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Guidelines on Public-Private Partnerships in digital infrastructure: Diagnostics in healthcare (telemedicine) and other digital public services

Note by the Bureau*

Background

This document contains guidelines with policy options and recommendations for governments showcasing Public-Private Partnerships (PPPs) and infrastructure projects that exist as a result of digital transformation in three critical social sectors: healthcare, long-term care and education.

The document draws heavily on panel discussions at the sixth and seventh sessions of the Working Party on PPPs, at the sixth, seventh and eights editions of the UNECE International PPP Forum, and at the fifteenth, sixteenth and seventeenth sessions of the Committee on Innovation, Competitiveness and Public-Private Partnerships (CICPPP). It also contributes to the cross-cutting theme of the 70th session of the Economic Commission for Europe (ECE) on digital and green transformations for a sustainable development in the ECE region.

The document was prepared by an international drafting team led by Gabriele Pasquini and has been endorsed by the Bureau of the Working Party on Public-Private Partnerships with a recommendation for the Working Party to endorse it. The drafting team leader was supported by core contributors (in alphabetical order): Mark Halliday, Nasser Massoud and Tamara Sunbul. The document also benefited from comments by public sector experts in ECE member States.

The document is submitted to the Working Party for decision.

The Bureau is grateful to the drafting team experts (listed in Annex II) for their contribution.

*This document was scheduled for publication after the standard publication date due to consultations with interested parties and stakeholders.

I. Introduction

This guide provides public authorities with strategic guidance on leveraging Public-Private Partnerships (PPPs) to deliver digital public social services and infrastructure aligned with the Sustainable Development Goals (SDGs). In doing so, it also highlights existing PPP and infrastructure projects resulting from digital transformation. The guide's aim is to enhance service delivery and outcomes through PPP projects driven by digital innovation, ultimately contributing to the achievement of the SDGs.

While the guide focuses on healthcare, long-term care, and education, the recommendations presented can be applied to other social sectors. Notably, given the profound impact of recent digital advancements in healthcare – especially in telemedicine, this sector receives special emphasis throughout the guide.

Integrating digitalization into healthcare, long-term care, and education services is a forward-thinking strategy with transformative potential. Procuring these digital services through PPPs can leverage the strengths and resources of both the public and private sectors, enhancing service delivery and infrastructure throughout the PPP lifecycle while supporting SDG achievement. In an era of profound digital transformation, PPPs can drive innovation and sustainability in social services, creating more resilient, efficient, and inclusive infrastructure.

This guide serves as a roadmap for public authorities considering or managing PPP projects that integrate innovative digital technologies. Drawing on international best practices and lessons from digital transformation initiatives, it supports the cross-cutting theme of the70th session of the Economic Commission for Europe (ECE) in April 2023 dedicated to "digital and green transformations for sustainable development in the ECE region."[1]

This guide should be read in conjunction with other policy documents published by ECE on the PPPs for the SDGs approach since 2015,[2] and with the ECE Guidelines on improving the delivery of PPPs and infrastructure through digital transformations in support of the SDGs.[3]

A. Defining digital transformation

Digital transformation is a widely used term, interpreted in various ways. In this guide, it refers to the process of transitioning an organization or sector from an analogue approach to one that is driven by data and technology, enabling the delivering services, products and infrastructure in innovative and improved ways. Hence, this concept extends beyond the mere adoption of technology, as it is intrinsically linked to creating value and driving growth.[4]

In this context, digital transformation is considered synonymous with *digitalization*, which is the transformation of business and sector processes and operations through the adoption of digital technology, creating new opportunities and driving change. This contrasts with *digitization*, which simply involves converting information from a physical format to a digital one, such as scanning a paper document to create a digital file. This guide focuses on digitalization, the comprehensive transformation of processes through digital technology.

In the context of PPPs and infrastructure projects, "technology" can refer to several aspects:

(i) Technology projects which build infrastructure in an economy, such as PPP projects for communication, energy, transport, telemedicine, education and other digital infrastructure;

(ii) Technology or physical, digital assets which enhance existing infrastructure, such as management and monitoring systems or surveillance and security systems; or

(iii) Technology which assists, enables or enhances the processes used to deliver infrastructure projects, such as digital platforms used to identify, select and manage projects or to collect and manage stakeholder feedback.

[1] See E/ECE/1504.
[2] See Standards, Tools & Guides | UNECE.
[3] See ECE/CECI/WP/PPP/2024/3.
[4] See What "digital" really means | McKinsey.

This guide focuses on the first aspect.[5]

B. Public-Private Partnerships for the Sustainable Development Goals

PPPs for the SDGs refer to PPPs designed to implement the SDGs and thereby to be "fit for purpose".[6] They can be defined as an enhanced approach for PPPs that overcome some of the shortcomings associated with the traditional PPP model by leveraging the efficiencies, expertise, and innovation of the private sector while safeguarding public interests through balanced risk-sharing, transparency, and accountability.

To align with the SDGs, PPPs must meet five desirable outcomes, which prioritize "people" and "planet" in meeting public infrastructure and service needs. These outcomes are:

(i) Access and Equity;
(ii) Economic Effectiveness and Fiscal Sustainability;
(iii) Environmental Sustainability and Resilience;
(iv) Replicability; and
(v) Stakeholder Engagement

When implementing this model, particular attention needs to be paid to the rights of vulnerable people by adopting a human rights-based approach to PPPs and infrastructure, particularly by considering the specific needs and rights of marginalized communities. This ensures that the benefits of PPP projects are inclusive and accessible to everyone, regardless of socioeconomic status, location, or ability. Prioritizing a human rights-based approach and key SDG outcomes in a standardized assessment not only enhances the attractiveness of PPPs to lenders but also facilitates a swift evaluation of their capacity to meet stakeholder needs.

In this context, PPPs for the SDGs can play a pivotal role in leveraging digital transformations in PPP projects to drive sustainable development and advance progress toward the SDGs. To support the implementation of PPPs aligned with the SDGs, the "UNECE PPP and Infrastructure Evaluation and Rating System (PIERS)" offers a robust evaluation methodology to score projects against SDG outcomes.[7] PIERS employs both qualitative and quantitative methods, enabling swift and consistent assessment. It is designed to be adaptable, allowing for the prioritization of specific needs and transparent decision-making based on project-specific challenges.

C. Public-Private Partnerships projects resulting from digital transformation and the United Nations "Pact for the Future"

The UN Pact for the Future (the Pact), adopted on 22 September 2024, outlines an ambitious agenda to tackle the world's most urgent challenges, including environmental sustainability, social equity, and economic development, with a focus on achieving the SDGs by 2030. The Pact recognizes the potential impact of PPPs to this effort, leveraging private sector expertise, efficiency, and capital.[8]

The Pact highlights that digital and emerging technologies, including AI, play a significant role as enablers of sustainable development and offer huge potential for progress for the benefit of people and planet today and in the future.[9]

To realize this potential and manage the risks through enhanced international cooperation by promoting an inclusive, responsible and sustainable digital future, the Pact contains a "Global Digital Compact".[10] The goal of the Global Digital Compact is to create an inclusive, open, sustainable, fair, safe and secure digital future for all, achieving it through the following objectives:

(i) Close all digital divides and accelerate progress across the SDGs;

[5] The ECE Guidelines on PPPs and Digital Transformation (ECE/CECI/WP/PPP/2024/3) focus on the third aspect.
[6] See ECE Guiding Principles on PPPs for the SDGs (Guiding Principles), ECE/CECI/WP/2022/07.
[7] See PIERS methodology | UNECE. PIERS complements and puts in practice the ECE Guiding Principles on PPPs in support of the SDGs.
[8] See Pact for the Future, Action 29, paragraph 53(f).
[9] See Pact for the Future, Action 27, paragraph 51.
[10] See Pact for the Future, Annex I, p.37.

(ii) Expand inclusion in and benefits from the digital economy for all;
(iii) Foster an inclusive, open, safe and secure digital space that respects, protects and promote human rights;
(iv) Advance responsible, equitable and interoperable data governance approaches; and
(v) Enhance international governance of AI for the benefit of humanity.

The Global Digital Compact opens by stating:

> "Digital technologies are dramatically transforming our world. They offer immense potential benefits for the wellbeing and advancement of people and societies, and for our planet. They hold out the promise of accelerating the achievement of the SDGs.
>
> We can only achieve this through strengthened international cooperation that closes all digital divides between and within countries. We recognise the challenges that these divides pose for many countries, in particular developing countries which have pressing development needs and limited resources."

This guide responds to the calls to action in the Pact and its Global Digital by offering insights and recommendations for governments and policymakers to enhance the implementation of PPP and infrastructure projects through data and digital transformation, ultimately supporting the achievement of the SDGs and contribute to closing the digital divide.

It also supports the Global Digital Compact's request for digital cooperation and advancement of digital transformation by providing targeted insights and recommendations for governments and policymakers on how to harness digital transformation within PPPs to advance social infrastructure. The guidelines outlined in this document align closely with the objectives of the Global Digital Compact, emphasizing the critical role of digital infrastructure in closing digital divides, promoting inclusive and equitable access to digital services, and ensuring that the benefits of digital transformation are broadly shared across all segments of society.

In the context of PPPs, the Global Digital Compact's focus on fostering an open, safe, and secure digital environment is directly relevant to the design and implementation of digital public services. This guide highlights how the adoption of advanced digital tools and technologies within PPP frameworks can lead to more effective, efficient, and resilient social infrastructure projects. By leveraging private sector innovation and public sector oversight, these partnerships can deliver digital public services that are not only technologically advanced but also inclusive, transparent, and accountable.

Furthermore, the guide supports the Global Digital Compact's aim to enhance international governance by providing practical policy options for managing the risks associated with digital transformation. By addressing issues such as data governance, privacy, and security, the guidelines support digital infrastructure PPP projects aligned with global standards and best practices, ultimately contributing to the broader goals of sustainable development.

Integrating digital solutions into social infrastructure projects through PPPs can be instrumental in advancing the SDGs. For example, digital healthcare initiatives can enhance the quality of care, expand access to health services, and strengthen public health monitoring, directly contributing to SDG 3 (Good Health and Well-being), and SDG 4 (Quality Education) as demonstrated throughout this guide. But more generally, in terms of infrastructure, developing digital networks through PPPs fosters innovation and builds resilient infrastructure, which aligns with SDG 9 (Industry, Innovation, and Infrastructure). Additionally, digital technologies in healthcare, education, and long-term care support the creation of inclusive, safe, and sustainable cities, addressing SDG 11 (Sustainable Cities and Communities). These technologies also optimize resource use and improve waste management in social sectors, promoting responsible consumption and production, as targeted by SDG 12. PPPs also encourage collaboration between governments, the private sector, civil society, and international organizations, facilitating the sharing of knowledge, resources, and technologies, which is essential for achieving SDG 17 (Partnerships for the Goals).

D. Overview of the healthcare, long-term care and education sectors

Healthcare involves the provision of essential health services, including health promotion, preventive care, curative care, rehabilitative care, and palliative care. Effective delivery of healthcare leads to better health outcomes and aligns with the World Health Organization's (WHO) definition of health as "a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity."[11] The healthcare sector is at a pivotal juncture, with technology playing a central role in shaping its future. This guide examines transformative trends, emphasizing the integration of artificial intelligence (AI), cognizant of its opportunities and risks, the importance of PPPs, and the transition towards value-based care in a digitized era. These trends are vital for enhancing healthcare delivery, improving patient outcomes, and ensuring system sustainability. Value-based care focuses on patient outcomes rather than the volume of services, incentivizing providers to deliver effective treatments that prioritize long-term health and well-being.

Long-term care provides a broad range of personal, social, and medical support for individuals experiencing or at risk of significant loss of personal autonomy due to illness or other incapacity. As populations age, the demand for long-term care increases, necessitating efficient and effective solutions. Digital technologies, particularly those enhanced by AI, are transforming long-term care by improving efficiency, personalizing care, and enhancing the quality of life for both users and care providers. These advancements support an integrated health and social care system, providing timely access to information, proactive care delivery, and better resource utilization. Like healthcare, digital solutions in long-term care contribute to achieving the SDGs by promoting healthy aging, minimizing the impact of non-communicable diseases, and ensuring access to comprehensive care services.

The education sector is fundamental to sustainable development, economic well-being, social stability, and peace. Children and young adults who acquire basic skills such as reading, writing, and mathematical aptitude are more likely to achieve better lifetime outcomes. Digital transformation in education, accelerated by the global lockdown during the COVID-19 pandemic, plays a crucial role in achieving SDG 4, which aims for inclusive and equitable quality education for all. Digital solutions enhance access to educational resources, improve engagement, and prepare students for the digital world. By integrating technologies such as e-learning platforms, adaptive learning systems, and virtual labs, education systems worldwide are becoming more inclusive and effective, thereby supporting the broader goals of sustainable development.

Across healthcare, long-term care, and education, the PIERS methodology and capacity-building efforts can significantly enhance the effectiveness of PPPs in aligning with the SDGs. The following sections will examine each sector in turn, showcasing key trends and best practices. These examples will highlight how PIERS and capacity-building can further harness the potential of digital transformation and PPPs to improve service delivery and outcomes in each area.

II. The healthcare sector

Technology is at the forefront of healthcare innovation, addressing long-standing challenges and creating new opportunities for care delivery. Digital technologies are transforming healthcare by streamlining operations and enhancing clinical outcomes. These advancements lead to improved access, better disease management, increased efficiency, and superior clinical outcomes. Amid healthcare staff shortages and clinician burnout, digital innovations automate routine tasks, enhancing both the quality and efficiency of care.

PPPs can drive the adoption and standardization of these technologies by providing financing, expertise, and a regulatory framework. Private sector innovation can further introduce advanced security measures and interoperability standards, while public oversight ensures accessibility, benefits across the healthcare ecosystem, and proper patient data protection. To better guarantee inclusivity and effectiveness of the partnership, it is essential to involve all relevant parties in the planning and implementation phases. Continuous

[11] See Health and Well-Being (who.int).

dialogue between public authorities, technology providers, service professionals, and users, along with incorporating feedback, facilitates multi-sectoral and international collaborations.

Innovations in the highly regulated sector of healthcare undergo rigorous scrutiny before they can be deployed. This is due to the direct impact these technologies have on patients' health outcomes. Hence, innovations must navigate a complex landscape of regulatory approvals. For instance, in many countries, AI-based clinical decision support tools – that is AI tools assisting healthcare professionals in making clinical decisions, must often receive medical device approval, demonstrating not only their safety and privacy compliance but also their clinical efficacy. Unlike mainstream tech products, healthcare innovations must undergo clinical trials to validate their effectiveness and safety. These trials guarantee the technology improves patient outcomes without introducing unintended harm, adhering to the principle of "do no harm" in medicine. Stakeholders can facilitate the responsible and effective integration of AI in healthcare. Hence, while innovation thrives, it does so with a foundational commitment to enhancing patient care, safety, and privacy. Promoting knowledge sharing and collaboration is, in this regard, essential to accelerating the adoption of digital technologies.

By involving all stakeholders, supporting transparency and accountability, promoting knowledge sharing, incentivizing private sector involvement, and building capacity for effective implementation, the healthcare sector can achieve substantial improvements in care delivery and patient outcomes. The case studies highlighted in this section support this analysis, demonstrating the significant potential of PPPs in leveraging technology to improve healthcare delivery.

A. Digital health records and health information exchange systems

The implementation of digital health records and health information exchange systems is foundational to transforming healthcare delivery. These technologies facilitate seamless access to patient information, so that healthcare providers have the most up-to-date and comprehensive data. Whether centralized or decentralized, these systems enhance the integrity and security of health data, reducing the risk of errors and enhancing patient safety. Moreover, health information exchange systems enable the efficient sharing of patient information among different healthcare providers, regardless of location. This interoperability is paramount for integrated care models, in which all members of a patient's care team, including specialists and primary care providers, have access to the same information.

Digital health records and information exchange systems also support public health efforts by providing aggregated data for research and analysis, helping to identify trends, track disease outbreaks, and inform policy decisions. By improving the accuracy and accessibility of health information, PPPs projects in digital health records and health information exchange systems can play a pivotal role in advancing the quality of healthcare delivery and patient outcomes. The case study of Estonia's electronic health record system below showcases how digital health records can significantly improve healthcare efficiency and patient outcomes.

Case Study 1 – Estonia, Electronic Health Record[12]

Estonia's digital healthcare transformation has been driven by collaboration between the government and technology providers, following a PPP model. This approach combines public oversight with private sector innovation to develop, implement, and manage its national EHR and e-Health systems. Estonia's e-Health Record system integrates data from various healthcare providers, enabling patients and doctors to access medical histories, prescriptions, and test results online, contributing to more efficient and accessible healthcare.

This initiative has significantly improved the efficiency of healthcare delivery, patient safety, and data security. According to the Estonian e-Health Foundation, the system has led to a 30 percent reduction in duplicate testing, saving time and resources.

[12] See Estonian e-Health Records (e-estonia.com).

To ensure alignment with the SDGs and a human rights-based approach, the implementation of digital health records and health information exchange systems in PPP projects must be underpinned by robust data governance frameworks. These frameworks should be designed to facilitate the secure and ethical management of patient data, protecting privacy while enabling the seamless exchange of information across healthcare providers. This is critical in maintaining patient trust and contributing to the success of digital health initiatives in social infrastructure projects.

B. Telemedicine and remote monitoring

The significance of telemedicine and remote monitoring surged during the COVID-19 pandemic, underscoring their crucial role in maintaining continuity of care remotely. The rapid shift to virtual consultations became the norm, breaking down long-standing barriers to adoption and accelerating the integration of digital health solutions into mainstream care. For example, virtual consultations enabled patients with chronic conditions to receive ongoing care without risking exposure, while wearable devices allowed doctors to monitor vital signs in real-time from a distance. The pandemic also revolutionized remote medical education, which, prior to the crisis, represented only a small fraction of global training. During the pandemic, nearly all medical education shifted online, and this approach has since become a primary mode of education delivery.[13]

Telemedicine and remote monitoring technologies are essential for extending healthcare services to rural and underserved areas, reducing the need for physical travel, enabling real-time health monitoring, promoting early detection and intervention for chronic diseases, decreasing hospital readmissions, reducing the burden on healthcare facilities, and minimizing the risk of infection spread. These technologies bridge healthcare access gaps, improve outcomes for underserved communities, and reduce geographical barriers..

This mode of health service delivery is intended to be supplementary to the classic in-person mode and, consistent with the clinical needs of the patient, may be used within regional health services throughout the care pathway, with particular attention to chronic patients. By leveraging telemedicine in PPP projects, healthcare providers can ensure timely and effective care, improving health outcomes and resource utilization. The case studies below highlight the practical relevance of telemedicine and tele-mentoring in PPP projects for the SDGs in Italy and the United States.

Case Study 2 – Italy, National Telemedicine Platform[14]

Italy, through the National Agency for Regional Healthcare Services (AGENAS), is developing the National Telemedicine Platform to ensure equitable and uniform telemedicine services across the country. This initiative is part of Mission 6 Component 1 “Health” of the Italian National Plan for Recovery and Resilience.

The Platform governs and monitors telemedicine services, enabling national harmonization of coding and terminology standards, process implementation and management, monitoring of implementation, measurement of benefits and results, and validation of solutions based on technical, organizational, and functional standards. This mode of health service delivery aims to be supplementary to the classic in-person mode and, consistent with the clinical needs of the patient, may be used within regional health services throughout the care pathway, with particular attention to chronic patients.

[13] See eg. Medical Education During the COVID-19 Pandemic | Request PDF (researchgate.net).
[14] See Agenas - Agenzia Nazionale per i servizi sanitari Regionali - AGENAS.

Case Study 3 – United States, Project ECHO (Extension for Community Healthcare Outcomes)[15]

Project ECHO is an innovative telemedicine model that began in New Mexico, to improve care for patients with liver viruses in rural areas. Through tele-mentoring, it connects primary care physicians with specialists in real-time, enhancing access to speciality care. Evaluations of Project ECHO have shown it significantly improves patient outcomes and expands the capacity of the healthcare system to treat complex conditions.

This PPP model uses telemedicine to connect primary care doctors with specialists in regular virtual clinics. Originating in New Mexico, ECHO has expanded globally, demonstrating how digital platforms can scale specialist knowledge, improve care quality, and enhance primary care providers' capabilities in managing complex conditions.

C. Artificial Intelligence

Using machine learning to improve healthcare delivery

Machine learning is revolutionizing radiology and pathology by improving the accuracy of diagnoses and enabling the early detection of diseases. These technologies can analyze medical images and pathology slides with high precision, assisting healthcare professionals in making informed decisions.

Machine learning applications in radiology and pathology exemplify how technology can elevate diagnostic accuracy and efficiency. By analysing medical images with “superhuman” precision, AI supports radiologists and pathologists in detecting abnormalities earlier and with greater accuracy. This leads to improved treatment outcomes, as diseases can be identified and treated at an earlier stage. Furthermore, machine learning can streamline workflow processes, allowing healthcare professionals to focus on complex cases and patient care. It is therefore becoming an indispensable tool in radiology, acting as an ever-vigilant assistant that enhances clinical decision support and workflow efficiency. It aids in diagnosing and reducing errors while streamlining prioritization processes.

Using Generative AI to create new solutions

Generative AI, a subset of AI, is also at the forefront of transforming healthcare through predictive analytics, personalized medicine, and automated clinical decision support systems. Generative AI can process vast amounts of data to identify patterns, predict outcomes, and provide insights that were previously unattainable. Generative AI is particularly groundbreaking, with the capability to create novel data instances, simulate patient responses to treatments, and generate realistic medical imaging for training and diagnostic purposes. These technologies can enhance diagnostic accuracy, optimize treatment plans, and facilitate the development of new drugs and therapies.

Generative AI applications in healthcare, such as diagnostic support and predictive analytics, can significantly enhance decision-making and patient care. These technologies enable accurate diagnoses and personalized treatment plans, contributing to a more sustainable healthcare system by reducing waste and predicting public health trends. Generative AI in healthcare is a game-changer, offering capabilities ranging from diagnostic assistance to predictive analytics for patient management. The collaboration between Google’s DeepMind and the NHS in the UK showcased below demonstrates how AI-driven solutions can enhance disease detection and healthcare delivery.

[15] See Project ECHO: Extension for Community Healthcare Outcomes | Digital Healthcare Research (ahrq.gov).

Case Study 4 – United Kingdom, Google and NHS[16]

The collaboration between Google's DeepMind and the UK's NHS on improving eye disease detection through AI technology exemplifies successful PPPs in healthcare. This project used AI to analyze eye scans for conditions like diabetic retinopathy and age-related macular degeneration, traditionally diagnosed by specialists. By leveraging DeepMind's AI to interpret optical coherence tomography (OCT) scans, the partnership aimed to enhance diagnostic speed and accuracy.

Trained on a vast dataset of de-identified OCT scans from Moorfields Eye Hospital, the AI system matched the accuracy of leading experts in identifying eye diseases. This collaboration improved diagnostic efficiency, relieved specialists through automation, and demonstrated the potential for scaling AI solutions across the healthcare system. This case study underscores the transformative potential of PPPs in leveraging technology to address healthcare challenges.

Importantly, as healthcare innovations, particularly in machine learning and generative AI, continue to evolve, there is a pressing need for public authorities to develop adaptive regulatory frameworks. These frameworks should be flexible enough to accommodate rapid technological advancements while maintaining rigorous standards for safety, efficacy, and data privacy. Collaborative regulatory pathways involving continuous dialogue between innovators, regulators, and patient advocacy groups can ensure that new technologies improve patient outcomes without introducing unintended risks.

D. Other digital technologies in healthcare

Robotic Process Automation (RPA)

RPA transforms healthcare operations by automating routine, time-consuming tasks such as patient scheduling, billing, and data entry. This automation frees healthcare staff to focus on more critical aspects of patient care and decision-making. By reducing administrative burdens, RPA contributes to lowering the risk of burnout among healthcare professionals and improves the overall efficiency of healthcare services. RPA augments healthcare workforce capabilities, allowing professionals to focus on complex care needs and improving patient outcomes. In healthcare, it automates repetitive, rule-based tasks, such as patient scheduling, billing, and claims processing, freeing up healthcare professionals to focus on patient care. As exemplified by case study 5, San Raffaele Hospital's use of robotic process automation highlights how automation can streamline administrative tasks and improve patient satisfaction.

Case Study 5 – Italy, San Raffaele Hospital, Milan[17]

San Raffaele Hospital in Milan has implemented RPA to streamline administrative processes, such as appointment scheduling and patient data management. This has led to a 60 percent reduction in processing times and a significant improvement in patient satisfaction, showcasing how automation can free healthcare professionals to focus on patient care. This encompasses telemedicine and remote patient monitoring technologies, which have been crucial, especially during the COVID-19 pandemic, in delivering healthcare services to remote areas.

Internet of Things sensors, and blockchain technology in sustainable resource management

Digital technologies play an important role in sustainable resource management within healthcare facilities. Systems that monitor and analyse energy use, waste production, and resource allocation help hospitals reduce their environmental footprint while ensuring optimal patient care. This approach not only supports environmental sustainability but also

[16] See Google DeepMind - Moorfields Eye Hospital.

[17] See eg. Robotic surgery in urology: a review from the beginning to the single-site - De Marchi - AME Medical Journal (amegroups.org).

translates into cost savings and improved operational efficiency. A report by the WHO highlighted the potential for smart technologies to optimize supply chains and reduce healthcare costs, contributing to the sustainability of health systems globally.

Internet of Things (IoT) sensors enhance access to healthcare for rural populations, early detection and intervention for chronic disease patients, and a decrease in hospital readmissions. This demonstrates how technology can bridge healthcare access gaps and improve outcomes for underserved communities.

Blockchain technology can play a crucial role in combating counterfeit drugs and improving supply chain efficiency in the healthcare sector. By creating an immutable and transparent digital ledger, blockchain enables every transaction and movement of a drug within the supply chain to be recorded and verified in real-time. This traceability ensures that each product can be tracked from the manufacturer to the end consumer, making it exceedingly difficult for counterfeit drugs to enter the supply chain undetected. Moreover, blockchain provides a single source of truth for all stakeholders, including manufacturers, distributors, pharmacies, and regulatory bodies. This shared, tamper-proof record aims to increase the accuracy and reliability of supply chain data, reducing errors and discrepancies that can lead to inefficiencies or safety risks. For example, in the case of recalls or quality issues, blockchain allows for the rapid identification and removal of affected products, thereby protecting patients from harmful counterfeit medications and ensuring that only safe, authentic drugs reach consumers.

However, while blockchain offers these significant benefits, it is important to acknowledge that implementing blockchain at a very large scale can be resource intensive. The technology's need for constant recalculation and consensus across the network to maintain the integrity of the ledger can require substantial computational power and energy, which could pose challenges as the system scales. Despite these challenges, the advantages of blockchain in reducing counterfeits and improving supply chain transparency make it a promising tool in the ongoing effort to enhance patient safety and trust in the healthcare ecosystem. Estonia’s blockchain-based health records system illustrates the role of blockchain in securing patient data and improving healthcare trust.

Case Study 6 – Estonia, Blockchain Technology Health Records System[18]

Estonia has implemented a blockchain-based system to secure patient health records across the country. This initiative is part of a broader digital transformation in Estonia's public sector. The Estonian government entered in a PPP and partnered with Guardtime, a company specializing in blockchain technology, to develop and implement this system. The use of blockchain has enhanced the security and integrity of health data, improved patient trust, and streamlined access to health information for both patients and healthcare providers.

Robotic innovation

Innovations such as pharmaceutical and surgical robots offer transformative benefits to healthcare systems, improving patient care, safety, and operational efficiency. Surgical robots enable minimally invasive procedures with greater precision and control, leading to shorter recovery times, reduced hospital stays, and better surgical outcomes. On the pharmaceutical side, robots streamline the medication dispensing process, significantly reducing errors, ensuring accurate medication management, and freeing pharmacists to focus more on patient consultation and care. Together, these robotic innovations represent a leap forward in healthcare technology, promising a future where medical treatments are safer, more efficient, and increasingly patient-centred enhancing healthcare efficiency and sustainability. In the US, the Veterans Health Administration’s partnership with Intuitive Surgical exemplifies the benefits of robotic-assisted surgeries in enhancing patient outcomes and reducing recovery times.

[18] See Blockchain and healthcare: the Estonian experience - e-Estonia.

Case Study 7 – United States, Veterans Health Administration[19]

The Veterans Health Administration (VHA), the largest integrated healthcare system in the United States, partnered with Intuitive Surgical, the maker of the Da Vinci Surgical System, to introduce robotic-assisted surgery across its hospitals. This PPP aimed to improve surgical care for veterans by incorporating advanced robotic technology into various surgical specialties, despite challenges like substantial investment in equipment and training. The partnership focused on deploying the Da Vinci Surgical System in VHA hospitals, providing comprehensive training for surgical teams, and conducting joint research to optimize outcomes. Intuitive Surgical supplied the robotic systems and training, while the VHA provided the clinical environment and patient population for implementation and study. This collaboration led to more precise and less invasive surgeries, better patient outcomes, shorter hospital stays, quicker recoveries, and expanded access to robotic surgery.

Mobile health applications: Empowering patients

Mobile health applications empower patients by putting health management tools directly in their hands. These applications can track vital signs, medication adherence, and even provide virtual coaching for lifestyle changes. These applications promote self-management of chronic conditions, improve health literacy, and foster a proactive approach to health and wellness. They empower individuals to manage their health, promoting preventive care and facilitating chronic condition self-management. Rwanda's partnership with Babyl highlights how mobile health applications can improve healthcare access and empower patients in managing their health.

Case Study 8 – Rwanda, Babyl - a Mobile Health Application for Comprehensive Healthcare Access[20]

In Rwanda, a partnership between the Rwandan Ministry of Health and Babyl, a digital healthcare provider, exemplifies a successful PPP. Babyl Rwanda uses mobile health technology to improve healthcare access and patient empowerment. Through a mobile app, patients can register, book appointments, receive prescriptions, and access medical advice remotely. This service, supported by the government, integrates with the national healthcare system. Babyl significantly enhances healthcare access, particularly in remote areas, fostering preventive care and reducing hospital admissions by empowering patients in their health management.

Digital therapeutics and gene editing

Digital therapeutics offer personalized treatment options through software programs that can treat a range of conditions. Gene editing technologies like CRISPR, a genetic engineering technique by which the genomes of living organisms may be modified, represent a groundbreaking approach to disease treatment and prevention, enabling precise modifications to DNA to correct genetic disorders. The development and application of digital therapeutics and gene editing require significant investment in research and development, as well as ethical and regulatory considerations. The collaboration between Vertex Pharmaceuticals and CRISPR Therapeutics showcased in case study 10 demonstrates the potential of gene editing to revolutionize treatment for genetic diseases.

[19] See Da Vinci Robot Technology Comes To Hines | VA Hines Health Care | Veterans Affairs.
[20] See Babyl – Rwanda's Digital Healthcare Provider.

Case Study 9 – United Kingdom, Gene-Edited Therapy[21]

A landmark PPP between Vertex Pharmaceuticals and CRISPR Therapeutics, in collaboration with academic medical centres and public health agencies, pioneered CRISPR-Cas9 gene-editing to develop CTX001, a potential cure for sickle cell disease (SCD) and beta-thalassemia. These disorders cause severe pain, organ damage, and shortened lifespans. The therapy edits a patient's stem cells to produce fetal haemoglobin, alleviating symptoms.

The collaboration involved biotech firms for development, public health agencies for regulatory guidance, and medical institutions for patient recruitment and study execution. Early trials showed promising results, with significant symptom reduction and improved quality of life. The partnership developed educational programs and ethical frameworks for gene editing. This PPP serves as a model for addressing genetic diseases, demonstrating how collaboration can accelerate gene therapy development and deployment.

Digital platforms that facilitate collaboration among healthcare stakeholders

These platforms are transforming the healthcare landscape by enabling more efficient, patient-centred, and collaborative care. This collaborative approach ensures that the platforms are not only technologically advanced but also aligned with healthcare policies and standards, making them more effective in addressing the needs of the healthcare community.

PPPs can drive the integration of these platforms with existing healthcare systems and digital health records, enhancing interoperability and the seamless exchange of information. Through such partnerships, digital collaboration platforms can be designed to be inclusive, catering to the diverse needs of patients, healthcare providers, and other stakeholders, thus democratizing access to healthcare information and services. The NHS COVID-19 app shows how digital innovation can swiftly respond to public health crises through effective public-private collaboration.

Case Study 10 – United Kingdom: The NHS COVID-19 app[22]

The NHS COVID-19 app exemplifies how PPPs can swiftly address public health crises through digital innovation. The partnership between the NHS, VMware, Zuhlke Engineering, and Oxford University led to a Bluetooth-based contact tracing app that notified users of virus exposure and advised precautions. This project showcased the private sector's agility and technological expertise, combined with the NHS's public health insights, in rapidly deploying a critical tool for the UK's pandemic response.

III. The long-term care sector

Populations are aging around the world, particularly in the ECE region, creating a growing requirement for long-term care. Equally, non-communicable diseases, such as diabetes require lifelong care outside healthcare facilities. Digital solutions, especially those enhanced by AI, can address the challenges of providing effective long-term care by offering improved efficiency, personalized care, and a greater quality of life for both users and care providers. These benefits are maximized when integrated into a layered health and social care system.

Not unlike the healthcare sector, to create a conducive environment for digital service innovations, it is essential to develop adaptive regulations that keep pace with technological advancements. Establishing open standards for data interoperability, privacy, and security, as well as promoting regulatory harmonization across jurisdictions facilitates seamless and

[21] See Vertex and CRISPR Therapeutics Announce Authorization of the First CRISPR/Cas9 Gene-Edited Therapy, CASGEVY™ (exagamglogene autotemcel), by the United Kingdom MHRA for the Treatment of Sickle Cell Disease and Transfusion-Dependent Beta Thalassemia | Vertex Pharmaceuticals (vrtx.com).

[22] See NHS COVID-19 app - COVID-19 response - NHS Transformation Directorate (england.nhs.uk).

secure information exchange. Unlike mainstream tech products, innovations in healthcare and in long-term care must undergo rigorous scrutiny and regulatory approval to ensure safety and efficacy, often involving comprehensive clinical trials. This makes sure that the technology improves patient outcomes without introducing unintended harm.

Key benefits of digital long-term care services include timely access to user information for integrated, person-centred support, systemic and individual insights for proactive care delivery, improved accuracy and security of individual records, and maximized effective use of limited resources. The objective is to promote healthy aging, minimize the impact of non-communicable diseases, and provide access to health and social care services, enabling people to live longer, healthier lives.

Aging populations have varying support needs, broadly categorized as community living (independent living at home, with informal or professional support), and in-patient care (patients receive medical treatment or continuous care in healthcare or social care facilities). Meeting these needs involves collaboration among governments, healthcare providers, community organizations, and individuals, lending these activities to PPP structures. Strategies include promoting healthy lifestyles, encouraging social inclusion, assisting with retirement planning, providing long-term care services, and designing age-friendly cities and communities. The partnership between La Poste and Medtronic below illustrates how digital solutions can enhance the management and monitoring of long-term care patients.

Case Study 11 – France, La Poste Santé[23]

La Poste, the French public postal service, and Medtronic plc, through its Integrated Healthcare Solutions division, entered into a collaboration in the healthcare sector to improve patient care through innovative delivery and monitoring solutions. The goal of the PPP is to improve the management and monitoring of patients with chronic diseases, particularly those requiring long-term care and regular medical follow-ups. The partnership leverages La Poste's extensive logistics network and Medtronic's medical expertise for efficient delivery of healthcare services, including remote monitoring and patient support.

This collaboration is designed to enable more efficient healthcare delivery, including remote monitoring and patient support, ensuring timely follow-ups and improved chronic disease management. For example, their shared capabilities enable real-time blood glucose monitoring and remote support for Type 1 diabetes patients, leading to better care outcomes. Similarly, telemonitoring solutions for cancer patients offer continuous symptom tracking and coordinated care, allowing for timely adjustments to treatment plans.

To ensure the inclusivity and effectiveness of digital health initiatives, all relevant parties in the planning and implementation phases must be involved. Creating platforms for continuous dialogue between governments, technology providers, service professionals, and users, incorporating user and provider feedback into the development and refinement of digital tools, and facilitating multi-sectoral and international collaborations to align goals and leverage resources comprehensively are essential actions. Regulations should establish clear standards for data interoperability, privacy, and security, facilitating the safe and effective deployment of digital technologies. Collaborative efforts among governments, private sector innovators, cost units such as health and long-term care insurances, and care providers are essential to develop these standards.

The following sections and case studies illustrate how PPPs can effectively leverage technology to enhance long-term care delivery, highlighting successful implementations and their impact on improving care quality and efficiency. Adaptable legal frameworks that keep pace with technological advances can help to integrate digital solutions into long-term care..

[23] See Les initiatives de La Poste Santé & Autonomie | La Poste Groupe.

A. Remote monitoring and management

Digital platforms enable real time, out of healthcare facility, remote monitoring of patients' vital signs, activities of daily living, and medication adherence. Real-time access to patient information, care plans, and communication channels facilitates efficient coordination across multidisciplinary teams, leading to better outcomes and reduced medical errors. Wearable devices equipped with sensors can continuously monitor vital signs such as heart rate, blood pressure, and oxygen saturation levels. This real-time data allows caregivers to track users' health status more effectively than periodic checks and, when coupled with AI analysis, pre-emptively intervene to prevent medical emergencies.

Remote management can be integrated with medication management systems to provide reminders and notifications for medication adherence. By delivering timely reminders, these devices help patients stay on track with their medication schedules, reducing the risk of medication errors or missed doses. Digital platforms can also facilitate seamless communication and collaboration among healthcare professionals, patients, and family caregivers. When integrated into the healthcare system, telemedicine supports virtual consultations with healthcare providers, reducing the need for in-person visits while still enabling timely interventions. It also allows non-medical caregivers to access virtual support from general or specialist medical providers.

There is considerable overlap between long-term care and healthcare, and this should be reflected in the structuring of remote monitoring and management systems. In the UK, Shropshire's Virtual Care Programme demonstrates the potential of remote care monitoring in improving the quality of life for long-term care patients.

Case Study 12 - United Kingdom, Shropshire Virtual Care Programme[24]

In October 2023 Shropshire council, a local authority in the North of England, was given around $1.5 million for the UK Government's Adult Social Care Technology Fund to develop virtual social care. The service uses a video conferencing device and 24/7 virtual professional care team provided by private sector delivery partners.

The service provides support such as reminders for mealtimes and medications, prompts for personal care and support for people with mental health needs or learning difficulties. Adults of all ages are now using virtual care services, with 12 percent under the age of 35, 38 percent aged between 36 to 69, and 50 percent aged over 70. In addition to soft benefits such as reduced feelings of loneliness, the service has achieved 95 percent success in achieving nutrition targets, 97 percent in achieving medication compliance and 98 percent in achieving hydration targets.

B. Wearables

Wearables, equipped with sensors, can record real-time individual data in long-term care settings. AI algorithms analyze this data to detect abnormalities, monitor health trends, and provide personalized recommendations for lifestyle modifications. In long-term care, wearables offer numerous benefits for both users and caregivers. They can detect and report events such as falls or abnormal activity patterns through built-in accelerometers and motion sensors, automatically alerting caregivers for prompt assistance.

Additionally, wearables with tracking and geofencing technology enhance safeguarding for users, particularly those with cognitive impairments, by alerting caregivers if a user strays outside a designated area, facilitating timely intervention and safety.

Effective remote monitoring and management in long-term care must be supported by strong data governance practices. These practices aim to ensure that sensitive health data collected through wearable devices and digital platforms is securely managed and used ethically, thereby enhancing the trust and reliability of digital long-term care services, and balancing innovation with respect for personal rights. While wearable technology, such as the Fitbit partnership with the NIH highlighted below, demonstrates the potential for advancing

[24] See Shropshire's Virtual Care Programme expands its support for adult social care - Shropshire Council Newsroom.

precision medicine, ethical and legal concerns must be considered, particularly regarding self-determination. For instance, blanket use of location trackers for vulnerable populations may infringe on personal rights, but in certain cases, such devices can enhance independence and participation.

Case Study 13 - United States, National Institute of Health (NIH) All *of* US Research Programme and Fitbit (Google) [25]

A notable PPP project in the wearable healthcare sector is the collaboration led by Fitbit (now part of Google) with the US NIH through the All of Us Research Program.

This program aims to enrol over a million Americans to gather health data for precision medicine. Fitbit provides wearable devices to participants, enabling real-time health monitoring, with a focus on inclusivity and health equity. Through this PPP, Fitbit and NIH leverage wearable technology to gather diverse health data, improving healthcare access and outcomes for underrepresented communities. Participants may choose what type of data to share and may stop sharing at any time.

C. Roster management

Long-term care is a sector which is subject to high levels of staff turnover. Digital platforms facilitate seamless communication and collaboration among (health)care professionals, patients, and family caregivers. These platforms centralize patient information, care plans, and communication channels, improving continuity of care.

They enable administrators to efficiently create and manage staff schedules by coordinating staff availability, preferences, and skill sets, often utilizing automated scheduling algorithms to optimize staffing levels and minimize gaps or overlaps in coverage. These systems provide real-time visibility into staff schedules, allowing administrators and staff members to access up-to-date information. This contributes to staff's awareness of assigned shifts, time-off requests, and any changes, reducing confusion and miscommunication. Many digital roster management systems include built-in communication tools, such as messaging or notification features, facilitating communication of important updates, announcements, or shift changes directly to team members and reducing reliance on traditional methods like phone calls or emails. Additionally, these systems help ensure compliance with regulatory requirements by automating rule-based scheduling and tracking qualification validity, and they can generate reports and analytics to fulfil regulatory reporting requirements.

D. Other digital technologies in long-term care

Many consumer technologies can be applied to the long-term care sector, but they require appropriate regulation to protect users' interests. AI-powered chatbots and virtual assistants provide round-the-clock support, answering inquiries, offering educational resources, and scheduling appointments. Natural language processing allows these virtual agents to understand and respond to users' needs effectively.

In addition, Virtual Reality (VR) therapy offers immersive experiences that alleviate pain, reduce stress, and improve cognitive function. VR simulations also provide training opportunities for caregivers and enhance users' mental well-being through virtual travel and recreational activities. The diabetes programme at Sant Joan de Déu Hospital highlights how digital tools and telemedicine can enhance chronic disease management.

[25] See All of Us Research Program Expands Data Collection Efforts with Fitbit | All of Us Research Program | NIH.

Case Study 14 – Spain, Sant Joan de Déu, Diabetes programme[26]

The Sant Joan de Déu Diabetes Programme delivers comprehensive long-term care for Type 1 diabetes patients by integrating continuous glucose monitoring, insulin pumps, and telemedicine services into daily care. This patient-centred approach helps "de-medicalize" the experience, reducing hospitalizations and in-person visits by enabling effective remote disease management. By leveraging technology and real-time monitoring, the program enhances chronic disease management requiring long-term care, providing patients with the tools to maintain better health outcomes from home while minimizing complications.

Working with a private sector partner, the hospital sought to implement an IT platform with the ability to interact with patients and families through a telemedicine coordination and assistance service, coupled with the provision of continuous glucose monitors and insulin pumps. The project led to an average reduction of 3 days of hospitalisation per patient and a 30 to 40 percent reduction of on-site patient visits.

Summarizing Sections II and III, both the healthcare and long-term care sectors are undergoing transformation through digital technologies like AI, telemedicine, telecare, digital health records, and remote monitoring, which enhance care efficiency and personalize services. PPPs have potential in scaling these innovations, including to contribute to secure, accessible, and effective delivery of services. Where a sustained private sector investment in these sectors is assessed as economically advantageous, public authorities can offer tax incentives, grants, or subsidies as part of the PPP and establish clear pathways to market, including pilot testing.

Building on these insights, the next section shifts focus to the education sector, where digital transformation through PPPs plays a pivotal role in achieving inclusive, equitable, and high-quality education using technologies such as e-learning and adaptive learning systems.

IV. The education sector

A core objective set forth by the SDGs is quality education. SDG 4 aims to ensure inclusive and equitable quality education for all and to promote lifelong learning. Digital solutions play a crucial role in achieving this goal by integrating technologies that enhance the overall quality of education and maintain environmental sustainability. Students gain equitable access to various resources and materials, which helps develop their knowledge and skills. Additionally, this integration fosters engagement, motivation, and preparedness for the digital world.

Not unlike for the healthcare sector, the turning point for digital transformation in education was the global lockdown caused by the COVID-19 pandemic. It was estimated that 1.2 billion students were out of school, forcing educational institutions to quickly adapt to the use of Education Technology' (EdTech). The significant surge in the usage of EdTech has accelerated the integration of technology, improved digital infrastructure, and brought about innovations in teaching methods. Long before the COVID-19 pandemic, EdTech was already seeing rapid expansion; the lockdown created a burning platform for accelerating adoption.

The global EdTech industry is expected to increase at a CAGR (Compound Annual Growth Rate) of 16.3 percent from 2019 to 2025, resulting in a total global expenditure of $404 billion.[27]

Digital technologies have emerged as powerful tools in addressing the evolving needs of the education sector enhancing education quality among other learning outcomes worldwide. Adoption of these digital technologies needs large commitments of financial resources. Therefore, governments, international organizations, and non-governmental organizations have stepped in to partner with learning institutions to finance digital solutions in education,

[26] See Diabetes Centre of Excellence | SJD Barcelona Children's Hospital (sjdhospitalbarcelona.org).
[27] See Online Learning Statistics: The Ultimate List in 2024 | Devlin Peck.

and this section highlights some cases where such initiatives have helped drive a positive impact on educational and learning outcomes across the globe.

Digital solutions have the potential to improve access and inclusivity in education by breaking down barriers to quality learning and providing access to educational materials regardless of geographical location or socio-economic background. PPP initiatives can play a role in this process by combining the financial support, technological expertise, and digital content provided by the private sector with the public sector's capacity to scale and address policy needs. However, while these initiatives can enhance accessibility, personalization, and distance learning opportunities, as seen during the COVID-19 pandemic, persistent digital inequalities – such as limited access to devices, internet connectivity, or digital literacy – continue to undermine digital equity, particularly for disadvantaged and marginalized groups.[28] Addressing these inequalities within PPP frameworks is essential to ensure that digital transformation in education leaves no learner behind.

The platforms and technologies that have been developed and innovated to improve access and quality of education fall into the following categories: E-learning platforms; Massive Open Online Courses (MOOCs); Adaptive Learning Technologies; Virtual Labs; and Augmented Reality.

A. E-learning platforms and Massive Open Online Courses (MOOCs)

In an era defined by advancements in digital technologies, the educational sector has experienced a massive transformation, with digital technologies transcending beyond the constraints experienced in traditional classrooms. The new educational realm or "e-learning" is one where education has no boundaries.

E-learning equips learners with educational materials, activities, and services using digital technologies, allowing access to content outside traditional classrooms from anywhere in the world. MOOCs, a cost-effective subset of e-learning, provide comprehensive course experiences such as video lectures, discussion forums, quizzes, and online assignments, enhancing global accessibility. Adaptive learning technologies further personalize learning experiences.

Digital advancements have transformed education, transcending traditional classroom constraints. Interactive e-learning platforms and MOOCs democratize education, eliminating geographical barriers and particularly benefiting underserved communities. AI and VR advancements could further enhance engagement and learning outcomes. These technologies are reshaping the global educational sector.

MOOCs have seen explosive growth, with over 49 percent of students worldwide completing online courses.[29] Online learning has grown by 900 percent since 2000, with projections of 57 million students enrolling by 2027. The industry is expected to grow at a CAGR of 9.1 percent from 2018 to 2026, reaching over $370 billion in revenue by 2026. The rapid adoption of e-learning and MOOCs is due to their global accessibility, cost-effectiveness, efficiency, and flexibility. Studies indicate that learning time can be reduced by 40 to 60 percent through online education, and 70 percent of students consider it better than traditional classroom learning.

E-learning platforms and innovative technologies have significantly improved educational quality and access, aligning with SDG 4 by promoting inclusion, equitable access, diverse learning environments, and sustainability. The Virtual University of Pakistan case study described below showcases how e-learning platforms can broaden access to education through public-private partnerships. Similarly, UNICEF's Global Learning Passport initiative illustrates how PPPs can bridge the digital divide and ensure inclusive access to education.

[28] See OECD (2023) Digital equity and inclusion in education: An overview of practice and policy in OECD countries.

[29] On the statistics in this paragraph, see Online Learning Statistics: The Ultimate List in 2024 | Devlin Peck.

Case Study 15 – Pakistan, Virtual University of Pakistan[30]

With a network of over 200 campuses across Pakistan, over 30 campuses are owned and operated by private partners who provide the infrastructure and digital facilities while the public provides the course material, examinations, and certifications. Other initiatives include corporates in the digital space such as Microsoft Corporation entering into international PPPs in education. Through the Partners in Learning (PiL) programs, Microsoft partners with schools and governments to offer inclusive digital learning programs that serve well to prepare learners for today's digital workplace, and teachers to develop innovative digital strategies for delivering learning.

Case Study 16 – UNICEF, Global Learning Passport[31]

UNICEF's giga-initiative that was launched in 2019 aims to connect over 1 billion children that learned without access to internet connectivity in schools across the world. It was projected that up to 3.6 million students could benefit from the Global Learning Passport.

In this program, the schools become the anchor points for the surrounding communities, connecting businesses and services. The UNICEF Giga program helps to address the problem of digital exclusion for vulnerable learners in poor communities, girls, and learners with disabilities.

As the education sector increasingly adopts digital solutions, it is important to explore and integrate international best practices in e-learning and MOOCs. Cross-border collaboration and knowledge exchange can enhance the quality of digital education, in order for students worldwide benefit from the latest innovations and pedagogical approaches.

B. Adaptative learning technologies

Adaptive learning technologies tailor educational experiences to individual student needs using data-driven insights. These systems track and report on student progress, engagement, and performance, leveraging algorithms and data analytics for personalized instruction. By creating unique learning pathways and adaptive feedback, they help students reach their full potential and support educators in delivering effective lessons.

Adaptive learning transforms teaching by providing personalized instruction, real-time progress tracking, efficient resource allocation, and data-backed decision-making. Acting as a "virtual teaching assistant," it helps students identify strengths, weaknesses, and learning pace. As education embraces digital solutions, adaptive learning stands out for addressing diverse learner needs and promoting lifelong learning, aiding in achieving SDG 4.

The global adaptive learning market size was estimated at $3.48 billion in 2023 and is expected to be worth $8.8 billion by the year 2028, growing at a CAGR of 21.4 percent.[32] The key drivers for the growth and expansion include the growth of innovative technologies such as data analytics and AI and government efforts to improve learning outcomes and prepare learners for the highly developing job market needs. This data-driven approach enhances the sustainability of educational interventions by enabling continuous improvement of teaching and learning strategies. The US-based case study below demonstrates the significant improvements in learning outcomes through the use of adaptive learning technologies.

[30] See Virtual University of Pakistan (vu.edu.pk).
[31] See UNICEF Global Learning Passport.
[32] See Adaptive Learning Market Size, Share & Trends Report, 2030 (grandviewresearch.com).

Case Study 17 – United States, Adaptive Learning Technologies and Median Scores in Exams[33]

Adaptive learning technologies have demonstrated remarkable outcomes in the learning process. Their transformative impact was realized when it was applied at the University of California in Los Angeles where the median scores in exams recorded a significant improvement, growing from 53 percent to 72 to 80 percent. The impact was also felt on the course attrition rate which experienced a four-fold reduction from 43.8 percent to a commendable score of 13.4 percent. In terms of diversity, equity and inclusion, a striking achievement was realized among female students who recorded a remarkable ten-fold reduction in course attrition from 73.1 to 7.4 percent. These statistics show the potential transformative impact of adaptive learning technologies, sourced from private companies, amplifying comprehension of learning, as they follow a path of uniquely tailored content that enhances the growth and expansion of knowledge.

C. Virtual labs and augmented reality in education

Virtual labs and augmented reality (AR) are emergent technologies that are revolutionizing the education landscape. Virtual labs present simulations of real-world environments, enabling students to undertake experiments and have hands-on, engaging learning activities in virtual settings that can be possible in a traditional class setting. AR uses digital content to represent the physical world, which facilitates hands-on learning by offering interactive and immersive experiences that create a highly engaging learning environment. Combined, these immersive technologies help learners to easily comprehend complex subjects and make learning content more appealing, and easy to remember. Furthermore, these technologies help build a collaborative learning environment where learners can collaborate to accomplish tasks in the virtual world and later apply those experiences to solving real-world problems.

AR has emerged as one of the leading and fastest-growing trends in EdTech. By 2023, there were approximately 1.4 billion active AR user devices, and this figure was expected to dramatically grow to over 17.3 billion AR user devices in the world by 2024. Statistics have also indicated that approximately 3 in 4 adults under the age of 44 years are aware of AR, and over 91.75 percent of Gen Zs are interested in AR applications. The AR market size in training and education is projected to grow to reach $173.2 billion at a CAGR rate of 54.8 percent by 2028, and the VR market size in education is projected to grow to reach $61.55 at a CAGR rate of 39.1 percent by 2028.[34]

Key trends driving the growth of virtual labs and AR technology include growing worldwide trends towards personalized learning and, growing emphasis on STEM (“Science, Technology, Engineering, and Mathematics”) education, where immersive experiences enabled by these technologies facilitate experimentation and problem-solving in STEM subjects. The growth of AR and virtual labs is also driven by their expandability and ability to offer cost-effective alternatives to traditional lab equipment, which makes learning more affordable and sustainable in the era of increasing student populations. This reduces the overall cost per capita to the economy, adding to the sustainability of providing education and learning to society.

Today, as in other industries, in the social sectors such as healthcare are deploying AR to simulate key processes for training purposes. Educational institutions can integrate AR technologies into their curricula for improved learning outcomes. Through their ability to simulate real-world situations, these technologies offer highly interactive, experiential learning that surmount physical restrictions, to facilitate access to quality education for all. Moreover, these technologies can promote inclusivity by accommodating diverse learning needs and styles, which promotes a supportive learning environment. Counting on their cost-effectiveness and scalability, the contribution of these innovative technologies will continue to grow, offering sustainable solutions that improve education quality and support, and better preparation of students for the challenges of tomorrow. The AR Lab mobile app in Brazil

[33] See eg. Adaptive Learning: A Revolution in Education (raccoongang.com).
[34] See 24+ Augmented Reality Stats (2024-2028) (explodingtopics.com).

described below exemplifies how augmented reality can enhance engagement and understanding in STEM education.

Case Study 18 – Brazil, AR Lab mobile app for chemistry education[35]

AR Lab, an Augmented Reality mobile app, was developed to enhance chemistry education by offering realistic 3D models of laboratory glassware. Developed by Unity and Vuforia SDK for high school chemistry students, the app provides an interactive learning experience, allowing students to visualize and understand the function of various lab items. The app includes a quiz mode for students to test their knowledge and share results with teachers, facilitating continuous learning and assessment.

This partnership effectively combined the technological expertise of the private sector with the educational goals of public institutions, resulting in a tool that is both educationally impactful and technologically advanced. In a study with 80 students, AR Lab's effectiveness was found comparable to traditional lab classes, highlighting its potential as a cost-effective alternative, particularly for schools with limited lab facilities

D. Other digital technologies in education

Other EdTech solutions include Gamification and Game-Based Learning platforms, that aim at making learning more engaging, interactive, and competitive, which fosters active participation, better comprehension, and knowledge retention in their learning endeavours.

There are also OER ("Open Educational Resources") that offer free or low-cost access to learning resources such as textbooks, educational simulations, educational videos, etc. This promotes affordability and therefore more equitable access to education. There are mobile learning apps that offer interactive learning tools that offer highly personalized, on-the-go learning. Voice Assistants and Chatbots, powered by AI, also offer learners instant access to information facilitating learning. Other emerging EdTech solutions include Social Media Learning which leverages connectivity and interactivity offered by social networking sites to facilitate communication, collaboration, and knowledge sharing among educators and learners. Furthermore, there is increasing application of Blockchain technology in education by offering block-based credentials and digital verification of digital certificates, which can enhance the security, transparency, and authenticity of the certificates and credentials offered after completing online courses.

Following the pandemic's EdTech surge, the focus has shifted to improving learning outcomes, adapting to evolving pedagogies, and preparing students for a digital workforce. Rwanda's Smart Classroom Initiative demonstrates how digital tools can enhance education in underserved communities.

Case Study 19 – Rwanda: Smart Classroom Initiative[36]

Rwanda's Smart Classroom Initiative aims to equip classrooms with digital learning resources and tools that could help to improve education quality and achieve better outcomes for learners. Consequently, learners under these initiatives have demonstrated improved learning outcomes due to the effectiveness offered in the personalized learning approach offered by digital solutions.

The initiative, originally launched by the Rwandan government to establish foundational connectivity, is now creating significant opportunities for private sector investment through PPPs. This collaborative approach aims to enable access to technology, thereby improving the quality of teaching and learning materials. By leveraging digital learning resources, such as multimedia interactive content,

[35] See AR Lab: Augmented Reality App for Chemistry Education.
[36] See Rwanda: Smart Classrooms, a digital solution to promote student learning - Resilient Digital Africa (digital-africa.co).

the initiative seeks to modernize education and enrich learning experiences across the country.

To foster effective digital transformation in education, governments should also consider investing in the foundational elements needed to attract private sector participation through small-scale PPPs. By focusing on discrete, manageable projects — such as developing targeted e-learning resources, boosting digital literacy, or introducing virtual labs — public authorities can create opportunities for private sector involvement without the risks associated with large, complex initiatives. This incremental approach is likely to be more appealing to private partners and can lead to meaningful improvements in specific areas of the education system, ultimately contributing to broader educational goals.

As a final point of clarity, the three sectors highlighted in this guide, public authorities should cultivate a culture of innovation and adopt collaborative strategies to tackle social challenges. This can be achieved by providing platforms for pilot projects within the PPPs for the SDGs framework, encouraging partnerships to develop scalable solutions. Public authorities should also offer targeted support for research and development (R&D) in digital services that address essential social needs. Increased investment in R&D will accelerate innovation and expedite the introduction of effective solutions to market, enhancing outcomes across these critical sectors.

V. Policy recommendations

Building on the PPPs for the SDGs approach and best practice case studies showcased in this guide, the policy recommendations below are designed to create a robust ecosystem for digital social sector PPPs, where innovation flourishes, stakeholders collaborate effectively, and social outcomes are significantly improved. Addressing these key areas allows governments and private sector partners to navigate modern technology complexities, ultimately delivering more efficient, accessible, and personalized services.

1. **Develop adaptable legal and regulatory frameworks:**

    1.1 Develop adaptable legal frameworks that keep pace with technological advances to help to integrate digital solutions into healthcare, long-term care and education.

    1.2 Develop robust frameworks for data governance in digital public services, ensuring secure and ethical management of data across digital platforms, particularly in sensitive sectors like healthcare.

    1.3 Create adaptable regulatory pathways specifically for AI in healthcare and long-term care, including clear guidelines for data handling, algorithm transparency, and outcome reporting. Foster ongoing dialogue between innovators, regulators, clinicians, and patient advocacy groups to ensure safe and effective AI deployment.

2. **Provide technical training and skills development:** Develop and implement specialized training programs on digital infrastructure for public sector officials. These programs should aim to enhance the officials' technical skills in managing digital PPPs effectively, including proficiency in project management software, financial modelling tools, and digital systems for monitoring and evaluation.

3. **Incentivize private sector investment:** Where a sustained private sector investment in these sectors is assessed as economically advantageous, public authorities can offer tax incentives, grants, or subsidies as part of the PPP and establish clear pathways to market, including pilot testing.

4. **Use PIERS for SDG alignment**: Leverage PIERS to assess and support PPP projects that are aligned with the SDGs. Use PIERS to evaluate projects on access, equity, economic effectiveness, environmental sustainability, replicability, and stakeholder engagement, to ensure that they contribute positively to social outcomes and SDG targets.

5. **Promote stakeholder engagement and knowledge sharing**:

   5.1 Establish continuous dialogue platforms involving governments, technology providers, service professionals, and users.

   5.2 Create forums, workshops, and online platforms for stakeholders to exchange knowledge, share best practices, and accelerate the adoption of digital technologies across borders. Ensure inclusivity in planning and implementation phases of digital health initiatives by incorporating feedback from all relevant stakeholders.

   5.3 Encourage collaborative regulatory pathways that involve ongoing dialogue between innovators, regulators, and patient advocacy groups, in order for new technologies to meet safety and effectiveness standards while expediting their deployment in social infrastructure.

6. **Promote collaboration:** Support multi-sectoral and international collaborations to align goals, leverage resources, and explore best practices in digital social services, ensuring that global standards and innovations are integrated to enhance service delivery and outcomes.

7. **Adopt international best practices**: Facilitate the exploration and adoption of international best practices in digital social services, supporting cross-border knowledge exchange and collaboration to enhance service delivery and outcomes.

8. **Pilot testing and market validation:** Provide opportunities for pilot testing and market validation of innovative digital technologies in real-world settings, allowing for the refinement of solutions before broader implementation. Pilot testing reduces technical risk. Market validation aims to ensure that the solution is economically affordable for public authorities, commercially sustainable for the private partner and ultimately delivers improved outcomes for users. .

9. **Foster innovation:** Promote a culture of innovation within public institutions by encouraging openness to new technologies and collaborative approaches to addressing social challenges.

10. **Support for R&D in digital services**: Offer targeted support for research and development in digital services, particularly those addressing critical social needs, to accelerate innovation and bring effective solutions to market.

Annex I

[English only]

Glossary

Term	*Definition*
AI	Artificial Intelligence – System programming approach in which systems are taught to learn for themselves and remember their mistakes, instead of simply executing predetermined instructions. As the technology develops, the more systems will be able to "understand" and read situations, and determine their response as a result of the totality of data that they acquire.
AL	Adaptive Learning - Delivering learning using data-driven instruction and insights to tailor learning experiences to the individual needs of each student.
AR	Augmented Reality – using technology to overlay information over real world views
CAGR	Compound Annual Growth Rate - is the mean annual rate of return over a number of years, smoothing out fluctuations in individual years.
CRISPR	is a genetic engineering technique by which the genomes of living organisms may be modified.
DNA	Deoxyribo Nucleic Acid- the basic building blocks of living organisms.
EdTech	Education Technology – Collective description of the provision of technology in the field of education
EHR	Electronic Health Record - also known as an Electronic Medical Record (EMR)
Genome	A pattern of DNA that describes a living organism
IoT	Internet of Things – Collective description of autonomous devices able to communicate over the internet.
Machine Learning	The training of AI systems through the automated analysis of very large sets of data.
MedTech	Medical Technology – Collective description of the provision of technology in the field of healthcare.
MOOC	Massive Online Open Course – Training and education delivered online to large numbers of, usually remote, students.
Out of Pocket	Paid by the individual receiving the service.
PBC	Process Based Care – the traditional episodic approach to care where conditions are treated separately in a process of diagnosis and treatment according to established pathways and protocols. Providers are incentivised and rewarded based on the volume of services provided.
RPA	Robotic Process Automation – the automation of repetitive processes
SDGs	The United Nations Sustainable Development Goals
Social Sector	The domain of industry for which historically governments have developed infrastructures and delivered services to citizens. In most countries (if not all), citizens are entitled to these amenities and services under the constitution or the "social contract". This includes healthcare and associated facilities such as residences for care workers, diagnostic centres,

Term	*Definition*
	laboratories, research institutions, nursing colleges, specialised treatment centres (e.g., oncology, dialysis); education covering schools, kindergartens and teacher training colleges; higher education and associated facilities such as student accommodation, research institutions, playing grounds, and administrative buildings; log-term care covering the full spectrum from assisted living to elderly homes; affordable & social
	housing; public sports facilities; government buildings and services such as court houses, and so on
VBC	Value Based Care – an approach to care that focusses on delivering outcomes, “the value”, rather than the volume of services provided. This approach necessitates significant shifts in policy, payment structures, and provider incentives to reward outcomes rather than procedures.
VR	Virtual Reality – A system of interaction that creates a simulated artificial space to interact in.
Wearable	Sensors and other devices embedded in the environment or integrated into clothing or carried by a person.

Annex II

[English only]

Members of the drafting team led by Gabriele Pasquini involved in the preparation of the document (in alphabetical order): Paul da Rita, Mark Halliday, Alfredo Lucente, Celso Manangan, Nasser Massoud, Ana Luisa Neves, Abhay Pandey, Tamara Sunbul, José Miguel Torres, and Esen Tumer.