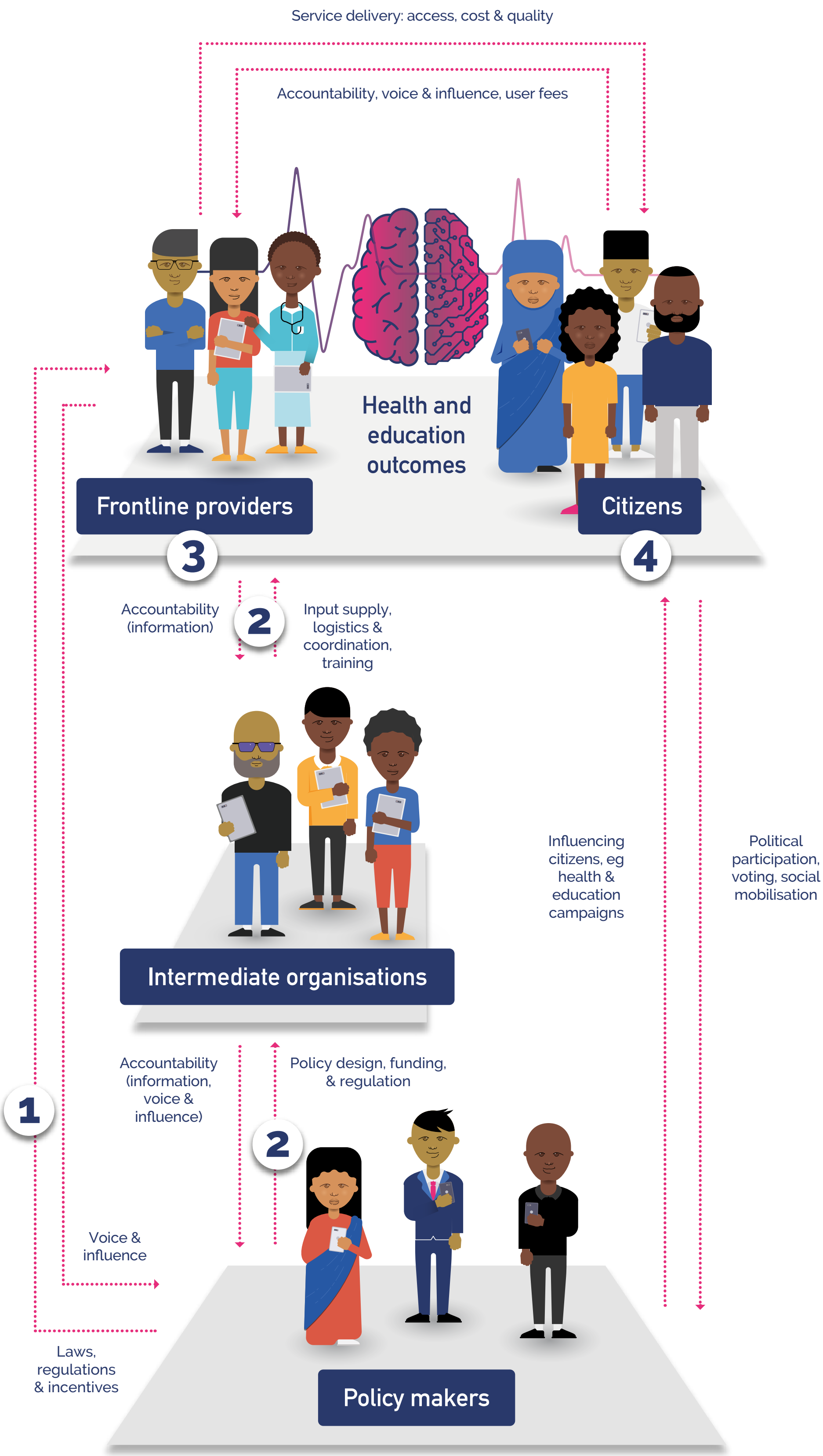
New technologies – particularly the most advanced ones – need to work in a way that is sustainable and scalable: the broader enabling environment needs to be right. This enabling environment includes many factors, such as funding availability, resource allocation, political economy, worker training, and supply chains. Service delivery entails complex systems, involving a variety of actors with different roles and motivations, all independent but connected, and all critical for the delivery of results. Systems approaches have been developed by public policy researchers to help better understand the complexities, interdependencies and structural constraints in a range of fields, including service delivery.[18] Mapping out these interdependencies, even at an abstract level, allows decision-makers to take account of dynamic causal relationships: when change occurs at one point of a system, it can have a ripple effect throughout the network.[19] Perhaps most usefully, a systems approach can help a decision-maker to consider all the peripheral factors that influence results, to avoid negative unintended consequences, and to mobilise technologies as part of a broader approach to inclusion, reform, and cost savings.

The impact of new technology in health and education to date has not always been positive, and crucial lessons from past failures must be learned. In the past, governments have tended to focus on investment solely at the point of delivery: the clinic or the classroom, as this is where the technology is most visible, and the political or bureaucratic gains of advancing new technologies are most immediate.[20] Notable examples are in the deployment of digital hardware for educational purposes, without due attention to the local context or the existing education system.[21] The One Laptop per Child initiative in Peru, for instance, had no effect on mathematics and reading scores 15 months after implementation, partly because teachers were not provided with any training on how to sensibly incorporate the laptops into their teaching.[22] A new tool or new method may seem simple, but it must be implemented day in, day out, by real people, with their own personal, financial, professional and political imperatives. Unless their everyday practices align with broader reform objectives, innovations will struggle to take hold.[23] Indeed, a large randomised control trial (RCT) in China showed that deploying digital equipment in schools did not have any effect on learning, while integrating such equipment into teaching practices did.[24]

Biwi Primary School, Malawi. Pupils use onebillion's "onecourse" educational programme.
Photograph: onebillion 2019.

Although education and healthcare system frameworks differ in important ways, they share many fundamental features related to their actors, motivations and interconnections. In Figure 3 on page 22, we suggest a general, simplified framework to understand both education and health systems (and perhaps other systems beyond these). This is not intended to be a comprehensive representation of systems, but it sets out the actors and relationships between them that are discussed in this report.

Figure 3. **A simplified system framework for health and education**



Note: the numbers 1–4 indicate common constraints examined in Chapter 3.

The framework identifies four main actors:

- **Citizens** are the potential recipients of education and health services (in this report, we use "citizens" as a catch-all for the general public). The outcomes (or results) of a system (ie better health and more learning) ultimately occur in the lives of ordinary citizens, so any attempt to optimise other parts of the system must consider how it will eventually improve these outcomes.

- **Frontline providers** directly interact with citizens at the point of delivery. These can be people such as doctors and community health workers, teachers and school principals, or frontline delivery units, such as schools and clinics.

- **Intermediate organisations** make up the broader organisational environment, and include the authorities that manage frontline providers, as well as organisations that provide other inputs (eg provider training, supply chain management, logistics).

- **Policymakers and funders** are the experts and authorities who design, regulate, supervise and finance services. They set the overarching goals and parameters of the system, but are not directly involved at the point of delivery.[25]

In addition to these four main categories, there are other actors that have a stake in health and education. For example, when diagnosing problems with a health system, it is worth considering non-state health providers. Similarly, when implementing technological solutions, it is worth thinking about organisations that mediate tech development and implementation, such as NGOs or private providers.

Despite being a crude approximation, this analysis provides benefits by highlighting interdependencies and connections – factors far from the point of delivery that inevitably influence outcomes. For a system to work, interventions and programmes must be designed in a way that is coherent with the broader system, with deliberate attention to identifying and assessing the fundamental constraints (see Box 1 for a case study of healthcare reforms in Africa). For instance, a health centre cannot fulfil its function if the drug supply chain is deficient; greater local autonomy for school management will likely make limited difference if resources remain centrally controlled; and expanded frontline staffing may not lead to top-quality services without training, motivation, and career structures that reward performance.[26]

Because a system is a collection of different actors, the individual people involved need to be included in considerations of change: a system's culture and institutions are of crucial importance. Sometimes service delivery systems are constrained by country-wide organisational culture. (For instance, corruption and disinterest at the top level can affect all actors across the system).[27] This means that a new technology or a novel programme should not be deployed simply because it is technically possible, or even because it worked elsewhere, but because there is a reasonable expectation that it will work within *a specific context* and *system*. It would be a mistake to start with technology as a solution in search of a problem.

Box 1. **Complex systems in the real world: healthcare in Africa**

A service delivery system is more effective when all its components function in an interconnected manner, even if none of the individual components are top quality. In Ethiopia, the mortality rate of children under the age of five dropped from 214 to 58.5 per 1,000 (a reduction of 73%) between 1987 and 2017.[28] This reduction was largely due to improved nutrition, vaccinations, sanitation, and treatment of diarrhoea and pneumonia. Such steps were part of a deliberate strategy to improve outcomes through strengthening all components of the primary healthcare system.[29] None of the interventions worked perfectly. In fact, only 27% of pneumonia cases were treated. Nevertheless, the combination of these interconnected improvements resulted in an impressive overall outcome. This contrasts with the experiences of Nigeria, which had almost seven times more qualified frontline health workers than Ethiopia (as of 2009), but achieved a smaller reduction in child mortality (a 52% reduction over the same period).[30] Though Nigeria was considered a top performer in Africa in terms of providing frontline staff, the Nigerian system supply chain functioned poorly, workers had low skill levels, and little money remained for drugs and supplies.[31] In Kenya, child mortality also improved only modestly (based on what one would expect from the country's level of GDP). According to researchers, key contributing factors to this outcome were a lack of unified policies to align the incentives of government, donors, stakeholders and beneficiaries, and suboptimal monitoring.[32]

Ethiopia's success stems from well-designed interventions that avoid investing in isolated silos. Previously, its health expenditures had focused largely on hospitals, while development partners had invested in disease control. These represented two largely separate lines of action. In 2005, the health ministry devised a strategy to align disparate funding, incentives, and goals.[33] In practice, this meant looking beyond the point of delivery and implementing reforms in several areas: creating more health posts, improving laboratories, creating an agency to manage the pharmaceutical supply chain, training health workers, building data-management systems, and investing in water and sanitation. The Ethiopian reforms were also successful because they were linked together in deliberate ways. When a programme created new health posts, a conscious effort was made to link these to the needs of the local citizens (not just to the priorities of central policymakers). For example, reporting went to local village administrators as well as health centre management, and some programmes involved community volunteers alongside frontline workers.[34] Despite the general positive trend, inclusivity remains a challenge: improvements in mortality rates for children younger than five were the lowest for the poorest Ethiopians, with no improvement at all on some other health outcomes. It will be worth tracking whether these numbers shift in a more positive direction as Ethiopia's current prime minister has placed far greater emphasis on connecting with traditionally marginalised groups across the country.

Patients in State Specialist Hospital, Borno State, Nigeria. Photograph: Serrano Redondo, Jesus Andres. International Committee of the Red Cross 2015.

Hendriyanti Benny teaches in a school in Nusa Tenggara Tengah, Eastern Indonesia. Photograph: Santirta Martendano A., Pathways Commission, 2018.

Chapter 3
Finding digital solutions to today's system constraints

Digital and digitally enabled technologies are already changing societies and economies. The dramatic improvements in computer processing speeds, in line with Moore's law (predicting the doubling of computing power roughly every 18 months), have led to an acceleration of progress in a wide range of advanced technologies such as robotics and machine learning, making the production of goods and services more efficient. There have also been substantial changes in the way people – and their devices – can be connected through improved internet infrastructure, the "internet of things" (and other interconnected devices) and new methods for communication. These developments are having profound impacts on all parts of society, as explored in previous Pathways for Prosperity reports.[35] Table 1 offers some examples of the different routes through which digital and digitally enabled technologies bring down costs across an economy. This framework can also bring to light the opportunities for more cost-effective service delivery.

Table 1. **How digital technologies are changing economies and service delivery**

	Economic applications	Service delivery applications	Service delivery examples
Production Producing goods Delivering health and education	Robots in factories, automation of tasks across the economy, replacing workers and changing the nature of work.	Changing how actors perform their tasks and functions, typically at the point of delivery.	Automated health diagnosis; codified or personalised computer-supported teaching and learning.
Interconnections Exchanging goods, services, information, labour and capital	Platforms for retail sales, transport; access to capital; skill acquisition; better labour market matching of skills; remote working.	Changing the quality of connectivity in the system, boosting performance through better allocation of available inputs and resources.	Digital supply-chain management; personnel, data and financial resources; monitoring and quality control systems.
Organisation The design and architecture of a system	Changing global value chains towards broader sets of goods, services and labour (eg outsourcing, remote maintenance, global work platforms).	New models for organising health and education.	Online education and health; remote "outsourcing" of diagnosis and treatment; "learning" health or education systems.

Note: Details on the economic applications are available in Pathways for Prosperity (2018a), *Charting Pathways for Inclusive Growth: from Paralysis to Preparation.*

Digital and digitally enabled technologies are changing how service delivery happens. Broadly speaking, the impact of technology can be divided into three distinct groups: production, connection, and organisation (as in Table 1). New technologies can increase the efficiency of the *production* of health and education services at the point of delivery. For example, digital educational assessment tools or diagnostic health tools may allow higher-quality, cheaper, or faster diagnosis of problems and their remedies. Such tools generate much of the excitement about technology in policy spheres, and can be a singular focus of policymakers. However, what tends to be forgotten is that digital technologies offer great potential to (literally) rewire a system to improve its *interconnectivity*. Improved connections between different parts of a system can lead to better allocation of available resources, as these connections enable better monitoring of results, feedback and support systems to frontline delivery staff, digital supply chain management, digital training platforms, and interventions that may encourage citizens to seek out and demand quality services. Such changes could go beyond better allocation, and lead to a more fundamental change in the *organisation* and feasible architecture of the system, for example by changing the geographic distribution of health clinics, the medium through which lessons are delivered (such as through an e-learning app or online classroom), or the role of citizens in managing their own health.

Innovation in service delivery – whether through technology or other solutions – must start with an in-depth understanding of the problems or constraints to be addressed. As Table 1 suggests, even assuming digital solutions are deployed with this in mind, new technologies may have multiple routes through which to improve the effectiveness, efficiency and equity of health and education systems. In the real world, every system will have its own constraints, interacting in unique ways, but for the purposes of this report, we focus on four common problems or constraints. These common constraints are:

1. System-wide incentives and motivational gaps for service delivery workers
2. Weak management and accountability structures
3. Knowledge gaps on the part of frontline workers
4. Low uptake of services by citizens

Digital solutions to common constraints

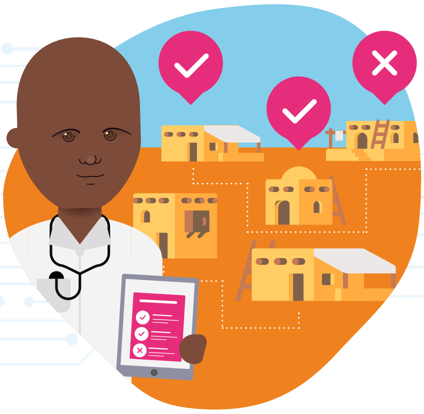
Tech for managing and empowering workers

Problem
Frontline workers disconnected from policymakers

Solution
Monitoring and direct digital feedback

Result
Empowered, accountable, data-driven staff

Evidence
In Mali, direct digital feedback led to better impact, with health workers visiting 40 more houses per month (a 10% increase)



Data for smart decision-making

Problem
Weak management and accountability

Solution
User-friendly data collection for decision-making

Result
More efficient resource management

Evidence
In Uganda, mTrac, an SMS-based malaria drug availability tool reduced the number of districts that were reporting stockouts from 79% to 15%

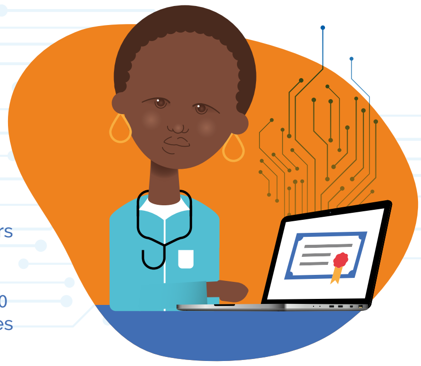
Digital learning for skilled workers

Problem
Staff often lack specialist skills

Solution
Online and digital training

Result
Better-quality services delivered by well-trained workers

Evidence
An online course effectively provided HIV training to 900 Zambian clinicians, leading to improved health outcomes



Connecting citizens to services

Problem
Low uptake of health and education services

Solution
Targeted digital reminders

Result
Better-attended services, and healthier and better-educated people

Evidence
SMS reminders increased Kenyan HIV-patients' regular use of antiretroviral drugs by over 30%, improving their wellbeing

These constraints are not directly at the point of delivery, and yet each of them may be amenable to emerging digital solutions, although in some cases only in combination with other changes. While some of the technological solutions analysed involve new forms of *productive* efficiency, most of today's digital solutions are about creating *interconnections* between different components of the system, whether connecting policymakers to frontline information, or exchanging information with citizens.[36] Some of these also start to hint at *reorganisation* of systems, a topic that is explored further in Chapter 4.

Of course, digital solutions may not always be the best way to address these constraints. Technology can be a positive disruptor, but this is not guaranteed. Choosing technologically advanced solutions over analogue alternatives requires a sober justification based on their effectiveness, efficiency and equity. Solutions must not be implemented for their own sake; they should be deployed only if they address an identified constraint in an appropriate and cost-effective manner.[37] And even when digital technologies are deployed, their implementation is not immune from the considerations outlined in the previous chapter; a new digital solution still requires alignment between actors to gain traction.[38] That said, the potential of technology to meet and exceed this standard is growing. The rest of this chapter will examine examples of digital and digitally-enabled technologies being applied today to address the four common constraints identified above.

3.1 System-wide incentives for service delivery workers: how digital monitoring and support systems are helping

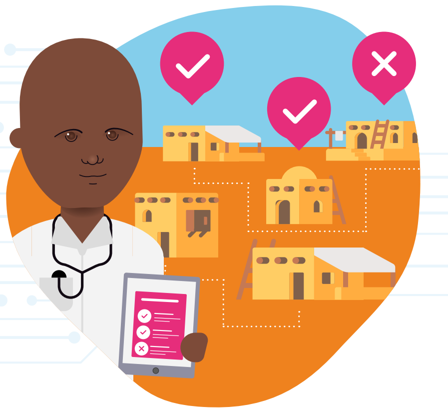
Tech for managing and empowering workers

Problem
Frontline workers disconnected from policymakers

Solution
Monitoring and direct digital feedback

Result
Empowered, accountable, data-driven staff

Evidence
In Mali, direct digital feedback led to better impact, with health workers visiting 40 more houses per month (a 10% increase)



The behaviours of frontline service delivery staff can contribute to poor outcomes. Most health and education professionals feel a deep sense of vocation and show commitment to their role in society. Nevertheless, there are motivational or even commitment gaps. One study showed absence rates among health workers of 40% in India and Indonesia, 35% in Bangladesh, 37% in Uganda, and 25% in Peru.[39] A study in Uganda pointed to absenteeism of hospital doctors, with rates as high as 65%, as the cause of delays in referrals of neonatal and maternal health cases.[40] A study of seven sub-Saharan African countries found that 20% of teachers were absent from school, and 45% of those present were absent from the classroom.[41] This does not solely reflect staff motivation and discipline, but also how those motivation levels are shaped through the broader system: recruitment processes, training colleges, teacher unions, inspectorates, and administrative organisations. Ultimately, this is not simply a frontline issue of individual motivation, but is also a product of the system's culture and environment created by high-level decision-makers.[42]

Digital tools are already helping to tackle absenteeism among health and education workers, and these tools may be more cost effective than other types of interventions. There have been some attempts to solve the problem by improving pay or linking it to performance, but these have met with limited success.[43] Better monitoring can be more efficient and effective: indeed, simply increasing the frequency with which teacher absences are monitored can be ten times more cost-effective than hiring more teachers.[44] Digital systems are being used to do this successfully. In Rajasthan, for example, making teacher salaries a function of attendance and using time-stamped camera photos as monitoring devices decreased absenteeism by 21%,[45] at least initially.[46] However, a similar programme for nurses in the same Indian state failed: six months in, absenteeism returned to prior levels as nurses started cheating or damaging machines, and local authorities started colluding by approving fake "exempt days".[47] This demonstrates the difficult and complex nature of implementing change in a system, and illustrates the importance of top-level governance: if corruption or gross inefficiency are tolerated or encouraged at the national level, it will send a powerful market signal that such behaviours are acceptable at a local level.

To make good use of digital technology for monitoring and supporting workers, policymakers need to take into account the incentives and motivations of actors, as well as other system factors. Indeed, the procedural tasks monitored through some accountability mechanisms, such as attendance, may not be the best predictors of good health and education outcomes.[48] For example, using a GPS tool to ensure that a teacher arrives for class will not ensure that the students learn. Such accountability measures merely address a symptom and there remains a need to resolve underlying issues like corruption, misaligned incentives, intrinsic motivation, or other barriers confronting providers. For instance, in Papua New Guinea, teachers had to travel to a district office to collect their salaries (in some cases taking a whole week), necessitating an absence from work which could be easily resolved through digital payments.[49] Increasing intrinsic motivation can also have outsize results compared to other investments.[50] In Uttar Pradesh, India, a simple voice-and-web-based feedback system gives personalised feedback to community health workers, with generally positive effects.[51] Technology can thus be used to good effect as a way of showing frontline workers that they are valued, and not just as a means to check up on them.

3.2 Weak management and accountability structures: how these are being addressed through better digital data flows

Data for smart decision-making

Problem
Weak management and accountability

Solution
User-friendly data collection for decision-making

Result
More efficient resource management

Evidence
In Uganda, mTrac, an SMS-based malaria drug availability tool reduced the number of districts that were reporting stockouts from 79% to 15%

Several failings at the point of delivery can be linked back to weak management and accountability processes, where the poor collection and flows of actionable data make appropriate decision-making impossible, even when decision-makers have the political will to drive change. In many places, the collection of outcome data to monitor the state of progress remains sparse. Decision-makers rarely have data on whether learning outcomes are improving, or infectious diseases are declining.[52] There are practically no standardised national learning assessments in low-income countries,[53] and even if data is collected, it is rarely acted upon. For example, Edo State in Nigeria had conducted annual teacher performance evaluations, but these evaluations did not affect decisions on teacher promotions, lead to sanctions, or result in rewards for teachers based on their performance.[54]

Digital tools are an effective means to collect the health data that is essential for decision-making.[55] Mobile VRS, a web-based application in Uganda, is one such successful example. Recording births is a key aspect of data collection for health planning: without this data, countries only have an approximate idea of the size, health, and longevity of their populations. Following a pilot in 2010, Mobile VRS has now essentially become the main system for recording births in Uganda. Where previously only 28% of births in the country were registered, this is now close to 70%.[56] At $0.03 per registration, the cost is very low,[57] and Mobile VRS is likely to become an integrated part of the forthcoming national ID system. However, while the system reaches more underserved areas than previous initiatives, it doesn't work for people or regions without cellular network access (although workarounds include sending paper registration forms to a regional office for digitisation).[58] A very different example comes from Nigeria, where micro-planning of polio vaccination administration has been improved using satellite imagery and GPS tracking to help teams identify missed settlements.[59]

Better data flows are also contributing to better management, allocation of resources, and accountability. The VISHWAS programme in rural Maharashtra, India, is best understood as a mechanism to improve the quality of data collection, in a context of potential corruption or non-compliance (by inspectors or school managers) that may create incentives to falsify records. Data is collected on a variety of indicators, including school attendance, test results and use of the free midday-meal scheme. Importantly, the information is location- and time-stamped on the GPS-linked devices of both the visitor and the school management team, reducing opportunities to falsify or lie about inspections. Operating across more than 1,600 schools, the system appears to have helped catch absent inspectors and teachers, and inspectors submitting false reports. It has also shown an apparent improvement in teaching practice.[60] Digital systems can also help solve problems with physical resource allocation, such as drug stock outs, which are still common around the world.[61] One successful example is mTrac in Uganda, which started in 2011 as an SMS-based tool to track the availability of malaria drugs. It rapidly became the system for tracking stock levels of 64 key drugs, together with an automated ordering system and built-in feedback loops for better decision-making. While not without challenges, stock management and disease reporting rates in the country have dramatically improved for only a modest cost, with weekly health facility report completion rates increasing from 50% to 78% within three years and the number of districts reporting stockouts decreasing from 79% to 15%.[62]

While digital data flows can improve many specific functionalities of service delivery, it is important to keep the wider system in mind. The collection of data is a necessary, but insufficient, condition for effective decision-making; ensuring that policymakers and political leaders are committed to using data and evidence will always remain a challenge. The use of data to support management is predicated on the assumption that policymakers and organisational managers are *willing and able* to redistribute resources, invest in their people, and allow themselves to be held accountable.

3.3 Knowledge gaps of frontline workers: how digital technology provides a bridge

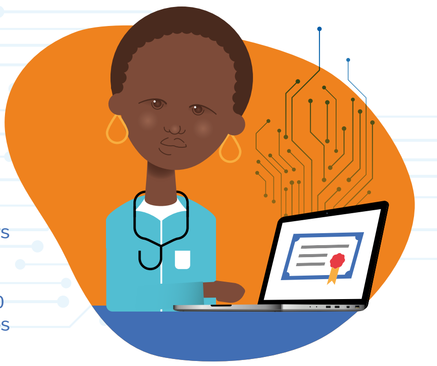
Digital learning for skilled workers

Problem
Staff often lack specialist skills

Solution
Online and digital training

Result
Better-quality services delivered by well-trained workers

Evidence
An online course effectively provided HIV training to 900 Zambian clinicians, leading to improved health outcomes

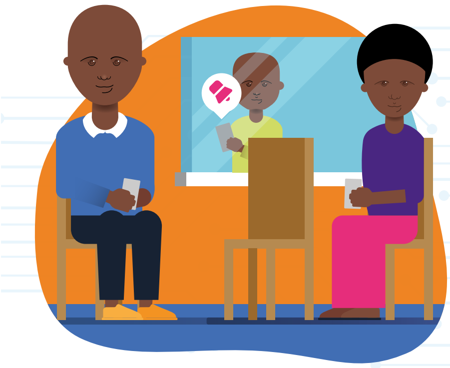


Skill levels among teachers and health workers remain poor. In sub-Saharan Africa, for example, both teachers and health workers often achieve very low scores in assessments of even the most basic skills.[63] In Uganda, only 35% of public health workers could correctly diagnose at least four out of five common conditions, such as malaria with anaemia, or diarrhoea with dehydration - one of the most common killers of infants and children. Moreover, teachers in many developing countries fail to demonstrate “minimum” knowledge of the curriculum, defined as the ability to correctly answer 80% of the questions on an assessment of the primary school curriculum. Those who passed this low standard represent 2.4% of teachers in Nigeria, under 1% of teachers in Togo, and just 0.3% of teachers in Mozambique. Even in Uganda and Tanzania, often thought of as better-performing countries, teachers who passed this minimum standard of knowledge represent a tiny minority: only 10.1% in Uganda, and 15.6% in Tanzania.[64]

Digital tools are contributing to improvement in both knowledge and practices. A number of organisations supply electronic versions of textbooks with the aim of making them accessible to teachers everywhere. For example, Kytabu in Kenya provides all required textbooks as e-books.[65] In addition, easily searchable and user-friendly specialist resources for teachers and health workers have also emerged. In India, Digital Infrastructure for Knowledge Sharing (DIKSHA) is a prime example of best practice guidance for education.[66] It is an open-source educational platform to which teachers contribute educational resources, guides and structured lessons. The platform effectively developed a community of practice, and in 2019 it gained the support of educational authorities in 28 states. There are similar examples in health: in Tanzania, e-IMCI (electronic-Integrated Management of Childhood Illness) uses mobile phones to provide community health workers with World Health Organization-approved protocols for treating common childhood diseases. The system gives the workers easy access to relevant expertise.[67] If aligned to curriculum and regulations, and developed with careful quality control, such models will serve those keen to improve their teaching or healthcare practices, and will offer low-cost ways of doing so. However, they are “for the willing”, that is, for those motivated to improve and sustain good practices. In this sense, it “works with the grain”, supporting and boosting motivation, and seeking progress without disruption.

Online on-the-job training offers a low-cost opportunity to ensure that service providers’ skills are developed, maintained and up-to-date. Training health workers and teachers using online tools is an increasingly common practice. For example, the HIV Clinical Care Course provided online learning for clinicians in Zambia. The course included live web chats and an online discussion forum. It gained traction, reaching 900 health workers at an average per student rate of $171, making it less costly than other HIV training available in the country.[68] Similar interventions in education are also proving promising. Teacher Education in sub-Saharan Africa (TESSA), Africa’s biggest teacher education collaborative initiative, has created a large, online bank of teacher education materials, with particular attention to the core areas of literacy, numeracy and science.[69]

3.4 Low uptake of services by citizens: how digital technology is helping



Connecting citizens to services

Problem
Low uptake of health and education services

Solution
Targeted digital reminders

Result
Better-attended services, and healthier and better-educated people

Evidence
SMS reminders increased Kenyan HIV-patients' regular use of antiretroviral drugs by over 30%, improving their wellbeing

An enduring challenge in health and education is that citizens do not always make use of the services available to them. This tends to be disproportionately the case for women and for the poor. Reasons for this can be manifold. They may not have sufficient information on the benefits of health and education services (or even on the services that are available to them). They may find it difficult to commit to showing up for class or appointments, or to adhere to drug schemes. Or, the services on offer may be unaffordable, of low quality, prohibited by social norms, or simply inconvenient to access.[70] Addressing this low uptake (which we refer to as a demand-side constraint) is crucial; even if other constraints are tackled, health and learning outcomes will not improve if citizens do not take up the services offered to them. Technology can help to address this challenge, if it is implemented in a way that centres on reaching marginalised citizens who are not currently accessing these services.

Very basic knowledge – for example, about the benefits of preventative healthcare – has not spread to some regions. In Malawi, for instance, many misconceptions about infant nutrition persist, such as that the broth of a soup contains more nutrients than the meat or vegetables therein, or that eggs are harmful to nine-month-old infants.[71] More often than not, in matters of health information, patients and parents adhere to cultural traditions and the advice of local "influencers" rather than official, government-mandated guidelines. Demand for education and health services among women and girls tends to be particularly low. Financial, cultural, and social barriers often prevent girls from attending or continuing school, and similarly deter women from seeking care during pregnancy.[72] Reducing such gaps in service uptake can result in large gains in health and learning outcomes. For instance, a child with a literate mother is 50% more likely to survive past the age of five, in part because children of educated mothers are more likely to receive vaccinations.[73]

Digital technologies can be used to increase the uptake of education and health services. This may be directly, by disseminating information (eg on the benefits of formal schooling[74] and healthcare) and thus aiding commitment to the use of services; or indirectly, by shifting social norms, for example regarding stances on the use of schools, health services and technology by women and girls. The deployment of technologies is a natural next step in the effective use of social marketing to advance health and education goals. A project in Burkina Faso, for instance, sent mobile phone messages to pregnant women, new mothers, and people living with HIV, which led to increases in mothers seeking prenatal care, assisted deliveries and follow-up treatment.[75] Mental health patients in Nigeria who received SMS reminders for their next appointment were twice as likely to attend their appointment as patients receiving standard paper appointment reminders.[76] Digital communication technologies – through educational entertainment and social media, in particular – can also provide effective means for helping to indirectly shift social norms, and increase knowledge of preventative health measures.[77] In Nigeria, for example, viewers of MTV Shuga, an educational entertainment TV series with sexual health messaging, were twice as likely to get tested for HIV.[78] Although the space for influencing via the media is crowded and hard to break into, the increasing penetration of digital social media among younger people – even in relatively poor settings – is creating a massive opportunity to get a new generation to take ownership of their health and education.

To avoid exacerbating existing inequalities in health and education outcomes, digital solutions need to be tailored towards those citizens whose uptake of services is currently low. If the same social norms that prohibit girls from walking longer distances to attend secondary school also limit their access to mobile technology (which could offer an alternative education medium), inequalities will not merely remain but may even be exacerbated.[79] An earlier report by the Pathways for Prosperity Commission highlighted the limitations of women's and girls' access to mobile technology, as compared to that of their male counterparts, across seven countries. These disparities applied irrespective of their age, education, location, and income level. In Pakistan, for example, almost 80% of men own a mobile phone, compared to 39% of women, with the largest disparity existing for internet-enabled phones.[80] High handset and mobile data costs, as well as social norms,[81] prevent women from accessing digital technology, hindering the information flows available to them, including on the topics of education and health.

A doctor carries out medical checks on a newborn baby at a health centre in Yirimadio, Mali. Photograph: Muso, 2014.

Chapter 4
Glimpsing the systems of the future

Digital technologies can completely redefine the health and education provision of the future. The evidence from the examples quoted in the previous chapter suggests that digital technologies, used well, are already helping to overcome some of the specific, serious challenges of health and education delivery in the developing world. Such technologies offer improvements in the effectiveness, efficiency and inclusiveness of today's health and education systems. They also hint at more ambitious visions for the future, in which digital technologies help us to more fundamentally rethink how health and education service delivery takes place. This chapter looks forward, and begins to articulate possible visions for the future as follows:

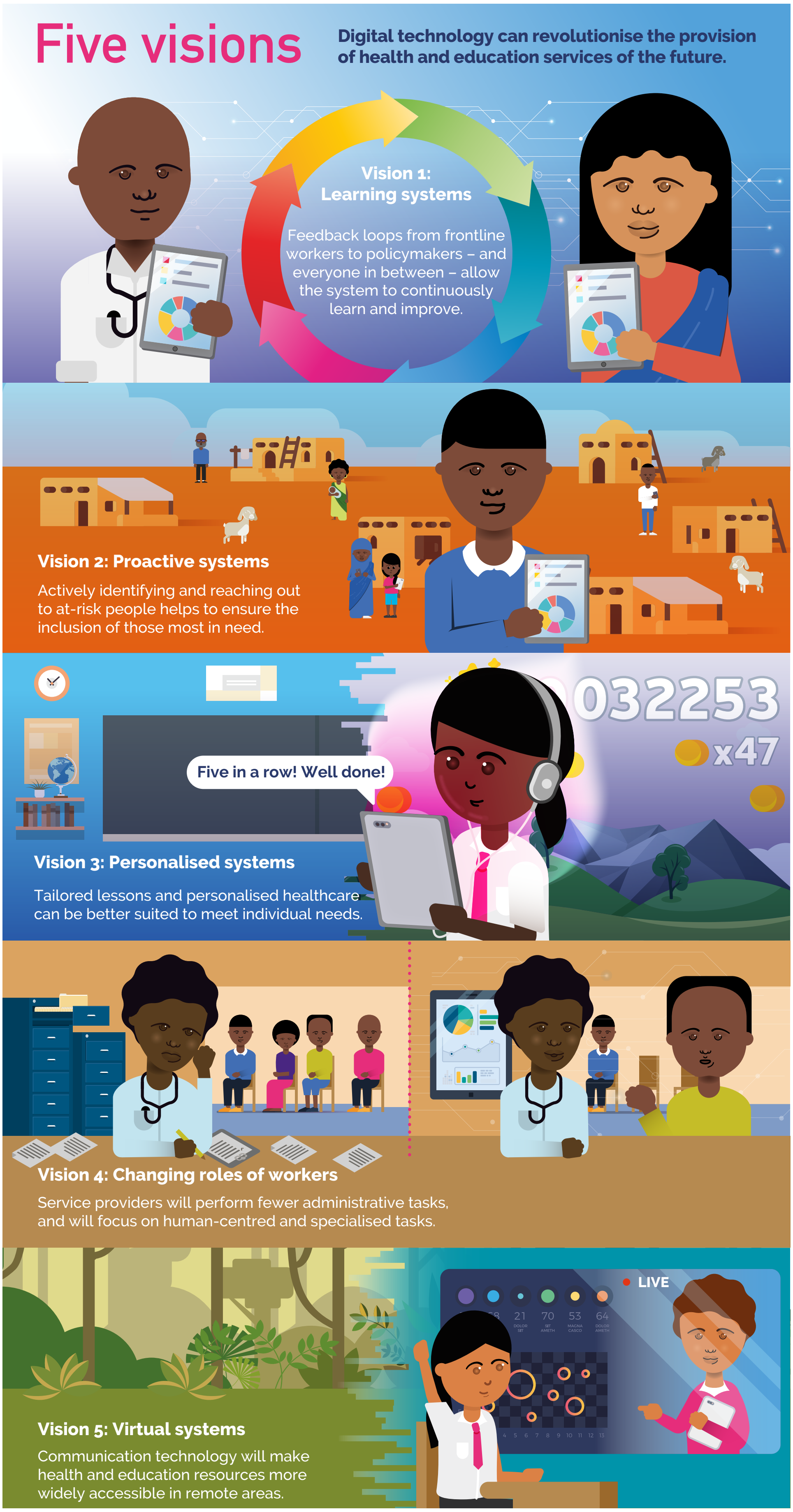
1. Careful and deliberate low-cost data collection will make it possible for health and education systems, supported by digital technologies and artificial intelligence or machine learning, *to continuously learn and improve* by creating feedback loops for decision-makers at every level.

2. The systems of the future have the potential to be *proactive, inclusive systems*, targeting the citizens most in need of services. Education and health services can be provided for those who are not reached by conventional methods, drawing technological resources not just to those who can afford them, but also to those who need them most.

3. Learning and healthcare will be *personalised* in ways that can be tailored to even the poorest and those left furthest behind.

4. Automation, and new formats of service delivery will *redefine but not diminish the roles of teachers and healthcare staff.*

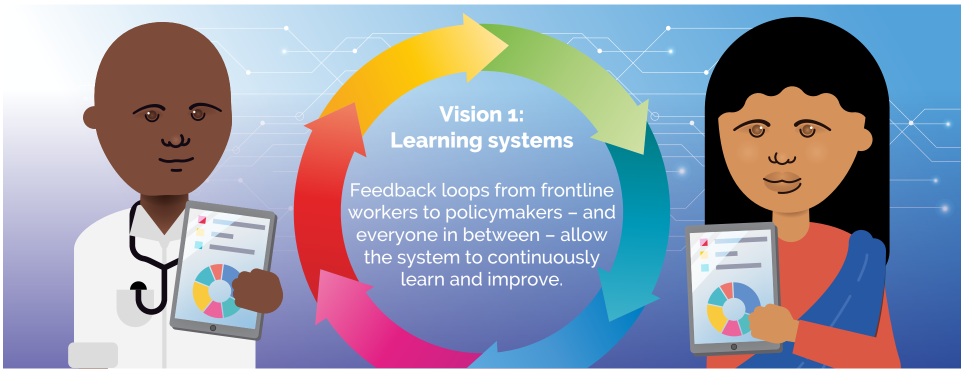
5. Improving communication technologies (from phones to video-link, and perhaps virtual reality) create the opportunity for a *virtual system*, bringing down the walls of classrooms and clinics and providing expertise even to remote areas.



Five visions
Digital technology can revolutionise the provision of health and education services of the future.
Vision 1: Learning systems
Feedback loops from frontline workers to policymakers – and everyone in between – allow the system to continuously learn and improve.
Vision 2: Proactive systems
Actively identifying and reaching out to at-risk people helps to ensure the inclusion of those most in need.
Five in a row! Well done!
032253
x47
Vision 3: Personalised systems
Tailored lessons and personalised healthcare can be better suited to meet individual needs.
Vision 4: Changing roles of workers
Service providers will perform fewer administrative tasks, and will focus on human-centred and specialised tasks.
LIVE
Vision 5: Virtual systems
Communication technology will make health and education resources more widely accessible in remote areas.

We start by reimagining systems, and then examine what practical steps can now be taken in developing countries to move towards these futures. Parts of these visions are for the coming decades, but other parts can begin to be realised within the next few years. Of course, in many locations, a wash basin in the health clinic and electric lights in the classroom would constitute a transformative "future vision". However, even in the most challenging of circumstances, digital technologies offer a promising tool to improve the design and architecture of existing systems. Explicit effort will be needed to build equity throughout implementation of the five visions, as these will not be inclusive by default. Too often, technological change exacerbates existing inequalities, benefitting the better off and those already digitally connected, rather than those most in need.[82] Such changes will necessarily be disruptive and challenge the status quo. The opportunity for reimagined future systems is here, but realising this opportunity requires determined political commitment and, as always, a profound understanding of the existing system.[83]

4.1 Vision one: learning systems



One future scenario envisions health and education systems that intensively collect and generate data used to help actors in the system to continuously learn and adapt. The concept of a learning system comes from healthcare, defined, for example, as a system in which "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".[84] This has inspired significant efforts in the US and the UK, but there are nascent indications that this may also be feasible and affordable in education for low- and middle-income countries. Such models offer huge potential for change in both health and education spheres.[85] In this vision, providers will take advantage of digital technology to make the collection, linking, storage and use of relevant data faster and cheaper than ever – and this trend will only accelerate. This is a system that records the real-time results of current practice, synthesises this into future recommendations, and learns from "live experiments" with slight variations in practice. A learning system will thus be a system in which data and information are optimally used and presented to enable the system managers and decision-makers to understand, learn, adapt and make better decisions.

Its impact will be most significant if the technology is used to optimise the overall architecture of and interconnectivity between all the elements of health and education systems.

There are important challenges that need to be confronted to ensure success. While data will be the fuel of such systems, experiences with concerted and integrated data collection within health or education systems to date have often been disappointing, indicating the complexity of the task. A learning system needs accurate and timely data, but data collection is often patchy across a population, burdensome on the frontline worker, and inconsistent from one programme to the next. In the future, the burden of data collection and analysis will likely be significantly reduced by technologies such as speech and handwriting recognition, and automated data collection at the point of delivery (eg directly from the citizen's or provider's device). If the appropriate "digital plumbing" (see Chapter 5) is properly in place to collect standardised data at high frequency, then experimentation – including using RCTs – could be implemented at low cost with fast feedback loops. The promise is that these feedback loops could be introduced to make a difference to health and education outcomes, and at little expense.

The power of a learning system comes from linking information from different sources to derive new insights and drive better decision-making. Some initiatives have already taken this route. For example, in India, a simple yet integrated smartphone-based digital platform for malaria surveillance, called MoSQuIT, was introduced in rural Maharashtra. It combined real-time surveillance with treatment data, which resulted in improved detection of outbreaks, better monitoring of medical supplies, and adaptive real-time responses.[86] Increasingly, tools are being developed to collect, visualise and use data on performance to make decisions. For example, Bluesquare – a company dedicated to using data systems and tools to improve the efficiency of public services – has worked with governments, NGOs and donors in 18 countries to develop technological health financing and decision-making solutions, such as tablet-based data collection and visualisation tools.[87] Work is also underway on the Ghana School Mapping platform,[88] a smartphone platform which allows users to collect and display information on the resources, teachers, infrastructure (eg state of roads, distance from students, and availability of toilets and facilities), and performance of the school. The platform represents a potential first for Ghana: an integrated database of the assets, people and resources in the education system. This tool should foster better decision-making as regards the allocation of resources and finance, such as for repairs and the placement of teachers. Moreover, it also allows for the monitoring of investments or outcomes (both by policymakers and by citizens) using relatively low-cost smartphones and cloud-based hosting. These methods have similarly enabled policymakers to monitor systems and make decisions in real time.[89]

Future systems will exploit this vast amount of data to develop a higher-quality, actionable evidence base, and to continuously learn from it. Within a learning system, knowledge is shared continuously as lessons are learned, to inform better practice for both doctors and teachers, and better decisions by stakeholders higher up in the system.[90] Moving forward, increasingly easy-to-use algorithms and platforms will bring analytical tools into more people's hands, not just into those of technocrats. In Zambia and Tanzania, for example, the BID (Better Immunization Data) Initiative creates a pipeline of quality immunisation data that can be used by providers and decision-makers alike. Such projects show that, with the right tools and training, frontline providers can use data to improve their work.[91] In the future, embedded feedback loops could help all actors in a system better understand the broader context in which they work, and more easily take on board new evidence, findings and best practice.

4.2 Vision two: proactive systems supporting education and health for all

Digital technologies offer the opportunity to proactively focus on including those left behind in current service delivery models. It remains the case that globally, 250 million children and youth are out of school, and about 330 million are in school but not learning.[92] Meanwhile, approximately 20 million infants each year (or 15% of all newborns) do not receive the required vaccinations.[93] The five visions described in this chapter have the potential to be inclusive of those people currently excluded – but this will not happen without specific actions and proactive, system-wide efforts and incentives.

In health, digital technologies can improve population-wide health and disease-prevention practices, and facilitate the timely use of health services. Community health workers who provide populations with health advice, and raise awareness of facilities, have long been part and parcel of health provision in poorer settings. Community case management, in which specific children or mothers are tracked, is one common model, although it does not always have the desired or expected effects.[94] That said, when partnered with a quality programme that is designed to work in the context of the local system, digital-monitoring and case-tracking tools can boost outcomes. In Mali, a proactive community case management programme initiated by an organisation called Muso contributed to rapid declines in child mortality in peri-urban areas. In the core programme, community health workers actively seek out patients who are likely to require care.[95] Health workers' efficiency was increased by using a digital tool, a platform-based dashboard, which complemented their supervision model by providing individual feedback on their work, leading to a 10% increase in the number of houses visited per month.[96] In another case, in Tanzania, personalised, automated SMS messages were used to remind community health workers that a visit was overdue, reducing delays in visits.[97] In Uganda, among other countries, a portable ultrasound device called Butterfly iQ is in use. This device, which connects to an iPhone, helps diagnose patients in remote areas, opening the possibility for proactive frontline workers to undertake more complex interventions.[98] Digital technology can also proactively triage and direct patients, ensuring resources are allocated to those who need them most. In principle, initiatives such as Babylon Health's chatbot, which has been rolled out in Rwanda, may offer effective triage, keeping relatively healthy or low-risk patients out of clinic waiting rooms.[99]

In education, digital technologies will allow more precise targeting of pupils whose learning is lagging behind, and of schools that perform poorly. Personalised learning tools that allow for adaptive learning will allow teachers – and, indeed, the overall system – to offer better targeted education. This will mean that instruction methods can effectively help those being left behind, not just those at the median or top performance levels, as is often currently the case. A future learning system should help to predict where children are at risk of falling behind or dropping out of school, triggering proactive responses to support these individuals. Time gained from automated learning can also be used to ensure that those from more deprived backgrounds gain the confidence to make the most of their education. None of this will happen automatically: such achievements will require deliberate measures and political commitment, including incentives for schools that are not based primarily on top-end performance, but rather on successful learning for all.[100]

Specific effort will still be needed to ensure that poor and vulnerable groups, not least girls and women, are actually included. Technology can help here, too. Approaches that address the "demand" side of health and education are often lacking in poor communities. Children are often not sent to school or drop out too early, while health services are generally underutilised or used too late. Section 3.4 showed how financial, social and cultural barriers can prevent people from accessing services, and how building up citizens' knowledge of and demand for services can start to overcome these impediments. In a truly proactive future system, it will be possible to identify these vulnerable and excluded populations, and to direct resources towards them. As we explore in Chapter 5, this will require digital infrastructure – including digital ID and authentication – to allow the sort of analysis required to bring marginalised populations out of the shadows. Such steps can also empower citizens and service beneficiaries, who can track whether they are receiving benefits, and engage in the feedback loop that powers a proactive system.[101] In some countries (such as India) this is already starting to reshape how policies are designed for people in poverty.[102] Opportunities for bridging the gender gap may also emerge, although this ambition is still far from being realised (see Box 2).

Box 2. **Gender in health and education: building digital bridges**

Gender gaps are present in both health and education, in terms of demand, access and outcomes. Financial, cultural and social barriers – including, for instance, potential danger in the walk to distant schools, and the lack of safe toilet facilities – prevent many girls from attending school. While disparities in primary school enrolment rates between boys and girls have largely ended, inequalities in secondary enrolment persist. In 2012, for example, for every 100 boys enrolled in secondary school, only 84 girls in sub-Saharan Africa and 93 girls in South and West Asia, respectively, were enrolled.[103]

Similarly, women face barriers in accessing healthcare. For example, antenatal care can be expensive. Women risk physical harm during travel and abuse in care settings.[104] Indeed, the figures on healthcare outcomes for women are alarming: in sub-Saharan Africa, the maternal mortality rate is one in 183, as compared to one in 10,000 in high-income countries.[105] Improving women's health is obviously crucial for both them and their children, but education is also hugely important: a child with a literate mother is 50% more likely to survive past the age of five.[106]

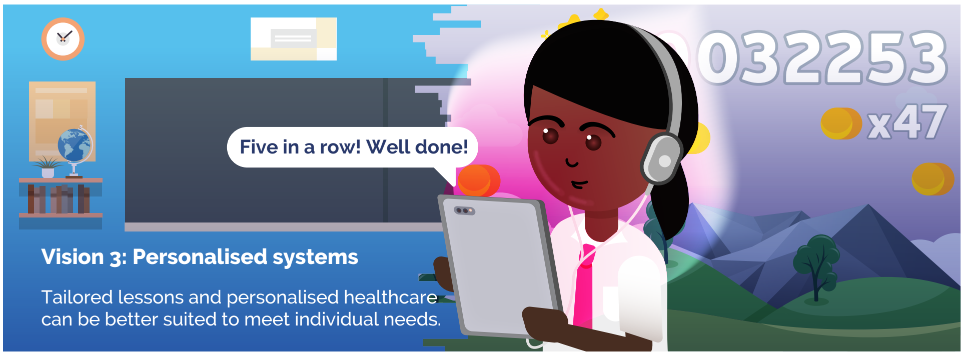
These gender gaps need to be addressed with targeted programmes such as land reform, cash transfers, anti-discrimination laws, and positive discrimination programmes.[107] Technology can also help. SMS services can be used as educational tools during pregnancy, with measurable effects on antenatal care attendance, utilisation of facilities, skilled health worker attendance at birth, and vaccination rates.[108] Existing video platforms also disseminate information on the value of schooling.[109]

Technology also offers great potential to help in reimagining services in ways that overcome gender barriers. For example, women can directly access specialist medical expertise via telehealth, without the associated costs and physical dangers of travelling. Chipatala Cha Pa Foni, a health call centre in Malawi, was first developed for maternal and child health. Qualified staff members refer patients to health centres if necessary, or resolve cases by phone. Evaluation has shown positive community effects, from better knowledge of the recommended number of prenatal visits, to preparedness for delivery at health centres.[110] In education, personalised adaptive learning digital tools are beginning to show their potential to bridge gender differences in students' attainment: onebillion's "onecourse", which delivers content and practice on a tablet, was found to prevent a gender gap in reading and mathematics skills from surfacing among first-grade students in Malawi – potentially by overcoming sociocultural factors responsible for gaps emerging in traditional classroom settings.[111]

However, while technology offers such benefits, these will not be guaranteed without deliberate action. Several factors exacerbate the issues that many women and girls face in accessing technology. As the Pathways for Prosperity Commission previously highlighted, there is a significant gender gap in access to mobile technology. The gap was seen across seven countries, irrespective of age, education, location and income level.[112] And even when there is equal access to technology, some technologies may exhibit inherent biases that disadvantage women. For example, medical technology that uses machine-learning algorithms trained on datasets with more male than female data has been shown to not work equally well for women.[113] The emerging lesson is that technology can help bridge gaps in both access to and outcomes in healthcare and education, but the foundations of any technological solutions need to be set in place with careful consideration of gender from the outset.

A pupil at school in Nusa Tenggara Tengah, Eastern Indonesia. Photograph: Santirta Martendano A. Pathways Commission 2018.

4.3 Vision three: personalised systems



By capturing and processing large volumes of individual data, digital and digitally enabled technology will make personalised "diagnosis and treatment" possible in both health and education systems. Mindspark, a digital personalised learning software, is one of the programmes that has been rigorously evaluated. In India, where Mindspark is based, the majority of children fall behind early on, developing large learning gaps. For example, by grade 9 children are, on average, performing with a deficit of 4.5 grades for maths. One study of a free after-school programme for students from public middle schools in Delhi that introduced Mindspark showed improvements of up to

38% in mathematics assessment scores after just 4.5 months – a much higher rate of improvement than from other comparable interventions.[114] Currently, Mindspark is expanding into state schools in Rajasthan, with much promise. Another carefully assessed edtech personalised learning innovation is onebillion's "onecourse", a modular course designed to teach basic skills via a tablet or mobile app.[115] This model is being scaled further following an RCT in Malawi that demonstrated its efficiency on numeracy for children in grades one to three.[116] The course was also shown to prevent a gender gap in reading and mathematics skills in first graders.[117] Both of these interventions have taken the wider system into consideration, meaning that at least some common challenges affecting the feasibility for scaling to reach a wider population have been addressed. For example, onebillion uses solar-powered tablets that are designed to fit with the local infrastructure, while its teachers' administrative tool allows the teacher to be continuously involved by tracking children's activity in real time and providing feedback. Similarly, in Kenya, individual electronic health records have been used to customise advice, alerting prescribing doctors to potentially dangerous interactions of medications.[118] In many cases, these predictive models are based on simple statistical regressions or hard-coded decision rules, although machine-learning techniques are starting to come onto the scene, increasing potential analytical power.[119]

The advantage of using digital technology to personalise learning and healthcare is that it helps address the problem of delivering a quality service at scale, but tailored to individual needs. It takes skill, training, and time for a doctor to develop a personalised treatment plan, or for a teacher to personally coach a student. In developing countries, there is often a scarcity of both competent providers and the funds to pay for them; this means that high-quality personal services are enjoyed only by the well off. But thanks to falling computing costs and developments in data analysis, algorithms can use students' test scores and patients' health records to design and implement personalised treatments at little cost. Once the technology has been configured to local needs and curricula, the marginal costs of delivering the service to more people are very low. Mindspark estimates that once it has been scaled up for use in around 1,000 schools, the per-pupil costs will fall to $2 annually, much less than the current $22 monthly per-pupil spending in Delhi's state schools.[120] In short, at scale it could dramatically reduce the learning gap at a fraction of the cost of current per-pupil spending in schools. While private tutors used to be the prerogative of the rich, a digital tutor that provides a personalised service may become more accessible for the poor. The scope of such personalised services, at least in the short term, is likely to be limited to basic functions. However, given the nature of problems in many developing countries, such services offer the prospect of progress in areas where there are currently serious gaps and for which resources for effective diagnosis are frequently missing.

The realisation of this vision will depend on developing tools that can offer personalised services for everyone (not just for select groups), and finding inclusive and effective delivery models. In education, personalised, adaptive learning tools work best when tailored to a local curriculum and local needs.[121]

In health, personalised diagnosis tools have sometimes run into difficulty in new hospitals and under different conditions, where data collection may be slightly altered from how it was originally implemented.[122] Further, algorithms' decisions will depend on the quality and representativeness of the data, touching on issues of data governance, ownership, and fundamental ethical challenges (which we explore further in Chapter 5). Finally, any implementation of these tools must recognise the constraints of the existing system to make sure frontline providers use these tools effectively. Many teachers are concerned that personalised adaptive learning tools will place additional burdens on them. This concern has reduced the effectiveness of recent attempts to scale these tools.[123] Ultimately, these advanced technologies will alter the roles of teachers and health workers.

4.4 Vision four: changing roles of teachers and health workers

Vision 4: Changing roles of workers

Service providers will perform fewer administrative tasks, and will focus on human-centred and specialised tasks.

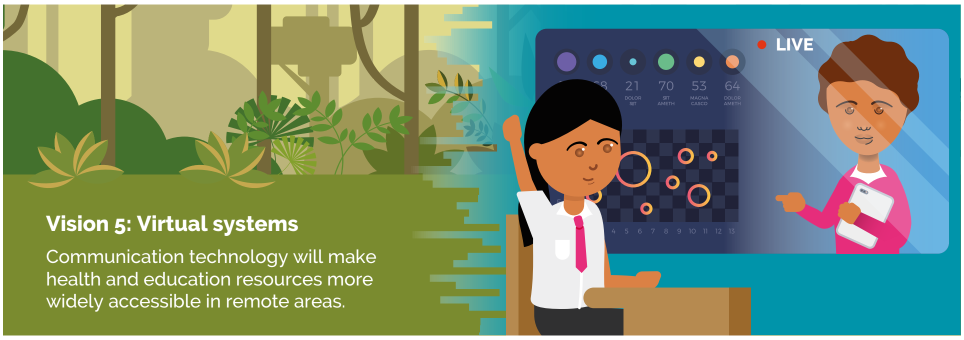
Emerging technologies mean that in the systems of the future, there may be substantial changes in how education and health workers will do their jobs and the tasks they will perform.[124] Digital technologies and machine learning will enable the simplification and automation of many routine tasks, such as data entry or regulatory compliance, relieving the considerable administrative burdens that can sometimes consume over half of the time of teaching and healthcare professionals.[125] However, the impact of new technologies on the roles of frontline workers will inevitably go beyond streamlined administration: we expect much deeper shifts in the nature of their work. For instance, as speech recognition and chatbots improve, they may automate more aspects of patient reception and triage, or a teacher's lesson plan could be scripted and digitally distributed.[126]

As fundamental tasks become more simplified and automated, the human touch and soft skills of frontline workers will become more central to their roles. The codification, automation, or augmentation of parts of frontline workers' roles will allow them to redirect their efforts towards more human-facing aspects of their jobs. Teachers will remain crucial to education and will continue to support students' learning, but where digital technologies put more sources of knowledge directly into the hands of pupils, teachers will have the capacity to build upon other core strengths. Staff may be more able to help students to understand which questions to ask, rather than to simply deliver answers or to rely on rote learning from a blackboard, and may then dedicate more of their efforts to developing students' socio-emotional and soft skills. In the health sphere, increases in automated triage or diagnosis will render the trust element of human tasks all the more important. For example, empathy and trust – which patients still envision as central to medical care – will be an increasingly important element of a doctor's role.

Increased use of digital technologies will also require frontline workers to develop new technical skills, while at the same time other core skills – such as judgement, initiative, problem-solving, creativity and innovation – will become more important. While socio-emotional skills will grow in importance, frontline workers will still require specialised skill sets to excel in their jobs. However, the necessary technical skills will likely come to include understanding and operating the new technologies; stepping in when a learning system (see Section 4.1) encounters an extreme outlier, or when a student fundamentally misunderstands a concept on an e-learning platform. In these cases, the human provider in the system must exercise a greater degree of initiative and judgement, understanding the technological system and knowing when to override or intervene. Automated protocols, machine-learning decision algorithms, and treatment protocols will ultimately still need to be supplemented with qualified staff to make decisions when something unexpected happens. This is not a model of total automation, but rather a model in which humans and machines work together, bringing complementary features that extend each other's impact. This is similar to how automation plays out across all sectors, from accounting offices to the factory floor: as technical or "process" tasks are automated, the balance shifts towards more people-facing tasks.[127] We even see this at the level of service delivery organisations, where digital technology is making it easier and cheaper to coach and train frontline providers.[128] Humans aided by machines can achieve more than either could do alone.[129]

Results will depend on how this change in roles and skills is handled. Even if there was broad support for the use of artificial intelligence in healthcare[130] or education, this does not mean that the transition will be smooth, or that the re-envisioning of the role of the frontline worker will be successful. Frontline providers need to be included in the process of change to ensure their buy-in: their trust will be crucial for a successful implementation of this vision. Technology will support the delivery of best practice, rather than replace the practitioner, and the human touch will remain essential for the best outcomes.[131]

4.5 Vision five: virtual systems – classrooms and clinics without walls



Advances in communication technology offer an unprecedented opportunity to bring down the walls of classrooms and clinics, providing quick and cost-effective expertise, even in remote areas that lack quality services. The model of teaching in a physical classroom to a group of children, or providing healthcare only using face-to-face contact, provided the only sensible model in an analogue world, but in the digital age, delivery of quality services no longer requires physical proximity. Improvements in communication technologies, which allow for much higher quality of images and sound, will change the relative costs of distance for effectiveness and efficiency of service delivery. For instance, a telehealth consultation is now almost as good as a face-to-face one, and this gap will only shrink as video-link or virtual-reality technology becomes better and cheaper.[132] Digital technologies will be able to change both the allocation and organisation of services, making it cheaper to get services to the poorest and most remote populations, and changing the skills and infrastructure needed for a frontline worker.

In the health sector, digital communication technologies will be able to ensure that expertise is not bound by location. Technologies such as videoconferencing, augmented reality, and remote control of equipment will bridge the gap in quality of expert services between poor and rich areas, so that experts from central areas can be involved in and engaged with the teaching or treatment being delivered elsewhere. For example, using an iPad and Proximie software, a specialist in Beirut conducted a remote surgery in Gaza.[133] Microsoft's HoloLens technology promises to help specialists intervene remotely through a virtual environment – as was the case in a trial connecting surgeons in India and England.[134] Of course, these examples still require the physical presence of a suitably trained person to perform the surgery or procedure, but the new technologies allow these frontline workers to tap into specialist knowledge, by collaborating with experts to deliver services that would have previously been impossible. The same model of connecting frontline workers to remote specialists is used in conducting teleophthalmology eye care camps in remote parts of India,[135] offering remote diagnosis in Honduras,[136] and helping primary care workers across 35 countries provide best-practice care to patients with complex health conditions.[137] Advances in telehealth are also allowing citizens to directly access specialist expertise, thus lowering financial and physical barriers.

Chipatala Cha Pa Foni in Malawi offers a call centre service for health advice, which has recently been scaled up to a national level. The service's trained staff members refer patients to health centres if required, but find that 75 percent of calls can be handled without referral.[138] Emerging evidence also suggests that remote or machine-based treatment can work as effectively as face-to-face interaction in situations in which one might expect in-person interaction to be crucial. For example, in mental health, studies have found remote treatment to be particularly effective. A pilot study in Brazil found treatment by video-link to be just as effective as face-to-face treatment for depressive symptoms.[139] In China, "My Trauma Recovery", an online self-help programme for post-traumatic stress disorder, has been shown to decrease PTSD (post-traumatic stress disorder) symptoms.[140]

In education, better communication technology already offers scope for high-quality education, even in the most remote areas. The sections above discussed how the role of the teacher will remain important despite the advance of personalised learning tools. While the experience of being in a shared classroom with a quality teacher may continue to convey benefits beyond those possible via remote learning, early experiences suggest that *online classrooms* provide lower-cost opportunities to reach especially remote populations with more effective educational services than has been the case to date. In Brazil, the Media Centre for education in the Amazonas (or *Centro de Mídias de Educação do Amazonas*) provides distance learning targeted at remote Amazonian communities, where the small number of pupils renders having specialised teachers for all subjects unaffordable. The centre broadcasts live lessons from teachers in the studio to hundreds of schools, while generalist tutors work in schools on the ground to provide support to students. In 2015, the Media Centre broadcast to 50,000 students across 6,000 communities, increasing progression to secondary school from 67% to 83% between 2007 and 2011, and reducing dropout rates by 50%.[141] Combining the remote lecturer with a locally based tutoring teacher (who saw the lecture materials prior to the lesson) meant that the lessons were well adapted to the local context – apparently a key factor in its success.[142] Plenty of mobile platforms, such as the well-known Khan Academy, provide lessons in a variety of subjects. While these generally have been of limited utility to poor families in remote locations because they require a child to have good-quality online connectivity, versions are being rolled out into less-connected areas via KA Lite, an open-source software that mimics the online experience of Khan Academy for offline scenarios.[143] Of course, the "supply" of quality offline material is only one part of the equation; students in remote communities also have to take up and use these tools. As we saw in Section 3.4, this is no small challenge, especially because such tools may be most effective with tutoring and parental support, making them less tailored to poor families.

Technology can fundamentally expand the level of access, even for the most remote and disconnected. Many of the examples provided above rely on relatively high-bandwidth internet connections. But other solutions are also emerging to ensure that education and health can be delivered beyond the four walls of a classroom or clinic. Multiple products are providing tutoring and learning services by SMS messaging, accessible to students without internet connections or smartphones.[144] Other tools, such as the BRCK Kio Kit or RACHEL-Pi load a cache of educational content onto micro-servers that can be deployed in schools or village centres. This can give students access to sophisticated digital content (such as lectures, books, problem sets, videos, and even data-intensive programmes) in the absence of a fixed internet connection. At the most basic level, the widespread adoption of communication technologies is making it easier and cheaper for citizens to connect to their service providers (eg physicians have even used WhatsApp to keep in touch with regular patients during a natural disaster, saving them from needing to visit the clinic, and keeping the clinic resources free for needier patients). Physical face-to-face interaction will still be important for many things, but in this future vision, we expect that geography will one day cease to be a barrier to high-quality service delivery.

Ahumuza Bruno, 8, is checked for pneumonia using a butterfly ultrasound scan - a probe connected to a mobile phone - in Kabale, Uganda. Photograph: ©Esther Ruth Mbabazi/New York Times, 2019

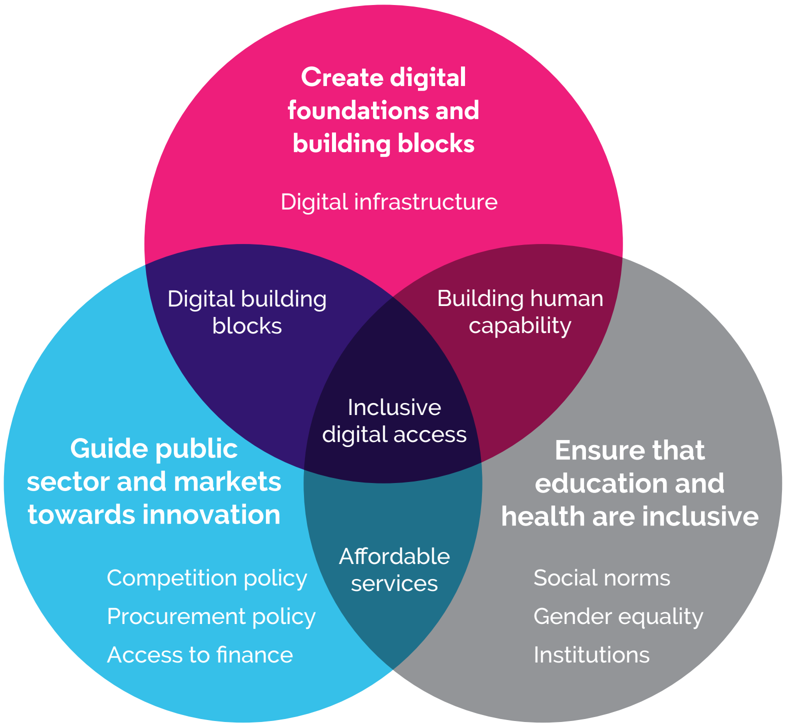
Chapter 5
Digital foundations and building blocks for data-driven systems

For digital solutions to work, countries should focus on getting the right foundations and building blocks in place. Digital technologies are not a panacea, but as outlined in Chapter 3, *once the core constraints have been identified,* they can help resolve issues and they can help power reimagined systems. This chapter presents digital foundations and digital building blocks as a framework for thinking about the requirements that must be in place to truly harness the potential of digital solutions. The foundations represent technical necessities (eg electricity), while the building blocks represent the required components to move towards the visions of the future we have outlined: data-driven systems that operate at scale. Health and education systems are full of innumerable small pilots that never move to large-scale impact; but with these building blocks in place, it will be possible to adaptively learn from experience, monitor interventions with consistent metrics, and set standardised procurement criteria. In short, these building blocks not only provide the technical framework for data-driven services, but they also provide the tools to support a systems approach and achieve better implementation at scale.

Looking beyond the foundations and building blocks discussed in this chapter, it is also important that countries have a broad ecosystem that supports innovation. Figure 4 below – adapting a framework from our previous report *Charting Pathways to Inclusive Growth* – describes the policy priorities necessary to ensure that technological change in health and education is effective and inclusive.[145] The rest of this chapter describes the scaffolding around which digital solutions can be built (the top set of Figure 4), but the actual process of building, testing, deploying, and scaling up new innovations requires more than this. A crucial priority for countries to benefit from technology is to ensure there is a broad environment that guides both the public sector and markets towards innovation – through access to finance, balanced regulation for entrepreneurship, and well-crafted competition and procurement policies. This is just as true for health and education as it is for other areas of innovation.

Proactive effort is also required to ensure inclusion for poor and vulnerable groups, girls and women, or other groups often excluded from technological change; digital foundations and an innovative environment alone will not guarantee inclusion. As we argued in Chapters 3 and 4, new technologies offer opportunities for more inclusion, but this will require proactive attention to ensure that progress is indeed inclusive. For example, to bridge gender gaps, the digital architectures of any technological solutions need to reflect gender considerations from the outset. In the rest of this chapter, these digital foundations and building blocks are developed further.

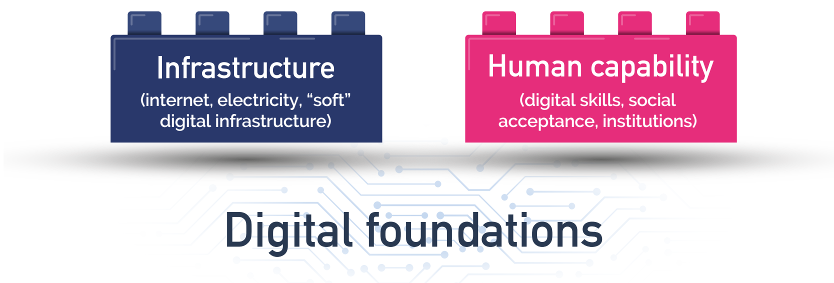
Figure 4. **A policy framework for health and education for all through digital technology**



5.1 Foundations for deploying digital solutions

A country must have digital foundations in place – in terms of both the infrastructure and the human capability – before considering digital solutions; anything otherwise would be a failure to properly apply a systems approach. Just as training for nurses will be less effective without a functioning drug supply, so too will an app-based solution be rendered less effective – or entirely ineffective – without a functioning electricity supply or the rights skills to use it. Two core elements are needed for even the most basic digital product to work: digital infrastructure and human capability.

Figure 5. **Basic foundations for digital services**



The visions for the future, and technological examples above all assume that a country has the ability to move, compute and process information at scale. This requires digital infrastructure. But available data across seven developing countries showed that only half the population has access to cellular internet coverage, and fewer than 15% of people use the internet at all.[146] In public systems, the situation is no better: in Malawi, only 2% of schools have computers.[147] New innovations, such as mobile systems that can work offline with periodic syncing to a database, are springing up to deal with this reality.[148] These new modes of operation may one day be able to completely substitute for "true" access, but at present there is a significant divide and distinction between online and offline services. In addition to "hard" infrastructure, it is also important to build "soft" digital infrastructure – data architectures and frameworks – to enable digital solutions.[149] Hard and soft infrastructure would lay the technical foundations for the digital interventions discussed in this report. Finally, digital technologies all require electricity – even the simplest, most stripped-back digital products function by pushing electrons around a circuit board. Any application will require stable and accessible energy generation, and, indeed, this is a crucial component of a digital-ready system.

Policymakers and organisations must also consider the human element: there must be a foundational level of digital skills, capabilities, and acceptance for these solutions to work. Not every person needs to be a coder or software engineer, but in order for digital solutions to work, people need basic digital literacy to operate them.[150] In many countries, only a small fraction of the adult population can perform basic digital tasks such as copying and pasting. (For instance, fewer than 5% of the people in Zimbabwe and Sudan have such skills, according to UNESCO analysis.).[151] This is important not just for providers and citizens; there needs to be governmental and institutional capacity for making use of technology, too. Centralised digital tools to improve management are ineffective without the right in-house expertise. However, innovations are lowering the barrier to entry, creating new ways for users to interact with digital services. Simple features such as a graphical interface to visualise management information, or automated data entry with a camera phone and OCR (optical character recognition), can lower the required level of technical expertise and expand the potential user base for a digital product.

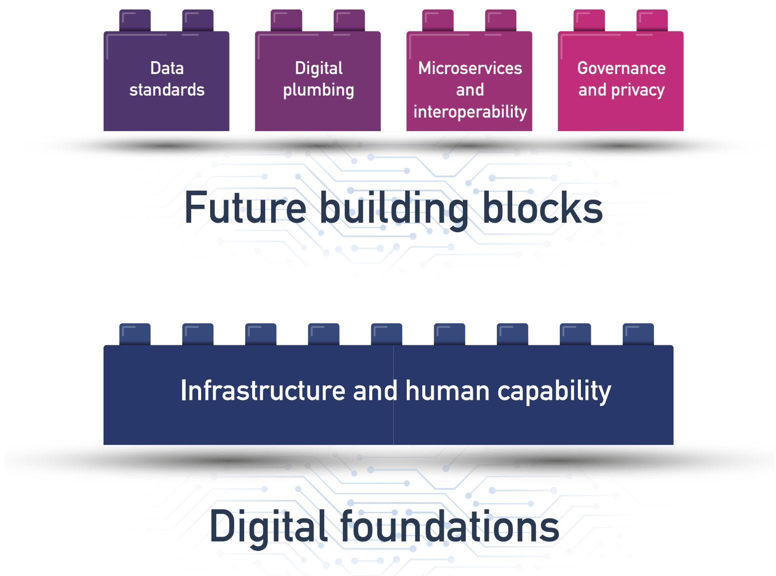
It is crucial that both digital infrastructure and digital skills are developed for all, not only for the well off.[152] Electricity and internet access are most scarce in remote areas, often where the poorest live, further restricting their access to services, from information to mobile banking. Existing business models for internet provision do not seem able to close this gap. It is not cost effective for network providers to reach rural and remote areas, and even where it may be technologically feasible, the pricing still excludes many potential users. And of course, the use of and familiarity with technology – as well as the English language proficiency that is often still required to operate it – is split along familiar lines of disadvantage. Marginalised people are the least likely to have access to technology, whether because of price or restrictive social norms and expectations. Again, some new innovations – such as building services to operate via SMS, rather than a smartphone app – can broaden the potential reach of technological solutions. Despite these promising advances, a significant barrier to broad digital solutions remains. These issues risk being exacerbated if the right skills for the jobs of the future are not taught to the pupils of today. The difficulty of building a foundation of basic digital skills and norms in a society should not be underestimated.

5.2 Building blocks for future digital systems

Data will be the fuel of future digital systems. The visions for the future presented in Chapter 4 all share one feature: the use of data and information as a tool to improve service delivery. They expand upon the current solutions presented previously in Chapters 2 and 3, harnessing data to redesign the architecture of a service delivery system. In this section, we discuss four building blocks (see Figure 6) required as initial steps towards achieving these visions for the future, moving from governance to technical specifications (eg data standards) and interoperability. Such building blocks provide the digital scaffolding around which new technological solutions can be deployed – and more importantly, *scaled up* – to improve health and education.

Many actors across society can contribute to these building blocks, as examples of input from NGOs, technology experts, governments, entrepreneurs and citizen volunteers demonstrate. Nevertheless, government will likely have to play a crucial role. Central leadership can play a pivotal role in setting a direction and encouraging other parties to contribute. For instance, establishing Aadhaar, the national digital ID system in India, sent the message that all Indians should be able to easily and simply access government social services. This sent a powerful message that made subsequent efforts to mobilise around education, health, and digitisation easier – largely because inclusivity had already become very much part of the design for the technology's intended use.[153]

Figure 6. **Building blocks for future health and education systems**



To begin with, system owners (and indeed, governments and society) should establish norms and rules around privacy, data protection, and data governance. Building blocks such as data standardisation, aggregation and system-level insights can bring great benefits, but policymakers and providers must remain aware of the highly sensitive nature of the data in question, such as a person's HIV diagnosis or educational history. Basic levels of anonymisation (eg encrypting a person's digital ID number) may not be sufficient. Data aggregation that makes all other information available, including metadata, may inadvertently reveal a person's identity. For example, it may be possible to identify a recipient of tuberculosis drugs based on geodata and timestamps. For this reason, policymakers and system owners will need to develop more sophisticated systems to protect citizens and give them control of their data.[154] Promising developments are underway: the Indian government, for example, is developing an electronic consent framework to let citizens easily authorise any use of their records,[155] and Google's recently released *TensorFlow Privacy* enables a machine-learning algorithm to be trained on privacy-sensitive data in such a way that no sensitive information can be inferred from the algorithm's resultant outputs and decisions.[156] It is worth noting that – even with these privacy, governance and citizen-control developments – the "future visions" presented in this report require an unprecedented centralisation of data about citizens. Various developed countries around the world have considered and rejected such ideas.[157] While the potential upside is large, so is the potential for abuse. Citizens can justifiably be cautious about such endeavours. The issue involves more than just privacy and data protection: policy is required to determine what decisions can be made by automated systems, and what safeguards will prevent errors and misuse.[158] Ultimately, policymakers will have to operate within the bounds of their social licence, weighing development benefits and societal risks.

Once the governance and social framework is agreed, data standards can help to ensure the *quality* and *relevance* of information – major factors in the extraction of valuable insights from large databases. People often speak about data as an amorphous product: a commodified input where more is inherently better. (Indeed, we are sometimes guilty of this in this very report). But data is not a uniform, infinitely interchangeable input: without a structure or a logic to its storage, it will have no value beyond the specific use for which it was collected.[159] Unfortunately, the stores of data across education and health systems are often unstructured (eg shorthand doctors notes). Without some sort of structure or consistency, using such data for machine learning and other advanced technologies is difficult, if not impossible.[160] Developing countries can, in theory, avoid these mistakes and deploy best-practice digital systems. However, there is little evidence that this is happening in practice. Currently, a proliferation of edtech apps and products is creating incompatible data silos, obscuring the visibility of system-level outcomes and effects. And while India's District Information System for Education does collect data on almost 1,000 educational indicators, it contains no measures of learning outcomes, highlighting the importance of collecting *useful* data.[161] In health, Botswana has nine different government-run e-health information systems. This may be useful for a hospital administrator with a unique management style, but it means that a given hospital's data will be irrelevant to the broader system. Even if the data could be pooled together, a significant challenge would remain in meaningfully translating diverse, inconsistent, and unstructured information into useful insights.

The biggest barrier to successfully developing digital standards is not low digital capacity, but rather a lack of coordination. It would be possible for governments, either individually or collectively, to determine standardised health and education data schemes suitable for a wide range of uses. Each product and service could adapt and build on these standards. By promulgating foundational data specifications, governments can encourage high-quality data collection and storage methods that are relevant, machine-readable, and consistent from one service to the next. If the data from each edtech app, or the data from each health clinic, had the same structure and meaning, it would enable the development of the sorts of future visions described in this report. Kenya's Clinical Information Network set-up offers a basic example. The network used a digital platform to collect basic standardised information about hospital functions, and to promote its use in decision-making.[162] Because the data standards and collection were consistent, this data then helped hospitals to negotiate better provision of essential supplies.[163]

Designing standards and establishing data requirements are crucially important for future visions, particularly for those involving machine learning. Machine learning algorithms can easily extrapolate bias in data: for instance, when biases around race or sex have influenced clinical decisions, an algorithm will perpetuate those past decisions.[164] Apart from being free from bias, datasets must also be broadly representative, particularly to ensure that any decisions or interventions reflect the needs of marginalised groups and women. An educational product designed on the basis of data about boys may entirely fail to help girls.[165] And, in some cases, data collection will require global coordination: genetic precision medicine tools have largely been developed using DNA from people of European descent, and the resultant tools are less accurate for people of African descent.[166] Finally, it matters for whom data is compiled and collated. Many databases of standardised metrics are compiled with little thought as to how the *data itself* can improve outcomes. Decisions about how to collect data and what data to collect are often made to meet the accounting and monitoring needs of donors and NGOs, whose needs do not always align with the those of policymakers, headmasters or clinicians. Indeed, education management information systems (EMIS) have been promoted for decades with little success, largely because they are often developed in silos, as side projects to track donor indicators (the few positive examples involve relatively radical design processes to ensure the tool is useful for the people and providers in the system).[167] Likewise, electronic health records (EHR), established to help optimise hospital financial management, generated considerable backlash from physicians because the records were not designed to support clinical tasks.[168] The end users should have input into and help to co-design the way – and for what purpose – data is collected, compiled and presented.[169]

Once data standards are set, "digital plumbing" must be built to aggregate and capture health and education data and to direct it to where it needs to go. Every time a person interacts with a digital service, many pieces of new information will be generated (even if it is just a record of each button press in an app), creating what is termed "digital exhaust". The first building block will help make this information standardised and consistent, but the data must still be aggregated and put to use for decision-making, feedback loops, and bottom-up accountability.[170] For example, in Kenya, schoolchildren's academic performance is often at levels more than two years lower than their grade would suggest. To address this, Tusome's package, which includes digitised teaching materials and a tablet-enabled teacher-feedback system, has been shown to boost learning performance. Findings suggest that, if used effectively at national scale, programmes such as Tusome can close the learning gap in early grades for under $150 per child.[171] But while the data could theoretically help understand broad determinants of learning outcomes, in practice, it is only used for monitoring the programme.[172] In India, the EkStep Foundation, the government, and the Global Innovation Fund, among others, are working to embed integrated data collection into new educational technology products procured via the government, creating shared digital infrastructure to aggregate across the system.[173] In health, there are solutions as simple and low tech as paper checklists for physicians. Developed by a Kenyan startup, these checklists are machine-readable: an image uploaded from any camera phone can be encoded into a clinical database.[174] This turns marks on a checklist, the by-product of a doctor's consultation, into a set of data points that a machine can interpret. Likewise, the careful data collection processes embedded in mTrac in Uganda, and in SMS for Life in Kenya and Tanzania, have delivered a positive impact on drug supply chain management and disease-burden monitoring in these countries.[175] Simple and automated digital plumbing can avoid such problems as those that arose in a maternal and child health-tracking scheme in Rajasthan and Uttar Pradesh, which relied on overburdened workers for data entry, resulting in many incomplete citizen profiles.[176]

Many of the future visions require the *connection* of digital products and services. To spur innovation, microservices, APIs (application programming interfaces), civic digital infrastructure, and other forms of interoperability will be crucial. Our first two digital building blocks describe the collection and central processing of standardised data. But the visions of future service delivery we outline in this report also require a broad ecosystem of information and microservices.[177] Basic fundamentals include the likes of citizen digital identification, digital payments, and messaging – three microservices that are crucial to facilitating many interactions. Many developing countries are at a comparative disadvantage in terms of the provision of basic digital microservices that can be used to power future digital services. For example, the tech community in East Africa is suffering from a lack of simple tools such as text recognition, address and location GIS (geographic information system) mapping, and natural language processing.[178] The global community is starting to respond, but it is still early days: as this report was going to print, the International Telecommunication Union (ITU) and the Digital Impact Alliance published a comprehensive digital investment framework, which sets out 23 microservices as priorities to mobilise governments, entrepreneurs, philanthropies and aid agencies.[179]

Beyond these basic tools, governments should be encouraging interoperability (the ability of computer systems and software to communicate, exchange, and make use of information) and building this capacity into their own systems.[180] For example, if a provider is offering remote tutoring, there should be a mechanism by which the student can authorise the provider's access to his or her learning record. If a health NGO is delivering treatment in a region, it should be able to tap into the latest insights and recommendations generated by the regional government's learning health system. These hypothetical examples are not trivial: they require the development of radical new interoperability frameworks and APIs at a technical level, and authorisation protocols to ensure that users can control who accesses their data. Countries such as Estonia and India seem to be leading the way in developing national-scale data structures with both interoperability and citizen control as core features.[181] Other locations could follow these examples if they put the right digital foundations, governance and relevant building blocks in place.

Twelve-year-old Lakshita uses Mindspark, an online education tool. Udaipur, Rajasthan, India. Photograph: Ishan Tankha, Pathways for Prosperity Commission, 2018.

Chapter 6
Conclusions

The evidence shows that there are many opportunities to transform health and education services in developing countries. Digital technologies offer scope not just to change and improve services at the point of delivery, but also to fundamentally rethink the inner workings of a system. As the current examples and future visions in this report demonstrate, there is scope not just to improve outcomes for people, but to deliver health and education outcomes more efficiently, likely at a lower cost, and with better ways to reach the poor and marginalised. Technology can contribute to systems at scale that are more effective, efficient, and equitable.

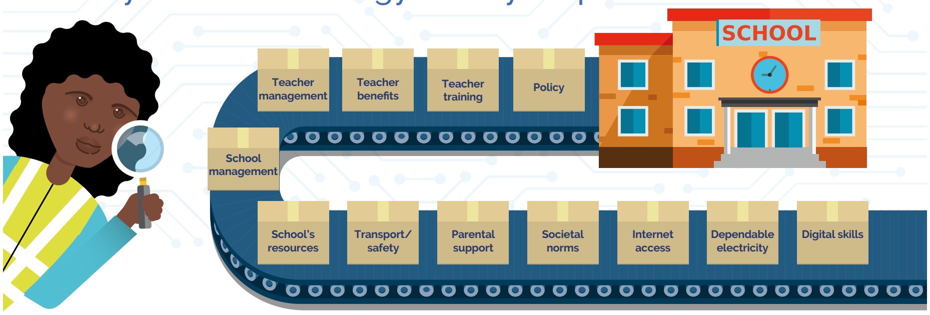
Successful outcomes via data-driven technologies are not guaranteed. However, uncertainty itself is not a reason to delay. Many of the examples in this report relate to recent attempts towards innovation whose success remains to be proven. Those with careful evaluations are typically no more than pilot studies, at a relatively small scale.[182] And, in most developing countries, the challenges of the existing health and education systems are extensive. However, this does not mean that trying to scale digital technologies is premature, or that introducing new solutions should be delayed until other problems are resolved. Success in adoption will depend on the people and culture of the system as a whole: the various actors, connections among these actors, organisational norms, and local and national political contexts. Nevertheless, we maintain that digital technologies, applied carefully, can offer ways to challenge the status quo. These might include, for example, using digital payrolls to stymie corruption, creating feedback systems to boost motivation and thereby tackle absenteeism, and implementing data systems to create incentives for more transparency in decision-making. Beginning such processes can also spur efforts to redesign systems in line with the visions described in Chapter 4.

The next step is to start using digital technologies to deliver at scale. This is a critical moment. If done poorly, this digital transition will entail high costs, exacerbate failings in existing systems, entrench inequalities, and serve as a distraction for policymakers. If done carefully, the use of digital technologies could be a force of positive disruption towards more effective, efficient and equitable systems. Below, we list four principles that can help everyone – citizens, workers, policymakers, funders and entrepreneurs – harness the opportunities of the digital age for better health and education, and avoid some of the previously experienced pitfalls of inappropriate adoption and poor implementation of technological innovations at scale.

Blueprint for health and education in a digital age

Four guiding principles

Principle 1.
Analyse: will technology solve your problem?

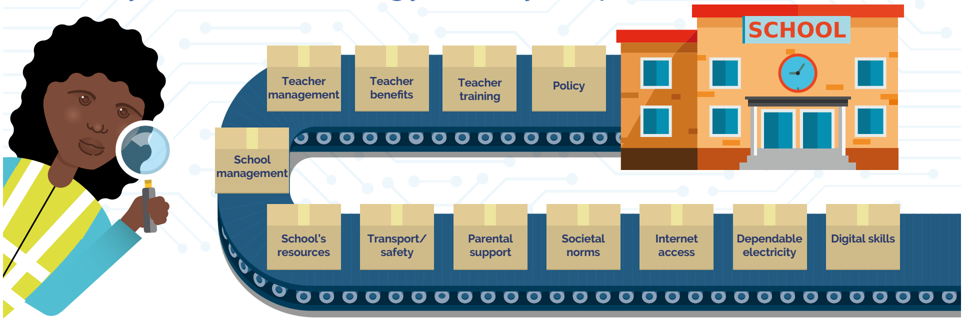


Principle 2.
Focus on content, data and connections, not hardware for its own sake

Principle 3.
Data is useful only with good digital foundations and building blocks

Principle 4.
Make deliberate efforts to build digital solutions that include everyone

Principle 1.
Analyse: will technology solve your problem?



1. **Deploy technology only when it offers an appropriate and cost-effective solution to an actual problem.** Policymakers and funders should invest time and effort in identifying the specific problems holding back their health and education systems. This needs to be followed by a clear-eyed judgement as to whether a technological solution is the best option. Precautionary principles may be wise, as when done wrong, technology can lead to unforeseen negative outcomes.

   Policymakers should evaluate potential gains from new technology with scepticism; consider improving existing approaches; evaluate their impact and cost, and assess potential solutions before committing to them at scale. System managers should be confident that an intervention will work in their local, regional, and national contexts. A new tool may deliver success inside a small NGO of skilled and committed staff, but it may never be implemented in the wider world, or fail to adapt to the local political or organisational culture, and hence fall flat upon national roll-out.

   Therefore, both a commitment to scale and ongoing monitoring and learning will be required. Digital and digitally enabled technologies offer significant potential to transform systems, but their proponents must be critical friends, not faithful adherents.

Principle 2.
Focus on content, data and connections, not hardware for its own sake

2. **Focus on the content, data sharing, and system-wide connections enabled by digital technology, not exclusively on hardware.** All too often, when policymakers look to deploy technological solutions to health and education, the focus is on procuring pieces of hardware. Of course, in the examples shown in this report, hardware was used – from mobile phones to advanced computers – but the real benefits come from using technology to create connections between people in the system (especially citizens), and flows of data. For these purposes, software and digital architecture are absolutely critical, but are often underrated by decision-makers, and are thus poorly procured. And, of course, content and connections determine *who* will use and benefit from new hardware.

   Digital solutions will only have impact if they are used by everyone - frontline workers, citizens, and officials. This means that people must have access to the right inclusive digital foundations (infrastructure and skills), and that software and digital components must be crafted to serve the end users. The design process should therefore include their input, and an appreciation and anticipation of their needs.

Principle 3.
Data is useful only with good digital foundations and building blocks

3. **Invest in digital building blocks, not just the bulk collection of raw data, in order to move towards the systems of the future.** Good data can inform decision-making, fuel active feedback loops in a learning system, and offer personalised services. Indeed, high-quality data will

have applications beyond its immediate use: it is a system-wide resource. Data generally works best at scale, demanding coordinated decision architectures. We suggest a strong focus on the building blocks for future digital architectures such as standardised metrics, system-wide "digital plumbing", microservices and APIs, rules of engagement, protections and safeguards. Having these building blocks in place will enable systems and system managers to get the most out of their data.

4. **Ensure the technology genuinely works for all by making deliberate, explicit efforts to engage with and build solutions for people who are typically left behind.** When conducting pilots, a focus on easy-to-reach groups, (such as the urban or middle-class population) could at times be defended, for example, to offer a proof of concept or collect evidence on possible impact. However, in general, this strategy has risks: the findings may be biased towards more privileged populations, or the proposed solutions may not realistically be accessible or affordable to the poor. If technology only confers benefits upon part of the population, it will exacerbate existing inequalities. Inclusiveness should therefore be a cornerstone of any deliberate design to strengthen health and education systems with technology, including explicit attempts to understand the specific wants, needs and priorities of marginalised communities. New technological solutions should be designed to scale to reach all citizens, not just those with higher incomes who enjoy a personal computer, English literacy, and high-speed internet access. Indeed, as we have seen, digital technology – when deployed well – can help bring down some barriers to inclusion, through measures as simple as an SMS reminder of a healthcare appointment, or a video series that challenges gender norms about education. Even for these interventions, however, a continued focus on broadening access to existing technologies, such as electricity and cellular coverage, is essential. If delivered well, the digital futures described in this report can bring hope for inclusion. A combination of data standards, digital IDs, and system-wide "digital plumbing" could help to identify and target those missing out, and monitoring and reporting systems are already helping citizens to hold providers accountable.

The time is ripe to plan for scale, to bring digital technologies into health and education systems. This report highlights the opportunities to use these technologies in new visions of data-driven service delivery systems in which teachers and health workers will be better supported; in which decision-making, management and feedback systems are vastly improved at all levels; and in which those currently underserved in classrooms and clinics can receive better, more personalised services. To achieve this, governments should create the required digital foundations and building blocks, guide the public and private sectors towards innovation, and ensure that health and ensure that health and education are inclusive. By deploying new tools, and by following the principles outlined in this report, developing countries can enhance the functioning of their health and education systems. They should critically monitor progress in terms of scale, impact and cost. If done carefully and judiciously, positive disruption is possible, and digital services will bring developing countries closer to offering better health and education for all.

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Endnotes

1 Fabian (2018). Unless otherwise specified, all $ figures are in US dollars.

2 Preliminary analysis by Angrist et al. (2019b) based on Piper et al. (2018a).

3 Muralidharan, Singh and Ganimian (2019).

4 Pathways for Prosperity Commission (2018a).

5 Pathways for Prosperity Commission (2018b).

6 Pathways for Prosperity Commission (2018a); Pathways for Prosperity Commission (2018b).

7 World Bank (2019b).

8 The World Bank's 2002 ICT Sector Strategy defines digital technologies as "hardware, software, networks, and media for collection, storage, processing, transmission, and presentation of information (voice, data, text, images)", and this definition remains relevant today (World Bank, 2002). In addition, this report mentions "digitally enabled technology", a term that refers to new digital technologies that enable existing devices to work better or more efficiently. Insulin pumps that are digitally connected offer a good example.

9 Note that the displayed "years of schooling" are the *expected* years of schooling, which describe how many years of school a two-year-old child today can expect to complete by age 18, based on current enrolment rates. See World Bank (2019c) for a detailed definition. The "years of learning" is a metric known as learning-adjusted years of schooling (LAYS), which takes into account the *quality* of the education by multiplying years of schooling with a factor that represents students' learning outcomes (Angrist et al., 2019a).

10 In both health and education, progress by orders of magnitude is needed to achieve the United Nations Sustainable Development Goals (United Nations, 2015), and metrics in the World Bank's Human Capital Index (World Bank, 2019c).

11 On average, sub-Saharan African children get 4.3 years of "learning-adjusted" years of schooling, compared to 11.3 years in North America.

12 Al-Samarrai, Cerdan-Infantes and Lehe (2019) offer a framework to examine how inefficiencies mean that returns to additional financial resources are lower in some countries than in others.

13 Data from World Bank (2019c). Learning-adjusted years of schooling (LAYS) is explained in Angrist et al (2019a).

14 The data displayed for child mortality was obtained from the World Development Indicators (World Bank, 2019d) ("health expenditure per capita, PPP"), and Gapminder (2019).

15 Greenwood (2014).

16 Afghanistan and Pakistan are the only two countries with wild poliovirus cases recorded since 2016 because some communities were hard to reach in remote and politically fragile areas (World Health Organization, 2019).

17 Callaway (2017).

18 Mansoor and Williams (2018).

19 Richmond (2000).

20 Mansoor and Williams (2018).

21 Muralidharan, Singh and Ganimian (2019).

22 Cristia et al. (2017); de Melo, Machado and Miranda (2014).

23 Aiyar, Dongre and Davis (2015). See also Greenhalgh et al. (2017) for a discussion of challenges to implementing technological solutions in service delivery systems, particularly pertaining to a lack of acknowledgement of the complexities of systems.

24 Bai et al. (2016).

25 Policymakers and funders are often different actors, and they are not always aligned. As with other relationships in a health or education system, better results generally surface when policymakers and donors work together coherently. Successful examples include Ethiopia's 2005 health strategy realignment (see Box 1). Today, the government of Gujarat is working with a group of donors and NGOs (including the Lawrence Ellison Foundation and the Central Square Foundation) to transform government education for 20 million children, rather than build new programmes in parallel.

26 Pritchett (2015).

27 Countries with high corruption do not just suffer from lost public funds: high levels of corruption can distort priorities across whole countries and systems, leading to fewer resources and less support for service delivery (International Monetary Fund, 2019).

28 *United Nations Inter-Agency Group for Child Mortality Estimation (2018).*

29 Ruducha et al. (2017).

30 World Health Organization (2018).

31 Kress, Su and Wang (2016).

32 Haley et al. (2019).

33 Assefa et al. (2018).

34 Ruducha et al. (2017).

35 Pathways for Prosperity Commission (2018a); Pathways for Prosperity Commission (2018b).

36 See Labrique et al. (2013) for a review of 12 different types of m-health applications, all aimed at increasing interconnections across different parts of the system. M-health uses mobile and wireless technologies to support the achievement of health objectives, usually through sending SMS information and reminders.

37 Indeed, digital technologies may not always be *cost saving*. In sectors that are heavily people-dependent, or where new technologies are particularly expensive, more spending may be required to deploy expensive technologies that improve outcomes. An OECD report on the fiscal sustainability of health systems (OECD, 2015) explores this issue.

38 See Omidyar Network (2019) for an accessible systems approach to achieving scale and impact with edtech solutions. See Greenhalgh et al. (2017) for an academic approach to predicting or evaluating the success of healthcare interventions.

39 Chaudhury et al. (2006). This study was based on unannounced visits to health facilities, with the intention of discovering what proportion of medical professionals what proportion of medical professionals was present in primary healthcare posts.

40 Ackers, Ioannou and Ackers-Johnson (2016).

41 Countries included were Kenya, Nigeria, Mozambique, Senegal, Tanzania, Togo and Uganda (Bold et al., 2018).

42 More studies on worker absenteeism can be found in work by Rogers and Vegas (2009), and Chaudhury et al. (2006), who also offer data for health workers.

43 For a review of public sector pay incentives, see Finan, Olken and Pande (2017). De Ree et al. (2017) found that a doubling of teachers' salaries in Indonesia had no effect on student outcomes two or even three years after the change. In case studies of health workers, Singh et al. (2015) found that financial incentives actually reduced worker motivation and performance in some circumstances.

44 Muralidharan et al. (2017).

45 See Duflo, Hanna and Ryan (2012). Another study in Pakistan digitised a monitoring system for polio vaccinators, and thereby greatly increased reporting accuracy (Andreoni et al., 2018).

46 Kisakye et al. (2016).

47 Banerjee, Duflo and Glennerster (2008) studied an initiative that temporarily decreased nurse absenteeism by collecting attendance data with a stamp machine.

48 Andrews, Pritchett, and Woolcock (2017).

49 International Commission on Financing Global Education Opportunity (2019).

50 An RCT showed that investing one dollar in improving motivation of teachers led to gains of seven dollars in teaching effort (World Bank, 2016).

51 DeRenzi et al. (2017).

52 For example, even though Zimbabwean health workers knew how to collect and send off stool samples for polio detection, and they thought the surveillance system useful, only one-third of them actually collected and sent samples and data, largely due to inadequate training on the use the reporting system (Makoni et al., 2017). See also Mutale et al. (2013).

53 Pritchett (2015).

54 World Bank (2018); Reboot (2013).

55 Early systems-strengthening programmes, such as the Tanzania Essential Health Interventions Project (TEHIP) administered health surveys to understand patient needs from 1993 to 2004. The data was visualised and used to support budgeting decisions, with apparent success in reducing mortality (International Development Research Centre, n.d.). Nevertheless, scaling such systems at reasonable cost proved difficult.

56 Fabian (2018).

57 Shanker (2012).

58 Kumar, Paton and Kirigia (2016).

59 Barau et al. (2014).

60 Centre for Education Innovations (2018).

61 See Seidman and Atun (2017) for a review of supply chain management, and centralised procurement processes. Furthermore, Pisa and McCurdy (2019) and Naughton (2018) examine the use of technology to trace and track global pharmaceutical supply chains.

62 SDSN TReNDS (2018).

63 World Bank (2019a).

64 Pritchett (2015); For further details on the performance of teachers in developing countries compared to developed countries, see also Bietenbeck, Piopiunik and Wiederhold (2018).

65 Global Innovation Exchange (2019).

66 National Portal of India (2019).

67 Perri-Moore et al. (2015) found that health workers gave parents more advice and information when they used e-IMCI compared to when they followed the same WHO treatment protocols in paper format. See also DeRenzi et al. (2008).

68 Bollinger, McKenzie-White and Gupta (2011).

69 Other providers are active in this space, too. For example, Edo State in Nigeria is working with Bridge Academies International as its delivery partner for EdoBEST (Edo Basic Education Sector Transformation), focusing on teacher professional development (Harley and Barasa, 2012).

70 Glasziou et al. (2017).

71 Fitzsimons et al. (2016).

72 Kyei-Nimakoh, Carolan-Olah and McCann (2017); Shaikh et al. (2018).

73 UNESCO (2010).

74 When people underestimate the value of education, providing basic information on the returns of education may increase demand for additional schooling (Jensen, 2010). Technology may facilitate this information sharing. For example, in Tanzania, Noa Ubongo teaches the value of education and employability skills through a free video-learning platform (MasterCard Foundation, 2017).

75 Yé et al. (2018). Another intervention in Vietnam sent awareness messages to both pregnant women and community health workers in their local language. This intervention was shown to increase demand for natal care and women's confidence in accessing that care (McBride et al., 2018).

76 Thomas, Lawani and James (2016).

77 For examples of behavioural economics in health, see University of Pennsylvania, Center for Health Incentives and Behavioral Economics (2019).

78 Banerjee, La Ferrara and Orozco (2018) study the use of an MTV soap opera to create behavioural change around HIV testing in Nigeria, while Jensen and Oster (2009) examine how simply being exposed to standard television media (in this case, the introduction of cable TV in areas of India) can challenge social norms, and improve the status of women.

79 Barboni et al. (2018).

80 Pathways for Prosperity Commission (2018b).

81 In parts of India, for example, an unmarried girl with a mobile phone may be associated with promiscuity, because digital activity could prevent a girl from being viewed as remaining "pure" for marriage (Barboni et al., 2018).

82 For more on this, see previous Pathways for Prosperity Commission work in our *Digital Lives* report, examining how digital technologies can exacerbate existing inequality (Pathways for Prosperity Commission, 2018b).

83 See Kruk et al. (2018) and the National Academies of Sciences (2018) for recent approaches to this in global health.

84 National Academy of Medicine (2019).

85 English et al. (2016) discuss the potential for this in health. In education, a nascent proposal from the Global Innovation Fund (with others) would create a "Science of Learning Library" to aggregate education data, analyse it, and turn it into pedagogical advice. The technical concepts behind these are discussed further in Chapter 5.

86 Naydenova (2016).

87 BLUESQUARE (2019).

88 Ghana Education Service, Ministry of Education (2019).

89 International Commission on Financing Global Education Opportunity (2019).

90 English et al. (2016).

91 PATH (2017).

92 International Commission on Financing Global Education Opportunity (2019).

93 World Health Organization and World Bank (2017).

94 For example, an integrated community case-management programme in Ethiopia and Malawi did not deliver the expected improvements in child mortality or care-seeking behaviours (Amouzou et al., 2016a, and Amouzou et al., 2016b).

95 This programme is implemented by Muso Health, an NGO, and the Malian Ministry of Health and Public Hygiene. Muso's proactive approach is a departure from common models in which community health workers wait for potential patients to contact them (Johnson et al., 2018).

96 Whidden et al. (2018).

97 DeRenzi et al. (2012) have more about this intervention to send SMS reminders to community health workers. How such reminders were sent mattered: if they did not include a threat of referral to a supervisor, the reminders had no impact, suggesting that local contextual factors will always matter for such feedback loops.

98 See Butterfly iQ (2019) for more information.

99 See Babylon (2019) for more information. It is too early to assess the intervention's effectiveness in addressing health care needs, but it seems to have potential, particularly when partnered with other tools (such as automated drug prescription and dispensing for low-risk and simple conditions). Another related example is Ping An Good Doctor, an application whose founders report 265 million registered users in China (Ping An Healthcare and Technology Company Limited, 2019).

100 Al-Samarrai et al. (2017).

101 Of course, there are risks with making digital ID the only way to access a service; it can end up excluding those who are not enrolled in the ID system.

102 See Masiero (2019) for a discussion of how the Aadhaar digital ID system is changing Indian service delivery systems (in this case, social protection payments). Misra (2019) gives a general background on the Aadhaar programme.

103 UNESCO (2015).

104 Kyei-Nimakoh Carolan-Olah and McCann (2017); Shaikh et al. (2018); Finlayson and Downe (2013).

105 Roser (2019); World Health Organisation, UNICEF, UNFPA, World Bank Group, and the United Nations Population Division (2015).

106 UNESCO (2010).

107 Kabeer (2010).

108 Sondaal et al. (2016).

109 MasterCard Foundation (2017).

110 Social Innovation in Health Initiative (2019a).

111 Pitchford, Chigeda and Hubber (under review).

112 Pathways for Prosperity Commission (2018b).

113 Peters and Norton (2018); Peters et al. (2016); Criado-Perez (2019).

114 Muralidharan, Singh and Ganimian (2019).

115 Onebillion's solution is generally named onecourse, but was also called the "Unlocking Talent through Technology" project for the purpose of the XPrize competition (Onebillion, 2019).

116 Over an eight-week period, students in the tablet-based maths teaching group gained numeracy skills at more than double the rate of both those in the non-tablet-based maths teaching group and those in a placebo group using tablets without maths teaching (Pitchford, 2015).

117 Pitchford, Chigeda and Hubber (under review).

118 Paton and Muinga (2018).

119 These include an adaptive learning tool developed by Carnegie Learning, similar to Mindspark or onebillion, but in which different statistical methods, including machine learning, are trialled, in order to understand students' competency levels (Fancsali et al. 2018). In health, potential opportunities for personalised medicine include tailored cancer care, and prescription decision support. IBM Watson for Oncology gives treatment recommendations based not just on recent tests, but also on the patient's previous medical record. However, evidence on the algorithm's accuracy is mixed, and it remains a work in progress (see Zhou et al. (2018) and Topol (2019a)). In the future, deep learning may be used to predict personalised drug response and optimise medication selection and dosing (Kalinin et al., 2018).

120 Muralidharan, Singh and Ganimian (2019).

121 Central Square Foundation (2018).

122 Zech et al. (2018); Tizhoosh and Pantanowitz (2018).

123 Pane (2017), Pane et al. (2017).

124 For health workers' changing roles, see Topol (2019b).

125 See Tuomi (2018) on automation of administrative tasks, and see Arndt et al. (2017) for a US study that found doctors spend more than half their time on patient records and reporting. In Australia, routine administrative tasks take up to 11 hours per week of teachers' home time, and 91% of teachers surveyed agreed that new administrative demands hindered teaching and learning (McGrath-Champ et al., 2018).

126 For instance, Tusome Early Grade Reading Activity in Kenya worked across 23,000 state schools to provide teachers with instructional materials and lesson plans, alongside coaching and tablet-based monitoring and feedback. Recent evaluations have found it to be quite successful (Piper et al., 2018a and 2018b; Republic of Kenya, 2017).

127 For a general overview of these trends, see Pathways for Prosperity Commission (2018a), and Banga and te Velde (2018) for a discussion of the skill needs of future workforces across all sectors.

128 Piper et al. (2018b).

129 See Liew (2018) and Saria, Butte and Sheikh (2018) for discussions on a future health workforce (specifically radiologists) augmented by machine-learning tools.

130 For one example study looking at public support for AI in healthcare, see PwC (2017). However, more research is needed to look at support within different sectors of the population.

131 The International Commission on Financing Global Education Opportunity (2019) provides some discussion of this, as does Topol's (2019a) review of the convergence of human practitioners and artificial intelligence. The review rules out "full automation" in future health systems.

132 A project at Facebook named Codec Avatars is using 3D image-capture rigs and machine-learning tools to generate realistic avatars that can communicate in a virtual reality space. Although still in its infancy, the project suggests that solutions for some challenges presented by digital communication may be solvable. See Rubin (2019) and Abrash (2019) for more on this.

133 East (2016).

134 In 2017, Microsoft HoloLens connected three surgeons in London and Mumbai for an operation in London. In a virtual space, they could see each other, discuss the patient's tumour, and offer judgements on treatments (NHS Barts Health, 2017).

135 John et al. (2012) used a teleophthalmology rig with a satellite link to allow a hospital specialist to consult and review scans of patients in remote settings in real time. More than 50,000 patients were treated this way over a 1.5-year-long study.

136 MosquitiaMed in Honduras lets health workers and residents in the remote La Mosquitia region connect to specialists in Tegucigalpa, the capital of Honduras (Social Innovation in Health Initiative, 2019b).

137 TeleECHO clinics use widely available teleconferencing technology to link specialists at 278 hubs with primary healthcare workers around the world. See Project ECHO (Extension for Community Healthcare Outcomes) (2019) for more.

138 Social Innovation in Health Initiative (2019a).

139 Hungerbuehler et al. (2016).

140 Xu et al. (2015).

141 Cruz et al. (2016).

142 For a discussion, see Trucano (2014).

143 A recent impact evaluation suggested that improvements occurred in the quality of students' learning (Manaus Consulting, 2016).

144 Examples of this include TextTETEA in Tanzania and Eneza Education in Kenya, Ghana and Cote d'Ivoire (Neumann and Wincewicz, 2016).

145 In *Charting Pathways for Inclusive Growth*, a similar representation for a policy framework for inclusive growth was offered, based on three pillars: guiding markets towards innovation, ensuring the gains are inclusive, and creating a digital-ready country. See Pathways for Prosperity Commission (2018a).

146 Pathways for Prosperity Commission (2018b).

147 Wallet (2015).

148 Examples of innovations that help bridge the access gap to technology, especially in education, are discussed in Kishore and Shah (2019).

149 Pathways for Prosperity Commission (2018a).

150 Pathways for Prosperity Commission (2018a).

151 Banga and te Velde (2018).

152 Pathways for Prosperity Commission (2018b).

153 Misra (2019); Gelb and Diofasi Metz (2018); National Institute for Transforming India (2018).

154 One alternative is personally held digital health records, which may be stored on people's mobile phones. However, this option would make data decentralised, and would require individual patients to manage their own data. Such a system may resolve privacy concerns, but would hinder the ability of a learning system to analyse data on individual patients centrally. These are the trade-offs that have to be balanced.

155 Government of India, Ministry of Electronics and Information Technology (n.d.).

156 See McMahan and Andrew. (2018) for a technical paper; or, for a blog post aimed at a more general audience, see TensorFlow (2019).

157 Gellman (2013). See Gellman (2013) for a discussion of biometric identification systems as data centralisation tools.

158 Errors in machine-learning tools – such as predictive assessment or automated resource allocation – can be particularly pernicious because they are not always easy to spot, particularly when the algorithm operates as a "black box" that simply produces a judgement from a complex mass of data. A broad literature is forming around these issues in healthcare. For example, Finlayson, Kohane and Beam (2018) describe how three different clinical diagnostic algorithms could be tricked by a malicious actor; Parikh, Obermeyer and Navathe (2019) and Arney et al. (2019) present a regulatory agenda and a research agenda, respectively, for the use of artificial intelligence in healthcare; and Froomkin, Kerr and Pineau (2019) consider the legal and ethical implications for doctors who work alongside machine-learning diagnostics.

159 Analysis of large data sets with techniques such as machine learning are – at the basic conceptual level – an attempt to find statistical patterns in the data. This can be quite effective if an algorithm is able to identify, for instance, the pattern in eye scans that point to retinal disease or diabetes (see De Fauw et al., 2018; Gulshan et al., 2016). But such an algorithm will not understand cause and consequence; it will not understand *why* the physical pattern is correlated with diabetes. Indeed, relying on statistical patterns can sometimes lead to wrong conclusions, for example where poor image quality leads to erroneous results (De Fauw et al., 2018). In such cases, the judgement of the clinician remains important.

160 Cvitkovic (2018).

161 See Pritchett (2018) for more information on problems with education dashboards, and District Information System for Education (2018) for additional information on its use in India. Further, Birdsall, Bruns and Madan (2016) propose five positive recommendations for data collection in education.

162 English et al. (2018).

163 Irimu et al. (2018).

164 See Saria, Butte and Sheikh (2018) for a discussion about machine learning in healthcare. In addition, Richardson, Schultz and Crawford (2019) explore this issue in a completely different field: policing and justice. Richardson and her co-authors examine how past police decisions that were racially fraught and sometimes unlawful led to "dirty data", and how unless the data is thoroughly audited and cleaned, these biases will be built into any future decisions made by a machine-learning agent. See also Hajian, Bonchi, and Castillo (2016) for further discussion of algorithmic biases.

165 Similarly, Peters and Norton (2018) and Peters et al. (2016) discuss how gender disaggregation is vital to understanding (and influencing) health outcomes. Criado-Perez (2019) presents a number of cases in which services were designed based on data about men, much to the detriment of women.

166 Bentley, Callier and Rotimi (2019); Gurdasani et al. (2015).

167 In Fiji, an effective EMIS was developed with strong political leadership, buy-in from school administrators, and the creation of tools that allowed both teachers and students to interact with the data (Abdul-Hamid, 2017).

168 Sinsky et al. (2016).

169 Principles for Digital Development (2019).

170 PATH (2017).

171 Preliminary analysis by Angrist et al. (2019b) based on Piper et al. (2018a).

172 Piper et al. (2015); Piper et al. (2018a); Piper et al. (2018b).

173 For example, Sunbird.org (2019).

174 Kleczka et al. (2018).

175 SDSN TReNDS (2018); Barrington et al. (2010); Githinji et al. (2014).

176 Gera et al. (2015).

177 "Microservices" refer to small functions (such as confirming a citizen's identity, transferring money, or identifying a location on a map) that can enhance another service. For example, an e-health firm that digitises old documents but does not want to employ machine-learning scientists to develop a text-recognition algorithm, instead purchases a microservice from Amazon to do this. See Pathways for Prosperity Commission (2018a) for more on this.

178 Cvitkovic (2018).

179 International Telecommunication Union (2019).

180 There are already some examples of designing interoperability into microservices and platforms. The EkStep Foundation approach relies on creating what has been termed a "societal platform" – that is, a shared digital infrastructure that government, civil society, and the private sector can all use to build apps and solutions (Societal Platform, 2019). Perhaps the furthest developed example of this work is the IndiaStack, which gives developers access to APIs for identity, consent, payment, and record-keeping microservices (IndiaStack, 2019).

181 For further discussion of data structures and citizen empowerment, see McGowan et al. (2018), Robert Bosch Centre for Cyber Physical Systems (2018) and National Institute for Transforming India (2018).

182 Many failures involving new technology are also poorly documented, making assessment difficult.

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