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Digital Skills, Innovation,
and Economic Transformation:
Opportunities and Challenges
for Sub-Saharan Africa

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Digital Skills, Innovation, and Economic Transformation: Opportunities and Challenges for Sub-Saharan Africa

Jamil Salmi, Alice Amegah, and Aarya Rajendra Shinde

Abstract

This study explores the link between digital skills, innovation, and economic transformation in the context of Africa, focusing on the role and potential contribution of higher education institutions in the development of advanced skills for the digital transition. It documents relevant global case studies from Asia, Australia, Europe, and North America that showcase good examples of investment in skills development through higher education and their impact on innovation and economic growth. The study investigates the evolving global demand for digital skills and explores how advanced digital skills can create new economic development opportunities for Africa and help solve the big challenges faced by the subcontinent, such as food security, health threats, learning poverty, and climate change. It takes stock of existing capacities for digital skills training in Sub-Saharan Africa and proposes a bold vision for improving and expanding digital skills education programs.

Keywords: digital transition; advanced skills development; innovation; economic growth; digital skills training.

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The use of AI in this report, which is about digital skills reflects the author's commitment to leveraging advanced technologies to enhance their analytical capabilities, while maintaining human oversight and judgment in the final product.

Abbreviations

ACE	African Center of Excellence
AI	artificial intelligence
CGIAR	Consultative Group on International Agricultural Research
CMU	Carnegie Mellon University
HIGHER Women	Higher Institute for Growth in Health Research for Women
ICT	information and communications technology
IFC	International Finance Corporation
IIT	Indian Institutes of Technology
IoT	internet of things
IT	information technology
ILO	International Labour Organization
MIT	Massachusetts Institute of Technology
MOOC	massive open online course
OECD	Organisation for Economic Co-operation and Development
RTP	Research Triangle Park
TVET	technical and vocational education and training
R&D	research and development
STEAM	science, technology, engineering, arts and humanities, and mathematics
STEM	science, technology, engineering, and mathematics
WEF	World Economic Forum

Summary

Introduction

This report explores the intricate relationship between digital skills, innovation, and the promise of socioeconomic transformation in Africa. It emphasizes the pivotal role that higher education institutions can play in cultivating the advanced skills necessary for the digital transition. Sub-Saharan Africa is grappling with a myriad of challenges, including persistent poverty, stagnated economic growth, political instability, vulnerability to climate change, high rates of infectious diseases, and inadequate social infrastructure. The COVID-19 pandemic has exacerbated these issues, underscoring the urgent need for digital transformation to stimulate social development and accelerate economic growth.

Skills and Research in the Knowledge Economy: International Lessons

The 2021 World Bank higher education strategy reaffirms that tertiary education systems are at the heart of the big social and economic transformations that are required as the world seeks to achieve green and equitable development in the wake of the COVID-19 pandemic. In this context, advanced digital skills are increasingly indispensable for employability, adaptability to rapid technological progress, access to information services, innovation and entrepreneurship, and lifelong learning.

As developing economies move up the technology ladder and the gap between them and the leading industrial economies narrows, their need for education and skills at all levels grows, particularly at the tertiary level. A wide range of higher education institutions with complementary missions are needed to help accelerate industrial change as they are the source of a growing share of entrepreneurs, managers, and skilled workers in the continent's labor markets. Workers with a quality postsecondary education are more employable, earn higher wages, and cope better with economic shocks. In most countries of the world, economic returns for a tertiary education graduate are the highest in the entire educational system, an average 17 percent increase in earnings per year of tertiary schooling, compared with 10 percent for primary and 7 percent for secondary education. Data from South Africa show a similar pattern. In 2023, employees with a bachelor's degree earned 24 percent more than diploma holders, while people with a master's degree received 29 percent more than those with only a bachelor's degree. PhD holders made 23 percent more than employees with a master's degree in a comparable position.

Higher education is one of the drivers of productivity that make economies more innovative and competitive in an increasingly global market, as shown by a series of case studies presented in this report. For example, the spectacular transformation of Singapore from a poor fishing village without any natural resources at the time of its independence in 1965 to a wealthy and smart city-state 60 years later is one of the most telling examples. From the outset, Singapore's government has guided its economic growth and transformation path with a clear strategic vision, careful planning, and effective implementation informed by regular system-wide reviews to identify gaps and take corrective actions. In

the absence of any natural resources, talent development has been at the heart of Singapore's vision and strategy from the beginning. The country has successfully built a world-class education system at all levels. Its excellent results in the Program for International Student Assessment tests attest to the quality of basic education. Singapore is renowned for its high-performing universities and technical and vocational education and training (TVET) institutions that produce the middle-level and advanced talent and the research needed by the economy and society. It has invested in the development of science, technology, engineering and mathematics (STEM) programs in the past 20 years.

Finland successfully transformed itself from an agriculture-based economy in the 1950s into a leading innovation-driven, knowledge-based economy and high-tech producer within a relatively short span. From the mid-1990s onward, Finland experienced extraordinary economic growth, with the information and communications technology (ICT) sector, led by Nokia as its flagship group, at the forefront of this development. The Finnish government took an active role in developing digital and mobile communications technologies as early as the 1970s and 1980s. During these decades, the state invested heavily in developing domestic technology and production capabilities through funding collaborative research involving private enterprises, public agencies, and universities. The state also played a role in expanding university degree programs in electronics and information technology, as well as directing technologically demanding government procurement to domestic firms.

Between the end of the 20th century and the beginning of the 21st century, Ireland successfully transitioned from an agrarian and manufacturing-based economy to one driven by knowledge-intensive industries. As a result, the "Celtic tiger" has become one of the wealthiest economies in the world, attaining a per capita GDP of US\$100,000 in 2021. To achieve this impressive result, Ireland implemented several complementary strategies for realizing an ambitious vision, long-term thinking, and a sustained commitment to investing in education and research. First, Ireland actively sought foreign direct investment by providing a competitive corporate tax rate, a highly skilled workforce, and access to the European market to attract multinational corporations. Second, the country put in place a supportive ecosystem for start-ups and entrepreneurship that offered funding, mentoring, and networking opportunities. Enterprise Ireland and Science Foundation Ireland were two crucial initiatives that supported innovation and research commercialization at universities and within firms. Third, Ireland invested substantially in upgrading its workforce by improving the quality of education at all levels. This included reforms in the primary and secondary education curriculum, strengthening of teacher training, and efforts to increase access to higher education, particularly in STEM. The government actively promoted collaboration between academia and industry to facilitate knowledge transfer, technology commercialization, and skill development. Fourth, to support the development of knowledge-intensive industries, Ireland invested in modern infrastructure, including high-speed internet connectivity, research facilities, and business parks.

As illustrated by these three examples, while the most dynamic countries that have made the transition to becoming knowledge economies have achieved global comparative advantages in different priority sectors, they share core strategic elements: all invested prominently and continuously in education, research, technology, and innovation to deepen and expand their areas of competitive advantages.

Looking at the impact of human capital development policies at the national level is not the only way of exploring the interface between innovation and higher education. Research indicates that the regional (subnational) dimension of economic development may be as important as what happens at the national level; sometimes it may be even greater. Within national economies, the most successful regions and cities are those that manage to attract and retain qualified people in employment, improve the adaptability of workers and enterprises, and increase investment in human capital through skills matching and upgrading. This is where innovation clusters emerge, that is, the geographic concentration of interconnected companies, specialized suppliers, service providers, and associated institutions within a particular future-oriented economic sector. Indeed, the presence of strong universities is important to regional development, through both direct linkages and spillover effects. The successful experiences of technology-intensive poles such as Silicon Valley in California, Research Triangle Park in North Carolina, Bangalore in India's Karnataka State, Shanghai in China, and Campinas in São Paulo State, Brazil, attest to the positive effects that the clustering of advanced human capital alongside leading technology firms can have.

New Prospects and Challenges for Skills in a Changing World

The Fourth Industrial Revolution is characterized by rapid developments in fields that were previously separate but have now become increasingly intertwined, such as artificial intelligence and machine learning or biotechnology and genetics. The combination of advanced technologies has blurred the lines among the physical, biological, and digital domains and brought about new development opportunities in numerous scientific fields. This rapid evolution in the business and production spheres has caused widespread disruptions in labor markets in three related ways: elimination of many jobs, emergence of new positions, and the necessity to transform and adapt the content of scores of existing jobs.

A key result of this evolution is that the loss of jobs through computerization is inversely related to educational attainment. Positions requiring creativity, high-level socio-cognitive skills, and the ability to deal with complex tasks are safe from being automated. These high-order skills are even more important today as artificial intelligence (AI) amplifies but does not replace human creativity. While AI can assist with the rapid search for information, humans are still in the driving seat in terms of conducting important conversations, resolving conflicts, motivating teams, and making value-based choices. Research consistently shows that the jobs that are at risk from automation are highly concentrated among lower-paid, lower-skilled, and less educated workers.

While these positive effects may not play out as strongly in the developing economies that still have a high proportion of employment in the informal sector, they will undoubtedly affect the modern sectors of these economies, where most tertiary education graduates seek employment. Among the expected consequences will be increased opportunities for the development of small and medium-sized enterprises (SMEs). Also, freelancing jobs will become more common in a world where production is more and more project based. This means that work and value creation will increasingly be organized

around temporary, goal-oriented initiatives rather than traditional, permanent structures like fixed departments or long-term job roles.

In designing their future programs and courses, tertiary education institutions must take notice of the considerable transformation that the labor market is undergoing in the digital era. First, they will need to provide the whole range of digital skills required by both new and existing jobs. Second, they must address the momentous implications of ongoing trends in terms of generic competencies that graduates are expected to possess.

The changing scope of work is making digital skills a decisive attribute for the workforce. In industrial sectors that adopt technology and digitalization, employers are increasingly seeking a digitally skilled workforce. The demand for digital skills is increasing steadily with the rapid pace of technology change. The adoption of technological innovations such as cloud computing, language models, big data encryption, nonhumanoid robots, artificial intelligence, and e-commerce is shaping business priorities and consumer experiences. The World Economic Forum (WEF) estimates that 84 percent of employers are going to rapidly digitalize working processes, including substantial growth in remote work. More than 44 percent of workers are likely to operate remotely as a result.

The intersection between digital and green skills is also important. One of the most significant shifts in response to climate change is the transition toward a green economy. This alternative vision for growth and development emphasizes economic growth through sustainable practices that prioritize environmental health, economic viability, and social equity. The United Nations Environmental Programme (UNEP) defines a green economy as low-carbon, resource efficient, and socially inclusive; that is, where growth in employment and income is driven by public and private investment into economic activities, infrastructure, and assets that allow reduced carbon emissions and pollution, enhanced energy and resource efficiency, and prevention of the loss of biodiversity and ecosystem services. The transition to a green economy is driven by technological advancements and the search for more environmentally sustainable production and consumption methods, such as the electrification of cities, urban greenery, and energy efficiency measures to mitigate the effects of climate change.

The transition to the green economy creates new employment opportunities in some of its key sectors. These sectors include renewable energy like solar and wind power, carbon capture and storage, nuclear fusion, electric vehicles, sustainable agriculture, and green construction. As these technologies become more affordable and accessible, they are being adopted more widely, leading to a significant transformation in the job market and the skills required for various occupations. The skills required in these industries range from technical expertise, such as renewable energy technicians and environmental engineers, to planning and management skills, including urban planners and sustainable business managers. Equipping the workforce with these specialized skills is crucial for ensuring that individuals can participate in and benefit from the growth of the green economy. It is important to note the high degree of overlap between digital skills and green skills.

Finally, digital skills are part of a broader skills framework that also includes cognitive and socioemotional skills. These transversal skills help to make digital skills work, especially when it comes to using AI effectively. They go beyond technical know-how and enable people to adapt, collaborate, and think critically in a rapidly evolving digital world. Transversal skills help people to understand and evaluate the information proposed by AI platforms and are therefore important to interact effectively with AI and to make ethical and socially responsible decisions.

Seizing Digital Transition Opportunities in Sub-Saharan Africa

The digital transition holds significant potential for modernizing agriculture, health, mitigating climate change impact, and the green transition in Sub-Saharan Africa. For instance, expansion of digital infrastructure and increasing the use of digital technologies can boost agricultural productivity, improving the livelihoods of approximately 250 million smallholder farmers and pastoralists in the region. Technologies such as the Internet of Things (IoT), big data analytics, and AI can also help reduce food loss and waste in agrifood chains. In health, as many Sub-Saharan African nations frequently encounter a shortage of healthcare professionals, particularly in rural and remote areas, telemedicine is leveraging advanced communication technology to provide high-quality healthcare services remotely. For instance, platforms like Babylon in Rwanda enable patients to connect with doctors through video consultations, significantly improving access to medical expertise and care. To mitigate and adapt to the devastating impacts of climate change, Sub-Saharan nations will require the development of advanced digital skills and the creation of new digital jobs and the adaptation of many existing professions, in agriculture, health, education, energy, and transportation, among others, to address the evolving digital economy and labor market trends.

However, digital technologies, particularly AI, present several risks that need careful consideration. One significant concern is the potential for job displacement due to automation, which can lead to economic inequality and social unrest. Additionally, AI systems can perpetuate biases present in their training data, resulting in unfair and discriminatory outcomes. Privacy and security risks are also prevalent, as AI can be used to collect and analyze vast amounts of personal data, potentially leading to breaches and misuse. Furthermore, the reliance on AI for critical decision-making processes raises ethical questions about accountability and transparency. As AI continues to evolve, it is crucial to address these risks through robust regulatory frameworks and ethical guidelines to ensure that its benefits are maximized while minimizing potential harms.

This report particularly takes stock of the supply and demand of advanced digital through higher education in Africa. Based on the literature review and a survey of 174 tertiary institutions in Africa, it discusses critical findings on digital skills gaps, economic opportunities, global cases, and higher education systems as facilitators of digital ecosystems. For digital skills gaps, the report shows a significant mismatch between the demand and supply of digital skills in Sub-Saharan Africa. Employers are increasingly seeking a digitally skilled workforce, yet many individuals lack access to reliable internet and necessary electronic devices. This gap hinders the region's ability to fully leverage digital

technologies for economic development. The report also expounds on the economic opportunities of digital skills. Digital skills present new economic development opportunities for Africa, and they can help address major challenges such as food security, health threats, learning poverty, and climate change to stimulate development and foster financial inclusion at a rapid pace.

The survey of higher education institutions across Africa provided an insight into the challenges and opportunities in terms of supply of advanced digital skills in Africa. The findings first underscore how much progress the region has made in addressing the digital skills gap. For example, a large majority of institutions offer programs that provide additional foundational digital skills for all students at basic, intermediate, or advanced levels. Approximately 150 out of 174 higher education institutions surveyed had these forms of foundational digital skills training for all students. Furthermore, the study shows that 75 percent of the institutions surveyed (approximately 131 out of 174 higher education institutions) offer at least a bachelor's degree in one or more of the 8 possible digital programs, such as computer science, cybersecurity, and computer engineering. In terms of enrollments and graduation rates for the eight programs of interest, the study shows high enrollment in computer science, with approximately 31 percent of students enrolled into a computer science program in the 2023 academic year. The highest enrollment in digital skills programs is observed in West Africa, where the average was 55 percent in 2023. The lowest enrollment was in AI programs, with only 1.5 percent enrolled in the 2023 academic year. Thus, on average, 12.5 percent of students in tertiary education institutions enrolled into a digital skills program at an advanced or specialized level.

Despite these encouraging overall pictures of digital skills training in higher education institutions in the subcontinent, there are gaps in enrollment, gender, and infrastructure that need attention. First, AI programs are available only in a small number of higher education institutions. Second, there are regional disparities in enrollments, with only 3.3 percent enrollment in digital skills in Central Africa. With 1.9 percent enrollment, Central Africa outperforms Southern Africa, which had only 0.9 percent enrollment in computer science. Third, as far as gender disparities are concerned, the distribution is approximately 68 percent male enrollments compared to 32 female enrollments. The widest gender gaps are in electrical/electronic engineering (76.4 percent males compared to 23.6 percent females), while information technology is the program with the best gender balance, relatively (57.5 percent males versus 42.5 percent females). As expected, there were significant gender differences across all types of qualifications of lecturers. Finally, in infrastructure, the survey found a deficit in most institutions. For instance, about 41 percent of students do not have access to the internet in lecture rooms, and 32.9 percent do not have internet access in ICT laboratories. Only 25 percent of the students have their own computer or have access to a computer from the university on a one-to-one basis. These deficits disrupt digital skills training and further hamper the quality of advanced digital skills supplied by higher education institutions in Africa.

The Way Forward

The report emphasizes that higher education institutions and systems in Africa are crucial to the supply of advanced digital skills, and that their functions deserve the attention of policymakers, development agencies, academics and analysts, and the public. Although most universities in Africa offer some form of digital skills training, it appears that the infrastructure and systems for advanced digital skills training are more limited in low- and lower-income countries. Because this disproportionately affects socially disadvantaged youth, there is a substantial equity dimension to their labor market outcomes and their subsequent financial inclusion problems. The untapped potential in advanced digital skills has a significant impact on human capital formation, as measured by the human capital index (HCI) and economic growth. For example, 50–55 percent of jobs in Kenya and 35–45 percent in Côte d’Ivoire, Nigeria, and Rwanda will need some level of digital skills.

In this context, the report makes a series of recommendations that will help to accelerate a deeper understanding of the supply and demand for advanced digital skills in Africa and the potential solutions to achieve the needed developmental advancement. To develop effective programs and policy actions further research is necessary; this includes testing different approaches so as to better understand the cross-disciplinary dynamics that contribute to sustainable supply of advanced digital skills for national, regional, continental, and global use. Three paths of potential remedies are proposed to pursue in the future: (1) invest in digital infrastructure; (2) enhance digital skills training, promote lifelong learning; and (3) leverage global partnerships.

Regarding investments in digital infrastructure, there is a pressing need to expand information technology (IT) and basic infrastructure such as internet connectivity, electricity, and advanced digital laboratories and to increase access to digital technologies with the establishment of specialized institutions. For the enhancement of digital skills training, tertiary institutions and governments need to design innovative systems to accelerate efforts to train more young people and adults in advanced digital competencies and skills. Resilient higher education systems, that can adapt to the rapid pace of technological change, will be needed. The promotion of lifelong learning is necessary to encourage continuous competency and skills development for adapting to technological and social changes. The lifelong learning approach should become an integral part of the education system to ensure that individuals remain relevant and productive throughout their careers. As governments and higher education institutions take the necessary steps, it is important to engage with the private sector to leverage local and global partnerships. Collaborating with international experts and institutions can help governments and institutions adopt the best practices and innovative solutions for digital transformation. These partnerships can provide valuable insights and resources to support Africa's digital transition.

The report points out that while many higher education institutions in Africa offer some form of digital skills training, the infrastructure and systems for advanced digital skills training are more limited in low- and lower-income countries. This limitation disproportionately affects socially disadvantaged youth,

especially their labor market outcomes and financial inclusion. The untapped potential of advanced digital skills significantly affects human capital formation and economic growth, with a substantial percentage of jobs in countries like Kenya, Côte d'Ivoire, Nigeria, and Rwanda requiring some level of digital skills. To address these challenges, the report has made several key recommendations.

First, it calls for significant investments in digital infrastructure, including expanding internet connectivity, electricity, and advanced digital laboratories, and increasing access to digital technologies through the establishment of specialized institutions. Second, it emphasizes the need to enhance digital skills training by designing innovative systems to train more young people and adults with advanced digital competencies. This requires resilient higher education systems that can adapt to the rapid pace of technological change. The adaptation to technological change can include the development and implementation of institutional and regional digital skills policies that target advancements in AI and green skills. Further, the promotion of lifelong learning is also crucial to ensure continuous competency and skills development, enabling individuals to remain relevant and productive throughout their careers. Institutions can adopt more flexibility in access to available programs, such as using microcredential system, hybrid modes of instructions and satellite systems for off campus students.

Finally, the report underscores the importance of leveraging global partnerships to support Africa's digital transition. Engaging with the private sector and collaborating with international experts and institutions can help adopt best practices and innovative solutions for digital transformation. These partnerships can provide valuable insights and resources, facilitating the region's ability to harness digital technologies for economic growth and social progress. By addressing these recommendations, Sub-Saharan Africa can unlock new economic opportunities and drive innovation, ultimately contributing to sustainable development

Main Messages

The report carries the following main messages:

1. Tertiary education produces advanced skills and research outputs that are essential to foster innovation, economic growth, and social progress.
2. Advanced digital skills are the backbone of a dynamic workforce capable of enabling innovation and productivity in the digital and green transitions. They are indispensable to making optimal use of digital infrastructures needed to power emerging technologies and transform traditional economic sectors.
3. More than any of the world's regions, Sub-Saharan Africa needs to seize the opportunities of the digital transition to overcome the big challenges it faces, including persistent poverty, slow economic growth, political instability and conflict, vulnerability to climate change, high rates of infectious diseases, and defective social infrastructures.

4. Though the production of digital skills has increased steadily in recent years, the quality and relevance of computer science and engineering programs and related areas in Sub-Saharan Africa universities leave much room for improvement.
5. National governments and higher education leaders in Sub-Saharan Africa must accelerate their efforts to train young people and adults in advanced digital competencies in innovative and resilient higher education systems with modern governance, robust quality assurance, and sustainable financing.

In conclusion, digital transformation holds immense potential for Sub-Saharan Africa. By addressing the digital skills gap, investing in digital infrastructure, enhancing digital skills training, promoting lifelong learning, and leveraging global partnerships, the region can overcome its challenges and unlock new economic opportunities. Higher education institutions play a critical role in this transformation by developing the advanced skills needed for the digital economy. With the right policies and investments, Sub-Saharan Africa can harness the power of digital technologies to drive innovation, economic growth, and social progress. This investment will help raise agricultural productivity, improve livelihoods, and enable more people to participate in the digital economy.

1. Introduction

“...All regions and countries can benefit from progress toward a knowledge-based economy, which does not depend heavily on material resources, places less of a burden on ecosystems and is more sustainable than other economic models. By shifting to a knowledge-based economy, societies can move from the age of scarcity to the age of abundance. Knowledge does not deplete with use but rather increases as it is shared among people. Through technological innovation, we can help usher in a more sustainable future...”

Ban Ki-Moon, UN Secretary General (April 24, 2014)

1.1 Background

The ascent of the digital economy in what has come to be known as the Fourth Industrial Revolution offers Sub-Saharan Africa new opportunities to address the great challenges it faces, accelerate the pace toward improved productivity throughout the economy, and achieve more efficient and effective service delivery. The creation of new jobs in the digital economy and the successful adoption of digital technologies and tools across all spheres in society can positively affect more people over a shorter period of time and with fewer resources than before. Sub-Saharan governments that can harness the digital transition can drive the diversification and transformation of their economies, fast-track growth for shared prosperity, and close the poverty gap.

The COVID-19 pandemic has accelerated the digital transition across many sectors. Lockdowns led firms to adopt remote work solutions. Schools, training centers, and universities embraced online teaching and learning. From museums to fitness classes, organizations have experimented with digital alternatives that are likely to lead to lasting innovations. E-commerce has thrived in many African economies. Mobile money has revolutionized financial services, leapfrogging traditional banking systems that were often inaccessible to a large portion of the continent’s population. M-Pesa, which was launched in Kenya, is an impressive example (Kagan 2023): it allows users to store, transfer, and receive money using their mobile phones. The service was designed to provide financial inclusion for millions of individuals who lived outside the official banking system. The platform operates through SIM cards inserted into mobile devices, enabling transactions via SMS messages. M-Pesa has enabled millions of people, especially those in rural areas, to enter the formal economy. Its success has inspired similar initiatives to foster financial inclusion across the subcontinent, notably in the Democratic Republic of Congo, Ghana, Lesotho, Mozambique, and Tanzania.

Healthcare providers have turned to telemedicine solutions that allow patients to consult with doctors virtually. Telemedicine is expected to become a key platform for providing convenient and accessible healthcare. Sub-Saharan African nations often face a shortage of healthcare professionals, especially in rural and other inaccessible areas. Telemedicine is bridging this gap by using advanced communication technology to deliver good-quality healthcare services remotely. Platforms like Babylon in Rwanda

connect patients with doctors via video consultations.¹ Known locally as Babyl, it offers triage tools and digital health services, powered by artificial intelligence (AI), to improve healthcare accessibility and affordability in the country. Its mission is to provide immediate and personalized health services by combining machine computing power with medical expertise. Patients can access healthcare book appointments through their phones, receive prescriptions and laboratory test codes via SMS, and consult with doctors remotely. The platform allows people in rural areas to access medical expertise they would not be able to benefit from otherwise, improving access to healthcare and potentially saving lives. Through partnerships with the government and innovative solutions like telehealth consultations accessible via text or voice, Babyl has significantly affected healthcare delivery in Rwanda, with over 2 million registered users and thousands of consultations conducted daily.

The digital transition holds potential for the modernization of agriculture in Sub-Saharan Africa. Expanded information technology (IT) infrastructure and increased use of digital technologies can raise agricultural productivity and improve the livelihood of approximately 250 million smallholder farmers and pastoralists. Digital technologies like Internet of Things (IoT), big data analytics, and AI can help reduce food loss and waste in agrifood chains. According to the UN Food and Agriculture Organization, more than 10 million hectares should be restored each year around the Sahara to stem land degradation and feed the Sahel's population, which is expected to double by 2050. Mali shows an encouraging example of the use of digital tools to combat desertification, soil degradation, overexploitation, and inappropriate land use. The nongovernmental organization SOS Sahel gave a grant to the "Agri-Mairie" project aimed at strengthening the economic and social autonomy of women in rural areas.² The group of agricultural entrepreneurs designed a website to connect women's cooperatives to market opportunities, financial partners, and training offered by their municipalities (Ollivier 2021).

However, the digital transition is not the only transformation that African economies must undertake. To fight the devastating impacts of climate change, Sub-Saharan nations also need to accelerate their transition to the green economy. This transition will require the creation of new jobs and the adaptation of many existing professions, in agriculture, health, education, energy, and transportation, among others. Here again, digital skills will play a critical role at the intersection of the digital and green transformations as countries put in place digital and green transition strategies, and higher education institutions work on modifying their programs and courses to educate and train individuals who can work effectively in the green economy or in economic and social sectors affected by climate change and the resulting environmental challenges.

At the same time, however, advances in artificial intelligence (AI) and associated technologies may adversely affect the economic development model that many Sub-Saharan African countries have followed in the past 30 years. The savings that increased automation in industrial production could bring to advanced economies in terms of both price of labor and use of resources mean that developing countries are at risk of losing their comparative advantage in these factors. Increased automation in the

¹ <https://www.mobihealthnews.com/news/emea/babylon-launches-ai-powered-triage-tool-rwanda>

² <https://sossahel.ngo/>

advanced economies could thus result in the collapse of the development model based on natural resources and manufactured exports that many emerging market economies, including those in Sub-Saharan Africa, have followed for decades (Korinek and Stiglitz 2021). This prospect makes it even more important for the African continent to develop high-value digital activities in all sectors of the economy.

The only exception is the continuing high demand for exports of lithium (from the Democratic Republic of Congo, Ghana, Mali, Namibia, South Africa, and Zimbabwe) and copper (from Botswana, the Democratic Republic of Congo, Namibia, South Africa, Uganda, and Zambia). These two metals are critical to the green transition as essential in the production of windmills, batteries, solar panels, electric vehicles, underwater cables, and energy storage systems. But, here again, countries in Sub-Saharan Africa should seek a larger share of the value chain rather than just exporting these minerals as raw materials to China, Europe, and North America.

In summary, digital technologies and innovation have emerged as major drivers of transformation in the social and economic sphere. In today's digital economy, digital skills are essential for learning, employment, entrepreneurship, and citizenship. Most occupations require basic or intermediate-level digital skills to find and understand information, communicate, access online public services, while advanced or specialized digital skills are indispensable for innovation.

The COVID-19 pandemic did more than give a big impetus to digital transformation. It also exposed the danger of digital divides and underscored the need for equal access to digital technologies, digital literacy, and digital skills. In Sub-Saharan African countries, many areas and people do not have access to reliable internet or do not have the necessary devices to participate in the online world. Addressing this gap will be crucial to ensure that everyone can benefit from the digital transition.

Africa has the youngest, fastest-growing population in the world. To be active participants in the digital economy and benefit from the new opportunities it offers, young Africans need not only foundational skills such as literacy and numeracy; they must acquire solid digital skills. Employers in Sub-Saharan Africa cite their growing need for workers with digital skills and the digital skills gap as a huge challenge. Recent estimates indicate that by 2030, 625 million people living in Africa will need digital skills.

1.2 Objectives

Against this background, the main objective of this paper is to explore the link between digital skills, innovation, and economic transformation in the context of Africa, focusing on the role and potential contribution of higher education institutions. The paper will document relevant global case studies from Asia, Australia, Europe, and North America on investment in skills and its impact on innovation and economic growth. It will investigate the evolving global demand for digital skills and explore how digital skills can create new economic development opportunities for Africa and help solve the big challenges faced by the subcontinent, such as food security, health threats, learning poverty, and climate change. It

will take stock of existing capacities for digital skills training in Sub-Saharan Africa and propose a vision for improving and expanding digital skills education programs.

1.3 Methodology

This paper relies principally on a desktop literature review of existing documents, including the following sources:

- Official publications and policy documents produced by the Organisation for Economic Co-operation and Development (OECD) and the World Bank;
- National reports prepared by the governments of Sub-Saharan African countries, as well as regional studies prepared by the Association of African Universities, Asian Development Bank, UNESCO, and the International Labour Organization (ILO);
- Recent academic works on the digital economy and digital skills training in OECD countries and Sub-Saharan Africa; and
- National, regional, and international statistics on various dimensions of the digital economy and skills training for the digital transition.

The report is divided into three parts. After this contextual introduction, the first chapter analyzes relevant global case studies of innovation hubs across the world and draws relevant lessons for Sub-Saharan Africa. The second chapter explores what the digital economy means in terms of digital skills requirements. The final chapter examines the present state of digital skills programs offered by African higher education institutions, the main challenges these programs face, and the prospects for scaling up and improving such programs in support of the digital transition.

1.4 Main Messages

The report carries the following main messages:

- Tertiary education produces advanced skills and research outputs that are essential to foster innovation, economic growth, and social progress.
- Advanced digital skills are the backbone of a dynamic workforce capable of enabling innovation and productivity in the context of the digital and green transitions. They are indispensable to making optimal use of the digital infrastructures needed to power emerging technologies and transform traditional economic sectors.
- More than any of the world's regions, Sub-Saharan Africa needs to seize the opportunities of the digital transition to overcome the big challenges it faces, including persistent poverty, slow economic growth, political instability and conflict, vulnerability to climate change, high rates of infectious diseases, and defective social infrastructures.
- While the production of digital skills has increased steadily in recent years, the quality and relevance of computer science and engineering programs and related areas in Sub-Saharan Africa universities leave much room for improvement.

- National governments and higher education leaders in Sub-Saharan Africa must accelerate their efforts to train young people and adults with advanced digital competencies, supported by innovative and resilient higher education systems with modern governance, robust quality assurance, and sustainable financing.

2. Skills and Research in the Knowledge Economy: Lessons from Asia and the Pacific, Europe, and North America

2.1 National Strategies to Promote Innovation in the Knowledge Economy

The innovation strategy articulated by the OECD in 2015 outlines five priorities: (i) the need to strengthen investment in innovation and foster a dynamic business environment, (ii) the importance of investing in an efficient system of knowledge creation and diffusion, (iii) the opportunity to capture the benefits of the digital economy, (iv) the need to foster talent and skills, and (v) the urgent need to improve the governance and implementation of innovation policies (OECD 2015). A strong tertiary education system is vital to support the second and fourth priorities with respect to research and skills.

Along similar lines, the 2021 World Bank higher education strategy reaffirms that tertiary education systems are at the heart of the big social and economic transformations that are required as the world seeks to achieve green and equitable development in the wake of the COVID-19 pandemic. In this context, advanced digital skills are increasingly indispensable for employability, adaptability to rapid technological progress, access to information services, innovation and entrepreneurship, and lifelong learning. Therefore, all the countries on the planet—from the poorest to the wealthiest—need strategically designed and effectively implemented investments in tertiary education to develop their talent and leadership pools, generate and apply knowledge to resolve local, regional, and planetary challenges, and participate actively in the global knowledge economy (Arnhold and Malee Bassett 2021).

Specifically, tertiary education supports knowledge-driven economic growth and poverty reduction strategies by (i) training a qualified and adaptable labor force, including high-level scientists, professionals, technicians, teachers in basic and secondary education, and future government, civil service, and business leaders, (ii) generating new knowledge through basic and applied research, and (iii) providing the platform for accessing existing stores of global knowledge and adapting this knowledge to local use. Universities are unique in their ability to integrate and create synergy among these three dimensions. Sustainable transformation and growth throughout the economy are not possible without the capacity-building contributions of an innovative tertiary education system, especially in low-income countries with weak institutional capacity and limited human capital (Salmi 2017).

As developing economies move up the technology ladder and the gap between them and the leading industrial economies narrows, their need for education and skills at all levels grows, particularly at the tertiary level (Vandenbussche et al. 2006). A wide range of tertiary education institutions with complementary missions are needed to help accelerate industrial change, as they are the source of a growing share of entrepreneurs, managers, and skilled workers. Workers with a quality postsecondary

education are more employable, earn higher wages, and cope better with economic shocks. Economic returns for a tertiary education graduate are the highest in the entire educational system, an average 17 percent increase in earnings per year of tertiary schooling, compared with 10 percent for primary and 7 percent for secondary education (Table 2.1).

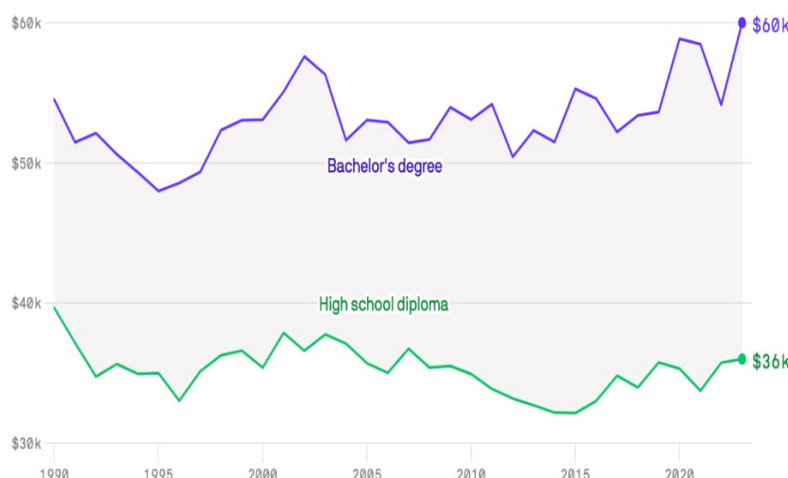
Table 2.1 - Private and Social Rates of Return (percent)

Country Income Category	Private Returns			Social Returns		
	Primary	Secondary	Higher	Primary	Secondary	Higher
Low Income	25.4	18.7	26.8	22.1	18.1	13.2
Middle Income	24.5	17.7	20.2	17.1	12.8	11.4
High Income	25.4	15.1	15.8	15.8	10.3	9.7

Source: Psacharopoulos and Patrinos 2018.

Recent data from the United States confirm the growing gap in earnings between university degree holders and high school graduates over the past two decades, notwithstanding the loss of confidence in the value of a college education. In 2023, recent college grads age 22–27 years old and working full-time earned \$24,000 more per year than 22–27-year-olds with only a high school degree, a wider difference than the \$15,000 of 1990 (Figure 2.1).

Figure 2.1 - Median Annual Wage for Recent High School and Bachelor's Graduates (in 2023 US dollars, 1990–2023)



Source: Federal Reserve Bank of New York.

Furthermore, the wage premium continues to grow over the course of a worker's lifetime. According to Deming (2023), the gap more than doubles. Following a group of college-educated employees through

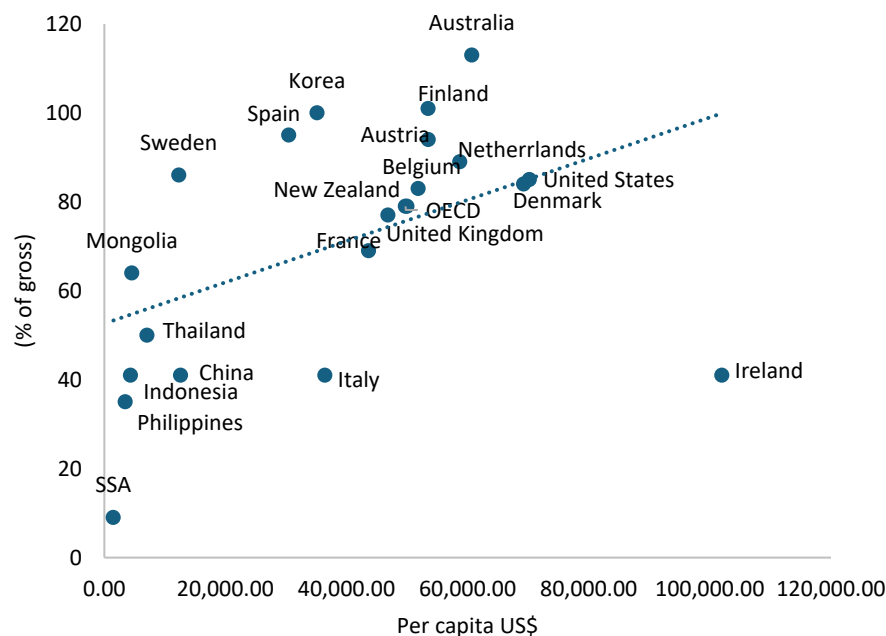
their working lives, Deming found that although they had enjoyed a 27 percent premium over high school graduates at age 25, that premium had reached 60 percent by age 55.

Data from South Africa show a similar difference. In 2023, employees with a bachelor's degree earned 24 percent more than diploma holders, while people with a master's degree received 29 percent more than those with only a bachelor's degree. PhD holders made 23 percent more than employees with a master's degree in a comparable position.³

As countries become richer and their economies diversify, research universities begin contributing to innovation through basic research that generates ideas, and/or upstream applied research and technology transfer that initiates the process of transmuting knowledge and ideas into applications with potential commercial relevance (World Bank 2011).

Higher education is one of the drivers of productivity that makes economies competitive in an increasingly global market. There is a growing consensus that tertiary education is positively associated with economic growth and GDP regardless of a country's development level, as illustrated by Figure 2.2, which shows tertiary education enrollments and per capita GDP for selected countries or groups of countries. Though causality cannot be established, given the many other contributing factors at play, it is a fact that no country or region has achieved, in the long term, high-income status without first achieving a reasonable higher education threshold (World Bank 2011).

Figure 2.2 -Tertiary Enrollment and Per Capita GDP (2021)



Source: World Bank database.

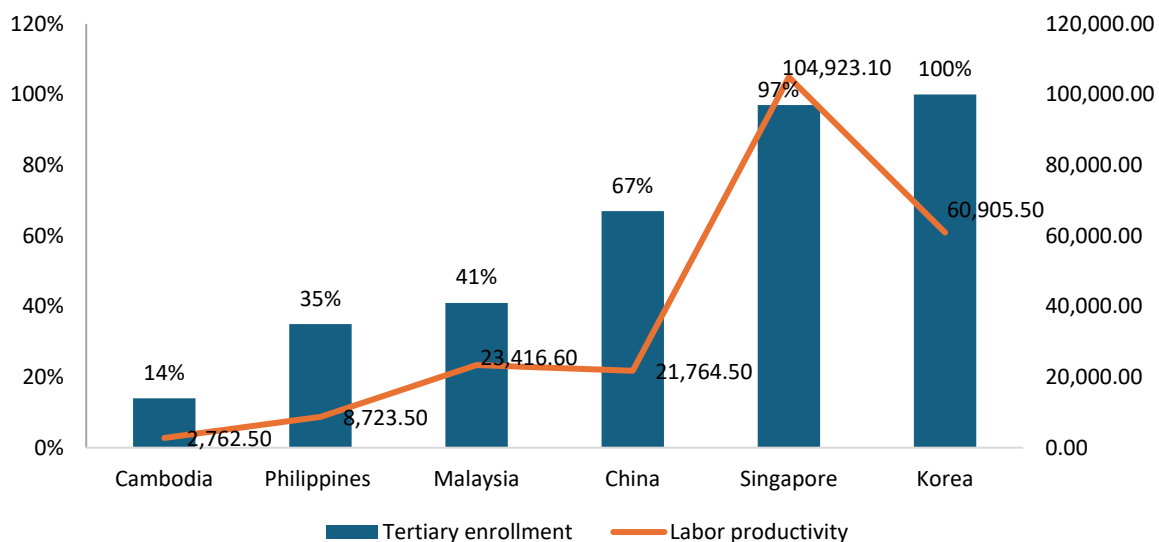
³ <https://www.timedocor.com/blog/average-salary-in-south-africa/>

2.1.1 Strategies for Innovation at the National Level

Lessons from the growth of economies in East Asia and Europe in the past three decades indicate that skills are positively related to innovation and productivity (World Bank 2011). Whether countries are engaged in technological catch-up or moving from catch-up to creation—both being elements of innovation-driven development strategies—higher education has become the principal source of scientific, technical, and analytical skills. A well-trained and highly educated workforce underpins growth as skilled labor can deploy flexibly, achieve high levels of productivity, apply existing technologies, and engage in innovation, thereby increasing a nation's competitiveness. The countries show-cased in the next section share the experience of successfully converting their economies into high-value knowledge economies by investment in higher education and by amplifying the benefits of that higher education through partnerships with industry, including foreign high-tech companies.

In the case of East Asian economies, it is worth noting that they have been absorbing a larger share of exports from the region itself; hence the need for the capacity to adapt technologies while customizing products, processes, and design. Figure 2.3 illustrates the positive relation between labor productivity and levels of higher education enrollment in select Asian countries, with Singapore showing the most dramatic results.

Figure 2.3 - Tertiary Education Enrollment and Labor Productivity (2022)



Sources: World Bank and International Labour Organization databases.

Singapore

The spectacular transformation of Singapore from a poor fishing village without any natural resources at the time of its independence in 1965 to a wealthy and smart city-state 50 years later is one of the most

telling examples. From the outset, Singapore's government has guided its economic growth and transformation path with a clear strategic vision, careful planning, and effective implementation informed by regular systemwide reviews to identify gaps and take corrective actions (World Bank 2022).

Stability in government has allowed the country's leadership to think long term and act accordingly in a consistent and coherent manner. Since independence, Singapore has used development planning based on rolling five-year plans, with broad participation of stakeholders but closely coordinated and controlled at the center of government. Industrial relations were carefully managed, with the federations of unions and employers involved not only in the decision making but also in the implementation of public policy. The government has followed the practice of commissioning systemwide and sectoral reviews of the economy, public administration, and private sector at regular intervals, with the participation of international experts. The findings of these reviews have led to policy adjustments, sometimes radical.

Singapore's economy grew in the 1960s and 1970s, driven by labor-intensive manufacturing. As the country started to lose its comparative advantage in the early 1980s, the government successfully intervened to avoid the middle-income trap by moving its economy up the value chain to advanced manufacturing and knowledge services. From the 1980s, industrial policy sought to build and encourage investment in industrial clusters in niches where current capability, development potential and future expected demand would meet, in industries such as electronics, shipping, and precision engineering, among others. By the early 1990s, this was complemented by a strategy to establish Singapore as a hub for traded business and financial, information technology (IT), and education services. The government aggressively developed the country's technological base through a series of investments in technology programs, starting with information and communications technology (ICT). Throughout the period, investment policy encouraged foreign direct investment in high value-added manufacturing and in services, and it discouraged investment in low value-added activities.

In the absence of any natural resources, talent development has been at the heart of Singapore's vision and strategy from the beginning. The country has successfully built a world-class education system at all levels. Its excellent results in the Program for International Student Assessment tests attest to the quality of basic education. Singapore is renowned for its high-performing universities and technical and vocational education and training (TVET) institutions that produce the middle-level and advanced talent and the research needed by the economy and society. It has invested in the development of science, technology, engineering and mathematics (STEM) programs in the past 20 years. To mention just one example of how talent development has served economic development, the establishment of a research institute on solar energy at the National University of Singapore with an initial US\$130 million budget paved the way for attracting, several years later, a US\$3.5 billion investment by a major Norwegian company, Bluestar Elkem, to set up the first solar panel factory in Singapore.

Singapore has also become a leader in setting up a strong lifelong learning framework under the umbrella of its SkillsFuture agency, which offers guidance, information, recognition of qualifications, and financial resources. As explained by the Committee on the Future Economy, since technologies and jobs

are likely to change throughout our lifetimes, we need to go beyond the pursuit of the highest possible academic qualifications early in life to focus on acquiring and using knowledge and skills throughout our lives as technology replaces routine tasks, our people need to acquire deeper skills to create value, and more importantly ensure that they can utilize their skills effectively on the job.⁴

One of the major strengths of Singapore is that basic education, tertiary education, and TVET have been led by a single ministry working in cooperation with all government agencies driving economic development, notably the Ministry of Manpower, the Ministry of Trade and Industry, and the Economic Development Board, as well as employers' representatives. A recent World Bank study identified the following elements of success in Singapore's tertiary education and TVET strategies: policy coherence over the long term, adaptability to changing circumstances, abundant funding, phased and gradual expansion, continuous and consistent orientation toward the application of international good practice, and achievement of excellence through reliance on international talent and modern governance (World Bank 2022).

The success of Singapore may be seen as a unique experience attributable to its small size, strong and stable government, and favorable location in Southeast Asia, conditions difficult to replicate; however, the impressive transformation of other Asian and European countries, such as Finland, Ireland, and the Republic of Korea, holds similarly relevant lessons worth examining.

Finland

Finland successfully transformed itself from an agriculture-based economy in the 1950s into a leading innovation-driven, knowledge-based economy and high-tech producer within a relatively short span. Interestingly, the conversion into a knowledge economy was triggered by a severe economic recession in the early 1990s, marked by a significant banking crisis, soaring unemployment rates, and mounting government debt. This crisis prompted a strategic shift towards diversifying into new knowledge-based industries and embracing knowledge economy features across all sectors of society. The nation adopted a systematic approach that combined investment in education and the development of innovative clusters, transitioning from an investment-driven to a more innovation-driven economic model. What the government did was to cut most public expenditures except those related to education, research, development, and innovation. In fact, Finland significantly increased its research and development (R&D) spending overall, with investments from both the government and private sector more than doubling. As a result, the country's R&D expenditure reached 3.5 percent of its GDP, surpassing the European Union average of less than 2 percent and the OECD average of about 2.5 percent.

These decisions later proved instrumental in enabling the remarkable growth of the ICT sector. The Nokia-driven ICT cluster, encompassing various aspects from digital content to network infrastructure, equipment manufacturing, and end-user terminals, forms the core of Finland's knowledge economy.

⁴ Government of Singapore, Report of the Committee on the Future Economy, February 2017, 6.

This cluster has experienced significant growth, accounting for more than 10 percent of the nation's GDP and a substantial portion of industrial R&D activities.

From the mid-1990s onward, Finland experienced extraordinary economic growth, with the ICT sector, led by Nokia as its flagship group, at the forefront of this development. The Finnish government had taken an active role in developing digital and mobile communications technologies as early as the 1970s and 1980s. During these decades, the state invested heavily in developing domestic technology and production capabilities through funding collaborative research involving private enterprises, public agencies, and universities. The state also played a role in expanding university degree programs in electronics and information technology, as well as directing technologically demanding government procurement to domestic firms.

Recognizing the pivotal role of education in driving a knowledge economy, Finland has consistently invested heavily in its education system since gaining independence. As reflected by its outstanding results in the Program for International Student Assessment, education is widely considered the bedrock of Finland's innovation-driven knowledge economy, influencing both the supply and demand for innovation. Basic education lays the foundation for developing literacy and other essential skills required in a knowledge economy. Finland has prioritized equal opportunities in accessing education, contributing to the remarkable success of its students, as illustrated by the outstanding results on international assessments in the early 2000s, which made Finland the world's envy. Key characteristics of the Finnish education system include highly competent teachers, universal access to education, a comprehensive regional network of schools that are well resourced, a focus on lifelong learning, high overall educational achievement among the population, and an autonomous governance structure.

The expansion of Finland's higher education system has been aligned with and supportive of economic development; graduates may enter the labor market from three types of institutions: postsecondary TVET institutes offering study programs that provide professional qualifications; universities of applied sciences emphasizing practical connections to industry, with research involving collaboration with enterprises and assisting regional development; and research-intensive universities with close connections between scientific research and teaching.

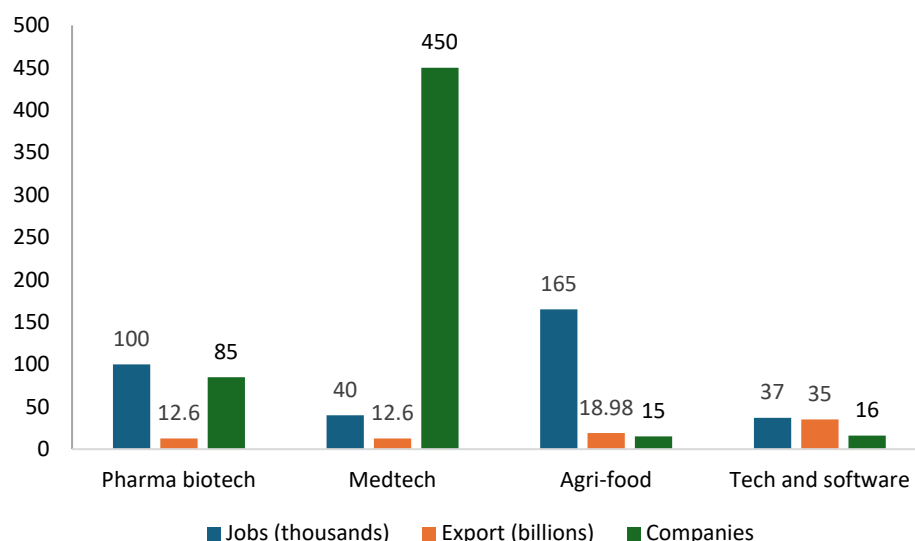
Ireland

Between the end of the 20th century and the beginning of the 21st century, Ireland successfully transitioned from an agrarian and manufacturing-based economy to one driven by knowledge-intensive industries. As a result, the "Celtic tiger" has become one of the wealthiest economies in the world, attaining a per capita GDP of US\$100,000 in 2021. To achieve this impressive result, it implemented several complementary strategies inspired by an ambitious vision, long-term thinking, and a sustained commitment to investing in education and research (McCoy 2016).

First, Ireland actively sought foreign direct investment by providing a competitive corporate tax rate, a highly skilled workforce, and access to the European market to attract multinational corporations. Many

of these, such as Johnson Controls, Eaton, CRH, Medtronic, Accenture, Apple, and Meta set up their European headquarters in Ireland, bringing in knowledge-intensive jobs and technologies (Love 2011). By 2021, Ireland was home to over 1,800 R&D active firms that spent €3.47 billion annually in R&D, a substantive increase from 800 firms active in R&D 25 years earlier.⁵ Figure 2.4 shows the level of R&D in key sectors.

Figure 2.4 - R&D Impact of Key Sectors in Ireland



Source: Dowsett 2024.

Second, the country put in place a supportive ecosystem for start-ups and entrepreneurship that offered funding, mentoring, and networking opportunities. Enterprise Ireland and Science Foundation Ireland were two crucial initiatives that supported innovation and research commercialization at universities and within firms. To promote R&D, the government gave various incentives in the form of tax credits, grants, and other support for innovation to encourage businesses to invest in research and development activities and higher education institutions to set up incubators. Ireland carefully identified and targeted a few sectors with high growth potential, such as information technology (IT), biotechnology, pharmaceuticals, and financial services (Barron 2022).

Third, Ireland invested substantially in upgrading its workforce by improving the quality of education at all levels. This included reforms in the primary and secondary education curriculum, strengthening of teacher training, and efforts to increase access to higher education, particularly in STEM areas. The government actively promoted collaboration between academia and industry to facilitate knowledge transfer, technology commercialization, and skill development. Fourth, to support the development of

⁵ <https://www.myriadassociates.ie/resources/news/which-industries-engage-in-the-most-rd-in-ireland/>

knowledge-intensive industries, Ireland invested in modern infrastructure, including high-speed internet connectivity, research facilities, and business parks (DFHE 2023).

Most universities in Ireland have contributed to country's growth through the technological skills and knowledge of their graduates. Hence, firms have access to global academic knowledge, which in turn results in innovative domestic products and services. It boosts economic growth through increased productivity within existing firms, while at the same time encouraging the proliferation of start-up firms near universities because of their well-qualified graduates.

To consolidate the tertiary education system, strengthen research capacity, and promote collaborations with industry, Ireland encouraged mergers during the second decade of the new century (Harkin and Hazelkorn 2014). Funding under the Program for Research in Third Level Institutions was conditional on close collaborative linkages with firms. The government also supported institutional collaborations through well-financed alliances, such as the Dublin Region Higher Education Alliance, the National Academy for the Integration of Research, Teaching, and Learning, and the National Forum for the Enhancement of Teaching and learning. Trinity College in Dublin and University College Dublin are recognized as instrumental in promoting the tech enclave. The research and innovation centers of these two universities have played a crucial role in the advancements of software, AI, and computer hardware. Intel's research lab at Trinity College Dublin has been instrumental in AI advancements in Ireland. Nuritas, a leading biotech start-up using AI, and Soapbox Labs, a speech recognition AI start-up, have made significant strides. NovaUCD, the Centre for New Ventures and Entrepreneurs that has been the hub of innovation and start-up activities at University College Dublin since 2003, was recently named one of Europe's Leading Start-Up Hubs by the *Financial Times*.⁶

Korea

Korea's transformation from a war-torn nation with very few natural resources to an economic superpower is a remarkable success story. After the Korean War, the country embarked on a path of industrialization and export-oriented growth through a series of five-year economic development plans.⁷ By the end of the 20th century, Korea had become a highly industrialized nation and a leading economy.⁸ Aware that sustaining growth and competitiveness required a shift towards a knowledge-based economy, Korea invested heavily in education, R&D, and ICT, and implemented policies to foster innovation, enhance education, and establish a robust information infrastructure.⁹ This strategy enabled

⁶ <https://www.ucd.ie/innovation/news-and-events/latest-news/novaucd-leading-start-up-hub-europe-ft/name,739369,en.html>

⁷ <https://documents1.worldbank.org/curated/en/923361468327364601/pdf/409300PAPER0KR101OFFICIAL0USE0ONLY1.pdf>

⁸ <https://documents1.worldbank.org/curated/en/409671468048836704/pdf/372280KR0Knowl1my1Overview01PUBLIC1.pdf>

⁹ <https://documents1.worldbank.org/curated/en/923361468327364601/pdf/409300PAPER0KR101OFFICIAL0USE0ONLY1.pdf>

Korea to emerge as a leader in high-tech industries and to maintain its competitive edge in the global economy.

Korea's transition to a knowledge-based economy was built on four critical pillars: a favorable economic incentive regime, an educated labor force, a dynamic innovation system, and a solid information infrastructure.¹⁰ These pillars supported the country's economic development strategy and successive stages of industrialization. To begin with, the government implemented policies to encourage innovation and entrepreneurship, including tax incentives for R&D and support for start-ups. These policies incentivized the efficient use of existing knowledge, the creation of new knowledge, and the dismantling of obsolete activities.

Second, Korea invested heavily in education, particularly in science and engineering fields, to develop a highly educated and skilled workforce. Programs like the Brain Korea 21 initiative in 1999 enhanced the research capabilities of universities and produced a highly skilled workforce capable of driving innovation and economic growth.¹¹ It was followed by the World Class University Project in 2008, which sought to attract and retain international scholars and researchers at Korean universities,¹² contributing to the internationalization of Korean higher education and the development of a globally competitive research environment. Launched in 2004, the New University for Regional Innovation Program began to restructure universities as essential players within regional innovation hubs.¹³

Third, the government developed a robust innovation system through policies that promoted partnerships between academia and industry, supported R&D activities, and facilitated the establishment of innovation clusters. These policies enabled interactions among firms, research centers, universities, and other organizations, fostering the creation and commercialization of new technologies through technology transfer offices, support for university spin-offs and start-ups, and incentives for researchers to engage in commercialization activities (Kim and Jang 2021). By promoting collaboration and knowledge sharing, regional innovation clusters have enabled regions to specialize in specific industries, enhancing their competitiveness and driving economic growth.¹⁴ The most prominent regional clusters in Korea are:

- Daedeok Innopolis, located in Daejeon, is a major innovation cluster that has been instrumental in fostering technological advancements and economic growth in the region. Established in

¹⁰ https://www.oecd-ilibrary.org/science-and-technology/korea-and-the-knowledge-based-economy_9789264188549-en

¹¹ <https://en.snu.ac.kr/research/units/bk21-groups>

¹² https://www.researchgate.net/publication/313504295_Higher_Education_Development_of_Korea_WORLD_CLASS_UNIVERSITY_PROJECT_2008_to_2012#:~:text=There%20are%20three%20main%20types%20of%20WCU%20Projects.&text=Type%201%3A%20Establishing%20new%20academic,Inviting%20distinguished%20world%2Dclass%20scholars

¹³ <https://kdijep.org/v.30/2/157/An+Evaluation+of+NURI+New+University+for+Regional+Innovation+Focusing+on+Changes+in+Graduate+Employment>

¹⁴ <https://www.brookings.edu/articles/the-new-cluster-moment-how-regional-innovation-clusters-can-foster-the-next-economy/>

1973, it is one of the country's oldest and largest innovation clusters, housing over 40 research institutions and 1,000 companies.¹⁵

- Gwangju Photonics Valley, focusing on the development of photonics and optics technologies. This cluster has been instrumental in driving innovation and economic growth in the Gwangju region, with numerous companies and research institutions collaborating to develop cutting-edge technologies.
- Busan-Ulsan Innovation City. This cluster has been instrumental in promoting collaboration between industries, academia, and research institutions, driving innovation and economic development in the region.

Finally, Korea has invested in building world-class ICT infrastructure, including high-speed internet and advanced telecommunications networks for the effective communication, dissemination, and processing of information and knowledge, enabling innovation and economic growth.

2.1.2 Common Strategies

In summary, while the most dynamic countries that have made the transition to becoming knowledge economies have achieved global comparative advantages in different priority sectors, they share core strategic elements: all invested prominently and continuously in education, research, technology, and innovation to deepen and expand their areas of competitive advantages. Table 2.2 shows the range of areas of comparative advantage for selected advanced knowledge economies as well as the top five Sub-Saharan African countries identified as most innovative economies by the Global Innovation Index, taking their income level into account. The numbers in the table confirm the high level of investment in education generally and in research and development made by most of the countries highlighted. It also shows their position in the economic complexity ranking.¹⁶

¹⁵<https://www.innopolis.or.kr/board.jsessionid=E74CF90C07238FEFB6607FC81AADA5B3?menuId=MENU00662&siteId=null>

¹⁶ The economic complexity index, elaborated by Ricardo Hausmann at the Growth Lab at Harvard Kennedy School of Government, measures the relative position of countries with respect to the level of sophistication of the knowledge embedded in the products a country makes and exports and the degree of economic diversification. According to the experts who developed this measure, "the economic complexity of a country is calculated based on the diversity of exports a country produces and their ubiquity, or the number of the countries able to produce them." The economic complexity index is calculated for 133 countries for which reliable data are available. <https://atlas.cid.harvard.edu/glossary>

Table 2.2 - Characteristics of Selected Innovative Economies (2023 or latest year available)

Countries*	Economic Complexity Index	Areas of Competitive Advantage	Share of GDP for Education	Share of GDP for R&D
Japan	1	Car industry, electronics, machine tools	7.4%	3.3%
Switzerland	2	Machinery and equipment, chemical and pharmaceutical products, watches	14.6%	3.4%
Korea	3	Mobile technology, electronics, semiconductors, display panels, and internet connectivity	12.8%	4.9%
Singapore	4	Integrated circuits, processed petroleum oils, machinery for making semiconductors, turbojets	13.3%	2.2%
Czech Republic	6	High tech engineering, electronics and machine-building, steel production, transportation equipment	10.9%	2.0%
Austria	7	Computers, electrical machinery, vehicles, pharmaceuticals	9.0%	3.2%
United Kingdom	8	Aerospace industry, medicine and biotechnology, IT, financial services	5.3%	2.9%
Slovenia	9	Electro motors and machines, household appliances, telecommunication equipment, electronic measuring systems	5.7%	2.1%
Slovakia	12	Automobiles, machinery, steel, chemicals, ceramics	9.4%	0.9%
Ireland	13	Computer software, electrical machinery, processed foods and beverages, chemical products, textiles	12.0%	1.1%
China	18	Electric batteries, hypersonics, advanced radio-frequency communications, artificial intelligence, financial technology, biotechnology, surveillance technologies, semiconductors, space technology	4.0%	2.4%
Romania	19	Electrical machinery, vehicles, computers, mineral fuels	3.3%	0.4%
Belgium	20	Metallurgy, steel, textiles, chemicals, glass, paper, food processing	11.3%	3.4%
Israel	21	Smart agriculture, medicine and biotechnology, defense industry, software	18.4%	5.5%
Denmark	24	Smart food and agriculture, ICT, environmental science, pharmaceutical products and biomedicine	6.9%	2.7%
Eswatini	63	Perfumes and cosmetics, mineral fuels including oil, sugar and sugar confectionery, other chemical goods, clothing, wood	5.7%	n.a.
South Africa	68	Platinum, gold, iron ores and concentrates, tourism	6.2%	0.6%
Mauritius	71	Fish including caviar, sugar, textiles and fabrics, tourism	4.8%	0.3%
Kenya	80	Agricultural products, textiles, coffee, tobacco, iron and steel products, petroleum products, cement, tourism	4.1%	0.4%
Malawi	89	Tobacco, tea, sugar, cotton	3.3%	2.6%

Sources: <https://atlas.cid.harvard.edu/rankings>; <https://www.macrotrends.net/global-metrics/countries>; <https://data.oecd.org/rd/gross-domestic-spending-on-r-d.htm>; <https://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZS?end=2022&start=2021> (for Mauritius, Kenya, Eswatini, Malawi).

* Advanced economies which kept or improved their position in the economic complexity ranking during 2016–21.

2.1.3 Innovation Strategies at the Regional Level

Looking at the impact of human capital development policies at the national level is not the only way of exploring the interface between innovation and higher education. Research from Europe indicates that the regional (subnational) dimension of economic development maybe as important as what happens at the national level, or sometimes even of greater magnitude (Ederer et al. 2011). Within national economies, the most successful regions and cities are those that manage to attract and retain qualified people in employment, improve the adaptability of workers and enterprises, and increase investment in human capital through skills matching and upgrading. This is where innovation clusters emerge, that is, the geographic concentration of interconnected companies, specialized suppliers, service providers, and associated institutions within a particular future-oriented economic sector.

Indeed, the presence of strong universities is important to regional development, through both direct linkages and spillover effects. The successful experiences of technology-intensive poles such as Silicon Valley in California, Research Triangle Park in North Carolina, Bangalore in India's Karnataka State, Shanghai in China, and Campinas in São Paulo State, Brazil, attest to the positive effects that the clustering of advanced human capital alongside leading technology firms can have.

Successful innovation clusters do not happen in a vacuum or in a sui generis manner, however; they are usually the result of a strategic vision supported by deliberate policy decisions and measures, as illustrated by the contrasting outcomes of Oxford and Cambridge in the development of linkages between the university and the local economy (Box 2.1).

Box 2.1 - Creating Dynamic Clusters: The Cambridge Model

The top two British universities, Oxford and Cambridge, are more than 800 years old. They share a similar history and stem from the same academic culture. They are both considered among the best universities in the world. And yet, when it comes to the impact each has had on its respective city, Oxford and Cambridge have followed divergent paths and achieved strikingly different results. Oxford remains an old-fashioned university city, whereas Cambridge has become the “most exciting technology cluster in Europe.” What began in the 1970s with the creation of business parks to welcome entrepreneurial academics and their doctoral students has evolved into a hub of 4,000 knowledge-intensive firms in electronics, pharmaceuticals, biotechnology and other frontier domains. It is today the most dynamic place in Europe, where professors, Nobel Laureates, and angel investors plot their next start-up.

With a productivity level 30 percent higher than London's, Cambridge generates more patents than its next six British rivals taken together, it hosts more billion-dollar firms than cities 10 times its size, and it boasts near full

Box 2.1 (continued)

employment.

The secret to Cambridge's success seems to lie in a balanced approach combining enlightened policies to provide the right infrastructure and economic environment and a laissez-faire attitude that trusts human ingenuity and serendipity. The university, the city council, and the neighboring authorities have worked in a coordinated way to create a favorable ecosystem by setting up science parks and incubators, encouraging the development of business and housing estates, attracting investors and lobbying the government for more open immigration policies. Notwithstanding this coordinated approach, they have kept away from imposing strategic priorities and micromanaging the city's economic development. The city does not decide what type of high-tech industry is more likely to become tomorrow's industry, and the university gives incentives to academics interested in setting up companies, making the membrane between its laboratories and private firms as porous as possible. This has resulted in dynamic partnerships where firms provide advice free of charge and invite students to help them, while academics and angel investors work together to chaperon new companies.

Unlike many universities in the United Kingdom that still work in silos, Cambridge University has been particularly good at stimulating collaboration across academic disciplines. As explained by Jeremy Sanders, one of the university's pro vice-chancellors, the philosophy is to "hire people smarter than you, give them as much freedom and research funding as possible, stand back, and reap the harvest ten years later."

Source: The Economist (2015).

In addition to contributing to the local economy through salaries and the purchase of goods and services, universities can be essential economic agents through relevant applied research and the training of highly qualified professionals and who can help make the local firms more innovative and productive. Universities, polytechnics, and technical institutes fulfill this role in several ways, not only through participating in innovation activity, but perhaps even more importantly by facilitating technology upgrade and absorption.

The following examples from Finland, the United States, and India illustrate how tertiary education institutions have contributed to the development of dynamic regional or local innovation hubs across the planet.

Nokia in Northern Finland

The University of Oulu, founded in 1958, played a pivotal role in shaping the educational and research landscape of Northern Finland, particularly in electrical engineering and telecommunications (Pokidina, Tuuainen, and Mainela 2023). This focus was aligned with the emerging needs of the electronics industry in the region. In the late 1960s and early 1970s, the Oulu Region began exploring the possibility of attracting electronics companies. This exploration led to the establishment of a technology park in

Oulu in 1982, inspired by the success of Silicon Valley and Scotland in attracting investments in the electronics industry.¹⁷

Nokia's expansion into telecommunications was a significant turning point in the development of Northern Finland. The company's focus on cable technology and base stations in the 1960s marked the beginning of a transformation that would position Oulu as a globally recognized center of innovation. Nokia's diversification into telecommunications fostered a high-tech cluster in Oulu and included cooperation with local firms and educational institutions. The University of Oulu's expertise in telecommunications and engineering aligned well with Nokia's core business, creating a symbiotic relationship between the university and the company.¹⁸ The university's strong research capabilities in relevant fields supported Nokia's technological advancements and innovation, contributing to the region's reputation as a high-tech hub. The collaboration between Nokia and the University of Oulu facilitated the development of a skilled workforce and promoted innovation through joint research initiatives and projects. This partnership not only fueled economic growth in Oulu but also played a crucial role in integrating the region into the global technology landscape.

Today, Nokia and the University of Oulu continue to collaborate on several projects, focusing on research related to radio technology and the development of new innovations.¹⁹ Most recently, they strengthened their collaboration by establishing a new research and training center focusing on work around wireless infrastructure for 5G and beyond.²⁰

*Stanford University and Silicon Valley*²¹

One of the most important factors in the origins of Silicon Valley is the historic role of Stanford University in the flourishing and survival of high-technology industries in the surrounding region. Stanford is credited with creating firms that accounted for half the revenues generated in Silicon Valley between 1988 and 1996 and with an exemplary contribution to local labor market needs. As of 2011, nearly 5,000 companies could trace their roots to Stanford, including Hewlett-Packard, Cisco Systems, Sun Microsystems, Yahoo, and Google.

Many observers recognize the unique legacy of Frederick Terman, who started as a young member of Stanford's engineering faculty in the 1930s, became dean of the School of Engineering in 1951, and provost in 1955. Early on, he encouraged his students to consider the commercial possibilities of electronic devices and to engage in multidisciplinary research with theoretical and practical potential. He urged two students, William Hewlett and David Packard, to set up a company, advised them on technical development of their product, helped arrange financing, rented property containing the now-famous garage where they began work, and assisted them in securing patent rights. Terman was

¹⁷ https://pure.coventry.ac.uk/ws/portalfiles/portal/42133770/Hyry2004_PhD.pdf

¹⁸ <https://www.nokia.com/about-us/news/releases/2021/12/03/nokia-to-build-new-campus-in-oulu/>

¹⁹ <https://www.oulu.fi/en/news/nokia-donates-250-000-euros-university-oulu>

²⁰ <https://www.6gflagship.com/news/nokia-donates-250-000-euros-to-the-university-of-oulu/>

²¹ Adapted from NRC (2013), Annex A.

instrumental in the establishment of Stanford Industrial Park, the first University-owned industrial park in the world. By 1977, Stanford Industrial Park was the site of 75 companies with 19,000 employees.

Terman oversaw the establishment of the Honors Cooperative Program at Stanford, in which engineers at electronics companies could enroll in graduate courses to remain current technologically. This program offered an important advantage to small companies that sought to attract top talent but were unable to provide the continuing education and training needed in a fast-changing technological environment. Terman also launched an industrial liaison program pursuant to which company affiliates that pledged \$5,000 a year for five years received access to Stanford's research projects, research results, and graduate students through vehicles such as seminars, guest lectures, and periodic reports.

Stanford's curriculum kept abreast with the rapid pace of ICT development. Each improvement in ICT products and processes was closely followed by the introduction of courses to prepare future engineers to work in the new technology. Stanford's Department of Electrical Engineering introduced a course in the design and fabrication of integrated circuits soon after these devices became available in 1961. Stanford's abiding commitment to offer an up-to-date and relevant curriculum in integrated circuitry led it eventually to establish its Center for Integrated Systems in 1983. Terman sought out the most talented and informed engineers at Silicon Valley companies and appointed them as adjunct professors at Stanford to teach both students and faculty about the most recent developments in the field.

The Stanford Research Institute was established in 1946 to foster innovation that would ultimately spur the economic development of the region. In 1968, an SRI scientist, Doug Engelbart, gave a 90-minute demonstration to an audience of about 1,000 people in San Francisco which was one of the first public demonstrations of the computer mouse, as well as a demonstration of teleconferencing over a computer screen, online collaboration, real-time text editing, and the first use of hypertext links. A member of the audience recalled, 30 years later, that the demonstration was "unlike anything else I've ever seen... just mind-boggling."

Stanford's Office of Technology Licensing opened in 1970, and in the 4 subsequent decades disclosed roughly 8,300 cumulative inventions and executed more than 3,500 licenses. Notable inventions licensed by the office include FM sound synthesis, recombinant DNA technology, functional antibodies, and digital subscriber line technology commercialized by Texas Instruments. The University's very well-known licensee is Google, which was created by two Stanford graduate students over four years while they were working on a project at the library. Larry Page and Sergey Brin, who worked on a project for the library for about four years. They used Stanford resources to develop a search engine that they tried to market to the four biggest search engine companies at the time, but nobody was interested. Katherine Ku of Stanford's Office of Technology Licensing recalls that the two students were frustrated and decided to start their own company. "We gave them an exclusive license, but we didn't know if they knew how to do business. We took a little bit of equity, and eventually that 2 percent share brought in about \$337 million in equity."

Stanford's role in Silicon Valley evolved over generations, and it continues to serve as a model for other institutions and regions seeking to foster local innovation. Georgia Tech recruited a former Stanford dean of Engineering as its president, established innovation institutions patterned on the Stanford Industrial Park and Research Institute, and, like Stanford, has pursued an innovation model based on local start-ups rather than recruitment of established companies to the region.

North Carolina's Research Triangle Park²²

North Carolina's Research Triangle Park (RTP) is strikingly different from what conventional wisdom holds to be the best approach to innovation. RTP did not spontaneously evolve out of the interaction between local universities and the surrounding region; nor has its success been primarily associated with start-up firms, although many start-ups are attributable to RTP. Although local universities were essential to RTP's ultimate success, they were, to some extent, recruited for the effort by local visionaries as part of a broader out-of-state recruitment strategy. RTP "is the only one of the three celebrated high-tech clusters [the others being Silicon Valley and Route 128 in Massachusetts] that was conceived of before it existed, and the only one where government and academia were equal partners with private industry during the initial development phase." RTP was the result of a centrally planned rather than organic process propelled by established firms rather than start-ups.

Thus, RTP is of considerable relevance to regions that have not been blessed with the dense networks of universities and innovative local industries that characterized the Boston area and the San Francisco Peninsula in the first half of the 20th century. RTP was established in the 1950s in one of the poorest regions in the southeastern United States. Today, the RTP region's per capita income greatly exceeds the North Carolina average and is significantly above the US national average.

The idea for RTP is generally attributed to Romeo H. Guest, a North Carolina entrepreneur who was trained as an architectural engineer at MIT, where he saw how research could contribute directly to the local economy. Guest advocated setting up a research center in North Carolina by pooling the resources of Duke University, North Carolina State University, and the University of North Carolina at Chapel Hill, and the recruitment of companies that had a research orientation. At the beginning, the Research Triangle Committee raised some funds from private investors through a for-profit company, but they quickly realized that more capital could be raised more quickly through appeals to wealthy firms and individuals to make contributions on a philanthropic basis based on their interest in serving the state of North Carolina. The funds were used to support the establishment of a separate Research Triangle Institute to perform contract research for government and industry and construct a building for the Institute in the Park.

"Our problem in North Carolina is not essentially technical; we have ... the same scientific information as is available elsewhere; we have the same books and the same facilities for training young people in science. Our problem is essentially cultural—it is the failure to grasp the uses of science in industrial

²² Adapted from NRC, 2013, Annex B.

development, the failure to put to work what is available, the failure to begin those chain reactions of research and innovation and commercialization which are the hall mark of mid-twentieth century life. ... Great advantage will accrue to the University if the Triangle area develops as we hope and becomes known as the research center of the South and as one of the major research and scholarly concentrations in the nation.”²³

RTP opened its doors in 1959 and started to prepare an inventory of the research strengths and faculty activities at the three universities, identifying the presence of significant competencies of potential interest to industry in pharmaceuticals, electronics, and chemistry. Faculty members visited hundreds of firms in the United States and Europe that needed a supply of graduates to staff future research projects and that could be enticed to set up shop at RTP. After a slow start, RTP became more successful when a more supportive governor was elected in 1965 and donated land for the project. The Park became the site of the National Institute of Environmental Health Sciences, at the time the only arm of the National Institutes of Health located outside of Bethesda, Maryland. The same year, IBM agreed to establish a presence in the park, eventually becoming RTP’s largest employer, with 11,000 workers. In the decades that followed, IBM brought about 40 IBM organizations to RTP, including a significant part of its product development and headquarters functions. By the early 2000s, RTP was the base for more than 150 industrial and government facilities employing over 45,000 people, and RTP was regarded as the engine for economic growth in the region. A 2000 study documented over 1,000 technology-based start-ups in the Triangle counties since 1970, over 150 of which were traceable to RTP universities.

In 1963, the North Carolina state General Assembly created the Board of Science and Technology to encourage scientific, engineering, and industrial research applications within the state. The Board initially operated as a grant-dispensing entity modeled on the National Science Foundation, operating the first competitive state research grants programs in the United States.

In the following decades, the Board proposed and acted as an advocate for a significant number of what have become the “state’s core institutional infrastructure organizations,” including the Microelectronics Center of North Carolina, the North Carolina Biotechnology Center, and the North Carolina School of Science and Mathematics. In 2000, the Board instituted the “innovation index” to benchmark North Carolina’s innovation-related performance relative to other states. In 2006, it promulgated the Roadmap for Nanotechnology in North Carolina’s 21st Century Economy to foster nanotech-based economic development in the state. In 2006, it established matching state grants to small businesses in North Carolina that succeed in winning federal Small Business Innovation Research and Small Business Technology Transfer grants.

In 1974, the President of the Research Triangle Foundation began advocating for the three research universities to have a presence within the park. This was achieved the following year in the form of the Triangle Universities Center for Advanced Studies, Inc., a nonprofit. This “park within a park” was unique in science parks in the United States and abroad.

²³ <https://www.ncbi.nlm.nih.gov/sites/books/NBK158811/>

North Carolina's RTP is the foremost US example of a successful innovation cluster established through a state effort to attract established high-tech companies from other states. North Carolina's more recent success in establishing biotechnology clusters demonstrates the continuing viability of out-of-state recruitment as a development strategy in innovation-based, technology-intensive industries. By some key metrics, the state ranks third nationwide (after Massachusetts and California) in the life sciences, and it ranks first in concentration of clinical trial research support firms. Significantly, in contrast to other prominent life science states, only 15 percent of North Carolina's biopharma manufacturers have local origins, and many of them were actively recruited from Europe, Japan, and other US locations.

As it did with respect to research, North Carolina has approached industrial recruiting in the life sciences over a long-time horizon. The North Carolina Biotechnology Center spearheads the comprehensive study of hundreds of prospective biotech company recruits, gathering data and information gleaned informally at conferences and industry events advance knowledge about companies' plans to establish new facilities. BioNetwork, a consortium of community colleges that provide biopharma training, is engaged in the early phases of recruitment deals and can highlight the state's advantages in the workforce area as well as identify and address skills gaps.

Bangalore, Karnataka

Bangalore, India's third-largest city and the capital of Karnataka, has transformed remarkably from a "pensioner's Paradise" in the 1980s into the "Silicon Valley of India."²⁴ Currently, it is the fourth-largest technology cluster in the world. The city's impressive growth in the IT sector and transformation into a global IT powerhouse is the result of proactive government policies, a robust educational infrastructure, a thriving entrepreneurial ecosystem, and a supportive economic environment.

By liberalizing the import and export of computer hardware and software in 1984, the federal government gave easier access to advanced technology and global markets, thus laying the groundwork for companies like Wipro and Infosys to thrive and setting the stage for Bangalore's emergence as a major IT center.

Bangalore's growth into an IT hub began when Texas Instruments established the first overseas development center in the city in 1985. This strategic move set the stage for other global companies to follow, as they recognized Bangalore's potential for software development and IT services.²⁵

Recognizing the potential of the IT industry, the Karnataka government was the first state to formulate an IT policy in 1997. The establishment of Special Economic Zones²⁶ and dedicated IT parks such as Electronics City and the International Tech Park in Whitefield provided the necessary infrastructure and

²⁴ <https://businessgoa.in/how-bangalore-became-a-technology-hub/>

²⁵ <https://thescalars.com/how-bangalore-became-asias-silicon-valley/>

²⁶ <https://www.india-briefing.com/news/special-economic-zones-warehousing-clusters-bengaluru-18943.html/>

incentives to attract not only domestic players but also multinational corporations like Google, Texas Instruments, IBM, Motorola, Microsoft, and Amazon²⁷. Google set up its R&D office in Bangalore in 2003, employing over 1,000 software engineers and computer scientists to work on cutting-edge projects in data mining, business intelligence, and knowledge management. IBM's extensive presence in Bangalore includes multiple research labs focused on artificial intelligence, blockchain, and data security.

Public-private partnerships have helped develop the infrastructure to support the IT industry. Bangalore has become a magnet for venture capital funding,²⁸ significantly boosting its start-up ecosystem. In 2020, the city attracted more than US\$10 billion in investments, a measure of its status as a premier destination for tech start-ups. Leading venture capital firms provide early-stage funding and strategic support, fueling the growth of innovative ventures.

Bangalore's start-up ecosystem is vibrant and dynamic, with more than 10,000 start-ups across various sectors. The city ranks first in India and eighth in the Global Startup Ecosystem Index. Organizations like India's National Association of Software and Service Companies support this ecosystem by providing mentorship, networking opportunities, and industry connections. Successful start-ups like Flipkart, Ola, and BYJU's exemplify the city's robust infrastructure, talent pool, and business-friendly environment.

The Karnataka i4 policy,²⁹ announced in 2014, emphasized IT, IT-Enabled Services, and innovation. To that end, the State government has linked up with countries playing a leadership role in innovation and technology development, such as Australia, Denmark, Finland, and Germany, through the Global Innovation Alliance launched by Singapore in 2017.

Bangalore's advanced infrastructure has been significant in attracting IT companies and talent. The city boasts modern facilities, reliable power supply, and efficient transportation networks, including the Namma Metro and an airport with good connections. Government initiatives and public-private partnerships have driven these developments, creating a conducive environment for the IT industry's growth. For instance, the Karnataka government's IT Investment Region project aims to develop a dedicated IT investment region with state-of-the-art infrastructure, including residential townships, educational institutions, and recreational facilities.

Bangalore's IT sector has evolved from providing outsourcing services to becoming a global R&D hotspot. While the city focused at the outset on cost-effective software development and IT services, it has gradually transitioned to R&D activities, attracting global tech giants to establish centers in the city. This phase saw a shift toward developing cutting-edge technologies, such as AI, cloud computing, and data analytics, further consolidating Bangalore's position as a global IT powerhouse. Today, Bangalore's IT ecosystem encompasses a diverse range of sectors, including e-commerce, fintech, edtech, and healthcare technology.

²⁷ <https://thescalers.com/5-multinational-companies-that-rd-in-bangalore/>

²⁸ <https://addressadvisors.com/blog/commercial-blog-list/why-bangalore-is-a-global-hub-for-start-ups>

²⁹ <https://ebiz.karnataka.gov.in/ebiz/pdf/KarnatakaITPolicy2020-2025.pdf>

Bangalore's cosmopolitan culture and social environment attract global talent. The city's diverse population, vibrant food scene, cultural events, and recreational activities make it an appealing destination for professionals. Additionally, the pleasant climate and lower cost of living compared to other major cities contribute to its attractiveness as a place to live and work.

Though the Indian Institutes of Technology (IIT) do not have a campus in Bangalore, the technical expertise and innovative mindset of IIT graduates have significantly contributed to the growth of the city's IT sector³⁰. Alumni have been instrumental in founding successful start-ups and holding key positions in major tech companies. Notable examples include Flipkart,³¹ founded by graduates of IIT Delhi, and Ola Cabs, co-founded by an IIT Bombay graduate. Moreover, IIT graduates have significantly contributed to leadership and innovation within multinational corporations operating in Bangalore, such as Google, Microsoft, and Amazon. Other higher education institutions have also contributed, including the International Institute of Information Technology Bangalore, established in 1998, which has been crucial in fostering innovation and entrepreneurship through its specialized programs emphasizing experiential learning and industry collaboration, ensuring students are well prepared for real-world challenges.

Bangalore's educational landscape also includes premier institutions like the Indian Institute of Science (IISc)³² and numerous engineering colleges. Established in 1909, IISc focuses on advanced education and research in science and engineering. Its collaborations with industry giants like Wipro and Infosys have led to significant technological advancements. In addition to IISc, Bangalore is home to over 150 engineering colleges that together offer a wide range of programs from computer science engineering to aeronautical engineering. The city's engineering colleges produce a vast pool of skilled graduates who are job-ready and bring fresh ideas and innovations to the table, thus contributing to the thriving IT industry.

2.1.4 Take-Aways

The case studies of innovation clusters explored in this section have shown a range of interactions among the main relevant actors involved, namely universities, start-ups, established firms (including multinational corporations), local authorities, and national policy makers. The contrast between Oxford and Cambridge illustrates variations in strength of connections with the local environment, while the Stanford and North Carolina examples reveal striking differences in terms of policy interventions and focus: creating and nurturing local start-ups versus attracting prominent companies from elsewhere. The Bangalore story, in turn, provides a good example of complementarity between national and state policies in the creation of an innovation-friendly ecosystem. At the same time, the innovation clusters showcased share, to a large extent, common success factors, such as (i) dynamic knowledge institutions

³⁰ <https://computerhistory.org/events/before-bangalore-silicon-valley-how/>

³¹ <https://restofworld.org/2023/iit-graduates-dominate-tech/>

³² <https://thescalers.com/5-initiatives-that-transformed-bangalores-it-ecosystem/>

that contribute skilled graduates, lifelong learning opportunities, leading-edge research, and pioneering technology transfer; (ii) a culture of entrepreneurship and risk-taking; (iii) high levels of networking and collaboration for sharing ideas, resources, and good practices; (iv) sectoral specialization allowing for deep expertise; (v) a favorable policy and regulatory environment; (vi) availability of venture capital; (vi) a rich talent pool combining locally -trained graduates and outside professionals attracted by the opportunities offered by the cluster; and (vii) supportive economic, digital, social, and cultural infrastructure.

2.2 Transformational Entrepreneurship

An additional aspect worth mentioning is the important distinction between subsistence entrepreneurship and transformational entrepreneurship (Shoar 2010). The conditions, policies, and investments that promote and nurture collaboration on innovation also foster transformational entrepreneurship. While subsistence entrepreneurship is primarily focused on survival and is characterized by microenterprises producing mainly for the local market, often limited in their growth potential and job creation, without the vision, capacity, or resources to innovate significantly or scale up, transformational entrepreneurship is focused on growth, innovation, and job creation. These firms are typically larger in scale, have a vision for expansion, and are more likely to drive innovation and productivity in the economy. Such firms often have more educated employees and have the skills and resources to be resilient, adapt to evolving market conditions, and create new opportunities. Transformational entrepreneurs can disrupt existing industries and create entirely new markets, leading to increased productivity and economic dynamism.

2.3 Social Benefits of Innovation

Tertiary education has a strong influence beyond the economic sphere. Nations with high level of educational attainment also enjoy important social benefits. Studies reviewed by the OECD indicate that people with higher education are much less dependent on welfare programs (OECD 2006). A DfID-commissioned literature review of 99 studies worldwide about the impact of higher education came to a similar conclusion: “a positive impact of tertiary-level study on graduates’ capabilities. Impact was shown in areas of health, nutrition, political participation, and women’s empowerment” (Oketch et al. 2014). Through internationalization and shared values of peaceful coexistence and tolerance, higher education institutions can help reduce all forms of conflict. Finally, it is doubtful that any developing country can achieve the United Nations Sustainable Development Goals (SDGs) without a strong higher education system (Salmi 2017). In addition to the essential contribution that higher education can make to the goals of sustainable economic growth (SDG 8) and poverty reduction (SDG 1), progress on all the other dimensions, from developing a vibrant agricultural sector and building up a resilient infrastructure to mitigating the devastating effects of climate change and preserving the environment, cannot happen without the participation of scientists and well-trained professionals and the application of leading-edge research to finding appropriate solutions to the big challenges faced by humankind.

The contribution of higher education is crucial for achieving real progress in education and health. Postsecondary education supports the lower levels of education through the training of teachers and school principals, the involvement of experts in curriculum development and educational research, and the design of appropriate tests to assess students' learning. Similarly, universities train the medical doctors, nurses, technicians, epidemiologists, public health specialists, and hospital managers who are the most important pillar of any health system. Universities and associated health institutes conduct the fundamental research and a significant share of the applied research that condition any significant progress in the fight against diseases and health hazards. This has never been more obvious than during the COVID-19 pandemic.

“When taken as a whole, the body of evidence ... suggests that tertiary education plays an important role in both economic and non-economic development in lower-income contexts.” For years, much of the international literature on tertiary education in lower income contexts emphasized the private benefits to individuals. However, recent studies have indicated that investment in tertiary education also yields significant social returns, both in terms of economic growth and in terms of non-economic benefits. The included studies show a consistent positive impact of tertiary education on societal institutions and on a range of capabilities that have public, as well as private, benefits (Oketch et al. 2014, 48).

3. New Prospects and Challenges for Skills in a Changing World

“If investments in factories were the most important investments in the industrial age, the most important investments in an Information Age are surely investments in the human brain.”

Larry Summers

3.1 Changing Labor Markets in the Digital Era

The 2016 Davos meeting organized by the World Economic Forum (WEF) was a turning point in bringing forth the significance and potential impact of the Fourth Industrial Revolution. Participants exposed ground-breaking developments in fields that were previously separate but have now become increasingly intertwined, such as artificial intelligence and machine learning or biotechnology and genetics (WEF 2016). Though computer science and related disciplines are clearly at the heart of these developments, there is also a substantial degree of overlap across the new areas. Robotics and autonomous systems, which are part of cyber-physical systems, are good examples in that respect. Many developments in these areas feed into each other. Table 3.1 shows how the combination of advanced technologies has blurred the lines among the physical, biological, and digital domains and brought about new development opportunities in numerous scientific fields.

This rapid evolution in the business and production spheres has caused widespread disruptions in labor markets in three related ways: the elimination of many jobs, the emergence of new positions, and the necessity to transform and adapt the content of scores of existing jobs. In the first place, the 2016 WEF report noted that many jobs would be threatened by redundancy as robots and intelligent machines became widely available to replace human beings in the performance of countless routine tasks. Reviewing 700 professions at risk of disappearing over the next 10 to 20 years as a direct result of the growing integration of robotics, artificial intelligence and information technology, Frey and Osborne (2013) estimated that up to 47 percent of total employment in the US labor market was likely to be affected by job computerization resulting from progress in machine learning and mobile robotics.

Another key result of their analysis is that the loss of jobs through computerization is inversely related to educational attainment; they also found that positions requiring creativity, high-level sociocognitive skills, and the ability to deal with complex tasks are safe from being automated. These high-order skills are even more important today as AI amplifies but does not replace human creativity. While AI can assist with the rapid search for information, humans are still in the driving seat in terms of conducting important conversations, resolving conflict, motivating teams, and making value-based choices (WEF 2025). Research consistently shows that the jobs that are most at risk from automation are highly concentrated among lower-paid, lower-skilled, and less educated workers. The implication is that automation will continue to put downward pressure on wages for this vulnerable group, which will accelerate economic inequality.

Table 3.1 - Multidisciplinary Dimensions of New Technologies

New Areas	Disciplines Combined	Potential Applications
Artificial Intelligence & Machine Learning	Computer science, cognitive science, mathematics, statistics	Intelligent systems that learn and adapt
Big Data & Predictive Analytics	Computer science, data visualization, statistics	Analysis and interpretation of large datasets
Internet of Things	Computer science, data analytics, electronics, telecommunications	Connected healthcare devices, industrial automation, smart homes
Cyber-Physical Systems	Computer science, control systems engineering, robotics	Autonomous vehicles, industrial automation, smart grids
Robotics	Computer science, electrical engineering, mechanical engineering	Intelligent systems performing tasks autonomously
Autonomous Systems	Computer science, electrical engineering, mechanical engineering	Independent systems operating independently
Digital Twin Technology	Computer science, data analysis, engineering	Virtual replicas of physical systems
Quantum Computing	Computer science, mathematics, physics	Complex system modeling, cryptography, materials science
Cybersecurity	Computer science, cryptography, data security	Protection of digital systems in all areas
Blockchain and Distributed Ledger Technology	Computer science cryptography, economics	Digital identity verification, secure transactions, supply chain management
Additive Manufacturing (3D and 4D printing)	Computer-aided design, engineering materials science, manufacturing	Aerospace components, custom prosthetics, rapid prototyping
Biotechnology, Bioinformatics, Biomedical Engineering	Biology, computer science, engineering, medicine	Genetic engineering, medical devices, precision medicine for diagnosis and treatment, synthetic biology
Nanotechnology	Chemistry, biology, engineering, materials science	Advanced materials, drug delivery, nanoelectronics
Augmented Reality and Virtual Reality	Computer science, design, engineering, psychology	Gaming, immersive experiences, training simulations
Human-Computer Interaction	Computer science, design, ergonomics, psychology	Accessibility, user experience, user interfaces
Smart Cities	Computer science, environmental science, engineering, urban planning	Efficient resource management, enhanced urban living, sustainable development

Sources: Adapted from World Economic Forum Center for the 4th Industrial Revolution <https://centres.weforum.org/centre-for-the-fourth-industrial-revolution/home>; Interaction Design Foundation <https://www.interaction-design.org/literature/topics/the-fourth-industrial-revolution>

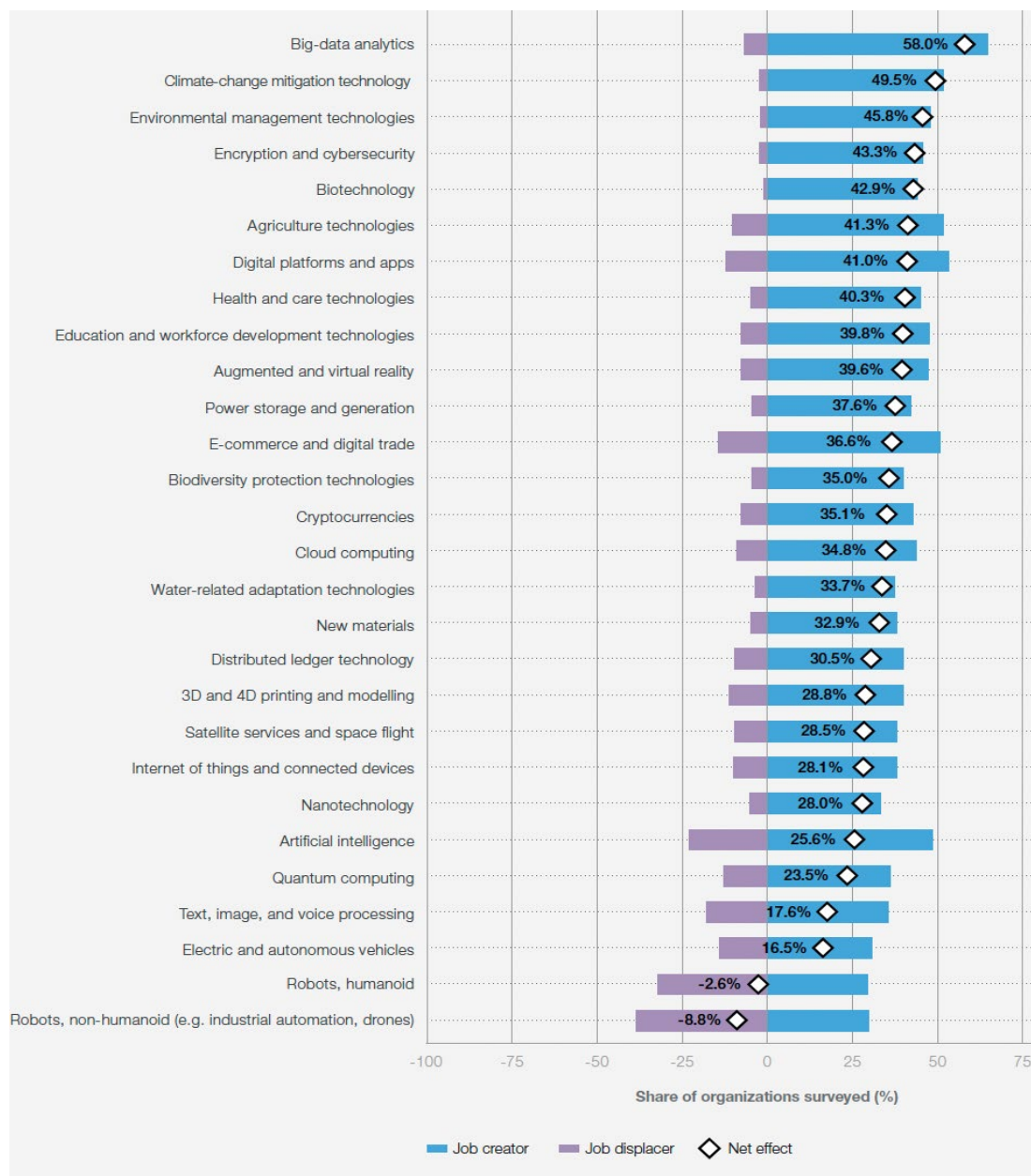
Along the same lines, a report published in 2016 by the Executive Office of the US President revealed that ... “every 3 months about 6 percent of jobs in the [US] economy are destroyed by shrinking or closing businesses, while a slightly larger percentage of jobs are added—resulting in rising employment and a roughly constant unemployment rate. The economy has repeatedly proven itself capable of handling this scale of change, although it would depend on how rapidly the changes happen and how concentrated the losses are in specific occupations that are hard to shift from” (EOP 2016, p. 2). More recently, the WEF’s 2023 *Future of Jobs Report* projected that by 2027, 83 million jobs will be eliminated globally as a result of the digital transition. The report identified administrative roles and traditional manufacturing as the most affected sectors, with significant job losses expected among clerical, secretarial, and data entry positions (WEF 2023).

The second trend is that the growth of the digital economy implies the development of a whole range of new professions and professional positions to be created. The Spanish Observatory of Employment in the Digital Era predicted that 4 out of 5 young people between 20 and 30 years old will work in positions, directly linked to the digital world, that do not exist yet today (*El Mundo* 2016). Among the professions likely to be most in demand are smart factory engineers, chief digital officers, digital innovation specialists, data scientists, expert in big data, smart city architect, director of digital content, expert in digital risks, director of digital marketing, and growth hackers. Firms will particularly be looking for big data specialists and growth hackers. Big data specialists, usually trained in computer science or mathematics, analyze the large databases collected by companies as inputs into decision making on corrective actions and strategic orientations. Growth hackers, coming from informatics, publicity or digital marketing, are trained to identify new areas and modalities that present a great potential for new products and services.

Similarly, the 2023 *Future of Jobs Report* estimates that 69 million jobs will be created by 2027 as a result of the Fourth Industrial Revolution, amounting to a 18 million overall gain (WEF 2023). Figure 3.1 shows the emerging sectors where job growth is most likely to occur, with big-data analytics, climate-change mitigation technology, environmental management technologies, encryption and cybersecurity, and biotechnology leading the way.

Though these positive effects may not play out as strongly in the developing economies that still have a high proportion of employment in the informal sector, they will undoubtedly affect the modern sectors of these economies, where most tertiary education graduates seek employment. Among the effects will be increased opportunities for the development of small and medium-sized enterprises (SMEs). Also, freelancing jobs will become more frequent in a world where production is more and more project based. This means that work and value creation will increasingly be organized around temporary, goal-oriented initiatives rather than traditional, permanent structures like fixed departments or long-term job roles.

Figure 3.1 - Expected Impact of Technology Adoption on Jobs 2023–27



Source: World Economic Forum 2023.

Increasingly linked to the digital economy are the cultural and creative industries, which also represent areas with high potential for the emergence of small companies and employment growth in developing nations, capitalizing on the specific culture and history of each country. In the European labor market, for example, these sectors accounted for 3.3 percent of total employment and 4.2 percent of Europe's GDP in 2015. The most recent data (2021) indicates that the cultural and creative industries' ecosystem generates 500 billion euro every year, accounting for 4.2 percent of Europe's GDP and 3.95 percent of

EU value added. This sector employs about 12 million people, representing about 7.5 percent of total employment in Europe. They are mostly working in SMEs.³³ The performing arts, the visual arts, and music are in the lead, followed by advertising, books, films, TV, architecture, and newspapers.

A few developing countries, India and Nigeria for example, have already shown the way in this direction with the development of their film industries. In Nigeria, the relatively recent success of “Nollywood” has resulted in thousands of new jobs. In 2015, the film industry employed one million people produced 2,500 movies and generated US\$600 million of revenue, up from 400 movies and US\$5 million in 2002 (Onishi 2016). By 2021, Nollywood employed about 300,000 people. Overall, the creative industries are the second employer in Nigeria after agriculture, with a total of 4.2 million persons. A recent UNESCO study projected that Africa’s film and audiovisual industry had the potential to create over 20 million jobs and generate an additional US\$20 billion in annual revenues.³⁴ In Nigeria alone, it is estimated that the creative industries have the potential to produce 2.7 million new jobs by 2025.³⁵ Close linkages between the ICT and creative industries can also materialize, for instance in the form of digital media in art production, or ICT-enhanced tourism.

The third trend is the ongoing transformation of many existing positions to adjust to the digital transition. Though there are no statistics on the number of jobs affected by this evolution, Table 3.2 shows examples of professions likely to undergo a rapid transformation in job content.

Table 3.2 - Digital Transition in Traditional Professions

Profession	Potential Changes
Agriculture	- Precision agriculture: GPS, IoT sensors, and drones to optimize planting, irrigation, and harvesting. - AgTech solutions: integration of sensors, drones, and AI for data-driven decision making to achieve better crop management, pest control, and yield prediction.
Construction	- Building Information Modeling: software to plan, design, and manage building projects more efficiently. - Drones and IoT: Use of drones on construction sites for surveying and IoT devices for monitoring site conditions and equipment.
Manufacturing	- Smart manufacturing: Incorporation of IoT, robotics, and AI to automate and optimize production processes. 3D Printing: faster and less costly prototyping, production, and customization.
Real estate	- Virtual property tours through VR and AR. - Online listings and marketplaces: listings and transactions through digital platforms to facilitate connection between buyers and sellers.
Healthcare	Telemedicine: remote consultations and monitoring through telehealth platforms.

³³ https://single-market-economy.ec.europa.eu/sectors/cultural-and-creative-industries_en

³⁴ <https://businessday.ng/big-read/article/fast-growing-nollywood-creates-the-most-jobs-in-5yrs/>

³⁵ <https://africa.businessinsider.com/local/lifestyle/new-report-shows-nigerias-creative-industry-is-the-countrys-second-largest-employer/mky68v9>

Profession	Potential Changes
	Electronic health records: electronic systems for better patient data management and accessibility.
Education	- Online teaching: online platforms for lectures, assessments, and remote interaction with students. - EdTech integration: educational technology tools like interactive whiteboards, learning management systems, and educational apps to enhance learning experiences.
Retail Commerce	- E-commerce: platforms to sell products and reach a global customer base. - Omnichannel strategies: integration of physical and online operations to provide a seamless shopping experience across multiple channels.
Marketing	- Digital marketing: digital channels such as social media, email marketing, and search engine optimization to reach wider audiences. - Content marketing: creation of valuable, relevant content to attract and engage audiences online.
Finance	- Fintech adoption: innovations like digital banking, blockchain, and automated trading systems. - Data analysis: use of big data and AI to analyze market trends and make informed investment decisions.
Legal	- E-discovery: software to manage and review electronic documents for litigation. - Online legal services: online consultations and services to make legal assistance more accessible.
Public Relations	- Digital PR: social media, content marketing, and online reputation management to shape public perception. - Influencer partnerships: collaboration with social media influencers to reach target audiences more effectively.
Accounting	- Automated accounting software: software to automate bookkeeping, invoicing, and financial reporting. - Data analytics: use of data analytics for deeper insights into financial performance and trends.
Customer Service	- Chatbots and AI: AI-powered chatbots to handle routine inquiries, allowing human agents to focus on more complex issues. - Omnichannel support: support across multiple digital channels, including social media, live chat, and email.
Human Resources	- Digital recruitment: online job boards, social media, and AI-driven recruitment tools to find and hire talent. - Remote work management: virtual onboarding and employee engagement platforms.
Journalism	- Digital journalism: multimedia storytelling, integrating videos, interactive graphics, and social media for enhanced reports. - Data journalism: data analysis and interpretation to uncover trends and stories, using tools like spreadsheets, databases, and data visualization software.

Sources: Adapted from Jobilico 2024, Rautu 2018, and Wavetec 2024.

Note: AI = artificial intelligence; AR = augmented reality; GPS = global positioning system; IoT = Internet of Things; PR = public relations; VT = virtual reality.

3.2 Balancing the Demand and Supply of Digital Skills

In designing their future programs and courses, tertiary education institutions must take notice of the considerable transformation that the labor market is undergoing in the digital era. First, they will need to provide the whole range of digital skills required by both new and existing jobs. Second, they must address the momentous implications of ongoing trends in terms of generic competencies that graduates are expected to possess. This section explores the needs for digital skills; those that follow will look at the necessary generic competences that graduates must acquire for the Fourth Industrial Revolution.

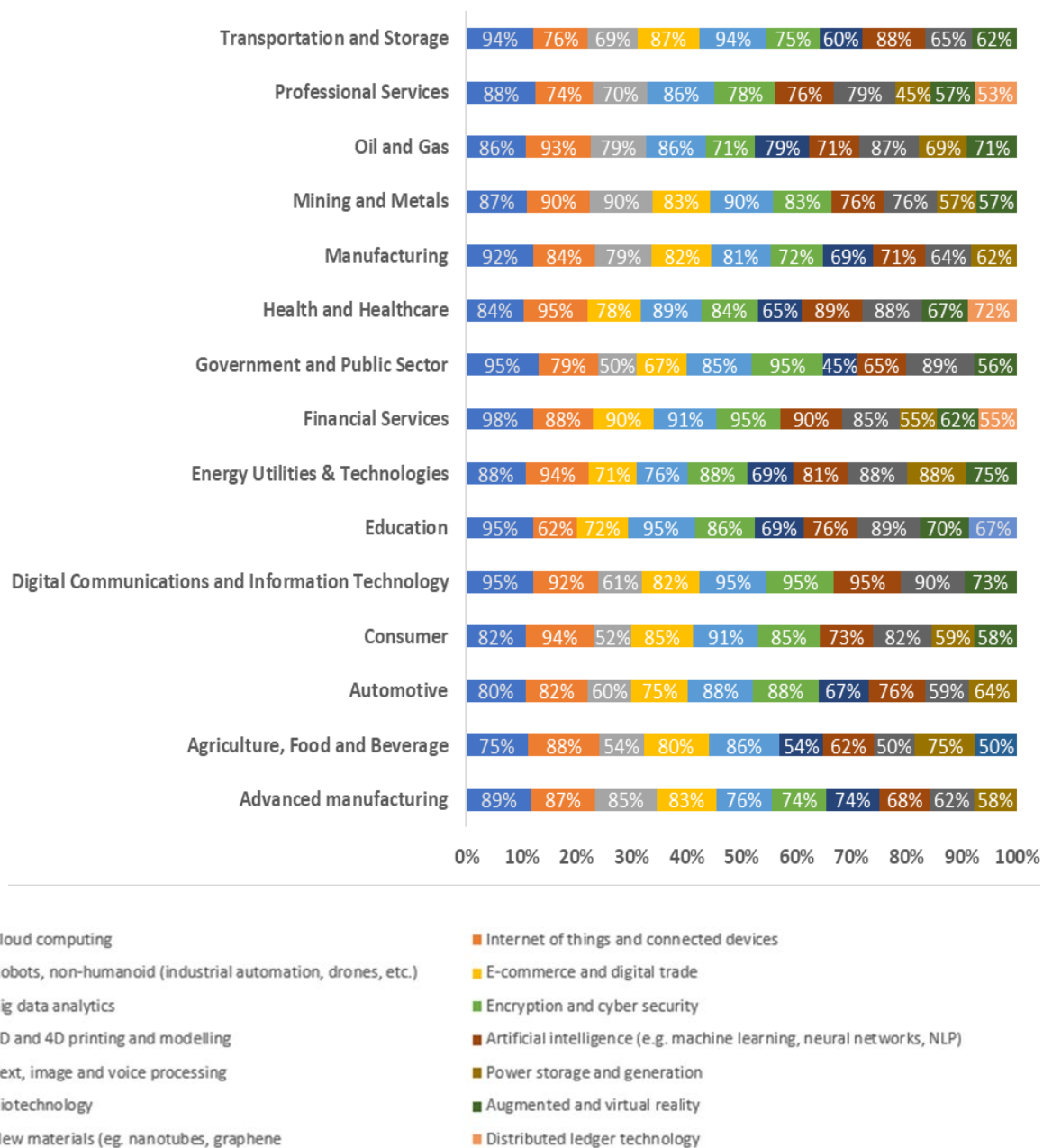
The changing scope of work is making digital skills a decisive attribute for the workforce. In industrial sectors that adopt technology and digitalization, employers are increasingly seeking a digitally skilled workforce. An overview of digital demand in Europe shows a substantial gap between supply and demand. The Digital Economy and Society Index reported that, in 2022, 57 percent of enterprises in Europe found it difficult to fill ICT specialist roles on average (for larger enterprises, this number stands at 64 percent and for SMEs, the share is 56 percent). In 2021, over 9 million persons worked as ICT specialists in European Union countries. Germany recorded the highest number 2 million, followed by France with 1.2 million ICT specialists and Italy with 0.8 million.³⁶

The demand for digital skills is increasing steadily due to the rapid pace of technology change. The adoption of technological innovations such as cloud computing, language models, big data encryption, nonhumanoid robots, artificial intelligence, and e-commerce is shaping business priorities and consumer experiences (Figure 3.2). It is estimated that 84 percent of employers are going to rapidly digitalize working processes, including a substantial growth of remote work. More than 44 percent of workers are likely to operate remotely as a result (WEF 2023).

The WEF conducted an analysis of technology adoption across multiple industries, including advanced manufacturing, agriculture, food and beverages, automotive, consumer, digital communications and information technology, education, energy utilities and technologies, financial services, government and public sector, health and healthcare, manufacturing, mining and metals, oil and gas, professional services, and transportation and storage. These sectors are adopting the following advanced digital skills: AI and machine learning specialists, big data analysts and scientists, information security analysts, process automation specialists, digital transformation specialists, and internet of things specialists.

³⁶ <https://ec.europa.eu/eurostat/databrowser/bookmark/1c09632a-e89f-4788-bda5-350d8afe878a?lang=en>

Figure 3.2 - Level of Technology Adoption across Industries



Source: World Economic Forum 2023.

In this rapidly evolving context, Table 3.3 gives a summary description of the range of digital skills for which training needs to be provided.

Table 3.3 - Digital Skills by Level of Skills

Proficiency Level	Level of Education	Specialized Digital Skills
Basic/Foundational Foundational skills to access and use digital technologies for performing basic tasks	Lower Secondary	Hardware Using keyboards and touchscreens Software Word processing Managing files on laptop Managing privacy settings Basic Online Operations Emails Web search Creating professional online profiles Completing online forms
Intermediate Use of digital technologies and professional software to analyze, create, and manage content	Upper Secondary / Vocational Education and Training Postsecondary Technical - postsecondary technical programs such as certificates, diplomas, or associate degrees	Desktop publishing Digital marketing Digital graphic design Basic programming
Advanced Skills needed to perform specialized ICT tasks	Non-university Tertiary Institutions Polytechnics, institutes of technology, community colleges Undergraduate programs in colleges and universities - bachelor's in mathematics, science, engineering	Programming Cloud computing Network management Web development Search engine optimization AI Big data coding Cybersecurity Augmented and virtual reality Digital entrepreneurship Internet of Things Mobile app development
Advanced Highly specialized	Post-Graduate - Masters and doctorates in applied science, applied mathematics, engineering, technology	Big data technology Data science Computational science and engineering Electrical and electronic engineering Computer science and engineering

Source: ITU 2018; World Bank 2021a.

To illustrate how universities have adapted their program and course offerings to respond to the growing demand for digital skills, Tables 3.4 through 3.7 show the results of a review of relevant programs at five leading universities or technology institutes in Asia, Europe, and the United States. They give a useful overview of the range of programs currently offered by these institutions. At the

bachelor's level, Hong Kong University of Science and Technology and Technical University of Munich offer more options than the other universities. Technical University of Munich leads also at the master's and PhD levels in variety of thematic offerings.

Table 3.4 - Bachelor's-level Digital Education Programs at Selected Institutions

Digital/ICT Bachelor's Programs	Imperial College (UK)	EPFL (Lausanne)	Hong Kong U of Science and Technology	TUM (Germany)	MIT (USA)
Artificial Intelligence and Decision Making					✓
Climate System Science and Engineering					✓
Communication Systems		✓			
Computer Engineering			✓		
Computer Engineering and Economics			✓		
Computer Engineering and Finance			✓		
Computer Engineering and General Business Management			✓		
Computer Engineering and Management			✓		
Computer Engineering and Marketing			✓		
Computer Science		✓	✓		
Computer Science and Economics			✓		
Computer Science and Engineering					✓
Computer Science and Finance			✓		
Computer Science and General Business Management			✓		
Computer Science and Management			✓		
Computer Science and Marketing			✓		
Computer Science, Economics, and Data Science					✓
Computing	✓				
Data Science and Technology			✓		
Data Science and Technology (DSCT)			✓		
Economics, Finance and Data Science	✓				
Electrical and Electronic Engineering	✓	✓			
Electrical Engineering and Computer Science					✓
Electrical Engineering and Information Technology				✓	
Electrical Science and Engineering					✓

Digital/ICT Bachelor's Programs	Imperial College (UK)	EPFL (Lausanne)	Hong Kong U of Science and Technology	TUM (Germany)	MIT (USA)
Electronic and Information Engineering	✓				
Electronic Engineering			✓		
Electronics and Data Engineering				✓	
Engineering and Business Administration			✓		
Environmental Management and Technology			✓		
Informatics				✓	
Informatics: Games Engineering				✓	
Information Engineering				✓	
Information Systems				✓	
Management and Data Science				✓	
Management and Technology			✓	✓	
Mathematics and Computer Science	✓				
Mathematics in Data Science				✓	

Sources: Imperial College - <https://www.epfl.ch/education/master/programs/computational-science-and-engineering/>; <https://www.epfl.ch/education/bachelor/programs/computer-science/>; <https://www.epfl.ch/education/master/programs/>; <https://www.epfl.ch/education/phd/programs/>; <https://www.epfl.ch/education/continuing-education/catalog/>

École Polytechnique Fédérale de Lausanne – EPFL

<https://www.epfl.ch/education/master/programs/computational-science-and-engineering/>
<https://www.epfl.ch/education/bachelor/programs/computer-science/>
<https://www.epfl.ch/education/master/programs/>; <https://www.epfl.ch/education/phd/programs/>
<https://www.epfl.ch/education/continuing-education/catalog/>

Hong Kong University of Science and Technology – HKUST

<https://emia.hkust.edu.hk/extended-major-artificial-intelligence-majorai>
https://ece.hkust.edu.hk/programs/pg_msc_ic; https://ece.hkust.edu.hk/programs/pg_msc_eleg
https://ece.hkust.edu.hk/programs/4yr_ug_beng_cpeg

Technical University of Munich – TUM

<https://www.tum.de/en/studies/degree-programs/detail/robotics-cognition-intelligence-master-of-science-msc>;
<https://www.tum.de/en/studies/degree-programs>
<https://www.tum.de/en/studies/degree-programs#page=5>

Massachusetts Institute of Technology - MIT

<https://catalog.mit.edu/schools/engineering/#degreesandprogramstext>

Table 3.5 - Master's Level Digital Education Programs at Selected Institutions

Digital/ICT Master's Programs	Imperial College (UK)	EPFL (Lausanne)	HKUST	TUM (Germany)	MIT (USA)
AI in Society				✓	
Artificial Intelligence and Decision Making					
Big Data Technology			✓		
Business and IT				✓	
Communication Systems		✓			
Communications and Electronics Engineering				✓	
Computational Mechanics				✓	
Computational Science and Engineering		✓		✓	✓
Computer Science		✓			
Computer Science and Engineering			✓		
Computer Science and Molecular Biology					✓
Computer Science, Economics, and Data Science					
Computing	✓				
Computing (Artificial Intelligence and Machine Learning)	✓				
Computing (Security and Reliability)	✓				
Computing (Software Engineering)	✓				
Computing (Visual Computing and Robotics)	✓				
Cybersecurity		✓			
Data Engineering and Analytics				✓	
Data Science		✓			
Digital Humanities		✓			
Electrical and Electronic Engineering	✓	✓			
Electrical and Electronic Engineering with Management	✓				
Electrical Engineering and Computer Science					✓
Electrical Engineering and Information Technology				✓	
Electronic and Computer Engineering			✓		
Electronic and Information Engineering	✓				

Digital/ICT Master's Programs	Imperial College (UK)	EPFL (Lausanne)	HKUST	TUM (Germany)	MIT (USA)
Electronic Engineering			✓		
Electrical Engineering					✓
Engineering in Computer Science				✓	
Informatics				✓	
Informatics: Games Engineering				✓	
Information Engineering				✓	
Information Systems				✓	
Information Technology			✓		
Information Technologies for the Built Environment				✓	
Integrated Circuits			✓		
Integrated Circuit Design				✓	
Machine Learning and Data Science (Online)	✓				
Management and Digital Technology				✓	
Management and Innovation				✓	
Management and Technology				✓	
Mathematics and Computer Science	✓				
Mathematics in Data Science				✓	
Quantum Science & Technology				✓	
Robotics		✓		✓	
Robotics, Cognition, Intelligence				✓	
Software Engineering				✓	
Sustainable Management and Technology		✓			
Technology Leadership and Entrepreneurship			✓		
Telecommunications			✓		

Source: Same as the sources listed under Table 3.4.

Table 3.6 - Doctoral-Level Digital Education Programs at Selected Institutions

Ph.D. Programs	Imperial College	EPFL	HKUST	TUM	MIT
Civil Engineering and Computation				✓	✓
Computer Science				✓	✓
Computer Science and Engineering			✓	✓	✓
Computing	✓			✓	✓
Electrical Engineering		✓		✓	✓
Electrical Engineering and Computer Science				✓	✓
Electronic and Computer Engineering			✓	✓	
Electrical and Electronic Engineering— Intelligent Systems and Networks	✓			✓	
Electrical and Electronic Engineering- Communications and Signal Processing	✓			✓	
Electrical and Electronic Engineering- Circuit and Systems	✓			✓	
Digital Humanities		✓		✓	
Computer and Communication Science		✓		✓	
Environmental Engineering and Computation				✓	✓

Source: Same as the sources listed under Table 3.4.

Note: At the Technical University of Munich (in Germany), prospective doctoral students can select their own research area and questions. They are encouraged to reach out directly to the most relevant advisor or faculty member for guidance. This approach allows students to explore a wide range of topics, comparable to those offered at the master's level in other universities. As a result, the Technical University of Munich covers most standard doctoral-level research areas while accommodating students' specific interests.

Table 3.7 - Digital Education Certificates at Major Universities / Institutes

Other Courses (Short/Certificate/Diploma)	Imperial College (UK)	EPFL (Lausanne)	Hong Kong U of Science and Technology	TUM (Germany)	MIT (USA)
Extended major in AI			✓		
Data Science and Machine Learning					✓
Applied generative AI for Digital Transformation			✓		
AI for Computational Design and Manufacturing					✓
Applied AI for Technical Innovation				✓	
Smart Farming and IoT in Agriculture				✓	
IT-Security & Privacy Management				✓	
AI in Production Engineering				✓	
Data Science				✓	
Big Data Analysis with Scala and Spark		✓			

Source: Same as the sources listed under Table 3.4.

3.3 Intersections of Digital, Green, and Blue Skills

3.3.1 Greening the Economy

One of the most significant shifts in response to climate change is the transition toward a green economy. This alternative vision for growth and development emphasizes economic growth through sustainable practices that prioritize environmental health, economic viability, and social equity. The United Nations Environmental Programme defines a green economy as low-carbon, resource efficient, and socially inclusive; that is, where growth in employment and income is driven by public and private investment into economic activities, infrastructure, and assets that allow reduced carbon emissions and pollution, enhanced energy and resource efficiency, and prevention of the loss of biodiversity and ecosystem services. The transition to a green economy is driven by technological advancements and a

growing awareness of the need for more environmentally sustainable production and consumption methods. The Intergovernmental Panel on Climate Change has highlighted the importance of climate-friendly options, such as the electrification of cities, urban greenery, and energy efficiency measures, to mitigate the effects of climate change.

The green economy contributes to reducing carbon footprints, and it creates new employment opportunities in some of its key sectors.³⁷ These sectors include renewable energy like solar and wind power, carbon capture and storage, nuclear fusion, electric vehicles, sustainable agriculture, and green construction. As these technologies become more affordable and accessible, they are being adopted more widely, leading to a significant transformation in the job market and the skills required for various occupations. The skills required in these industries range from technical expertise, such as renewable energy technicians and environmental engineers, to planning and management skills, including urban planners and sustainable business managers. Equipping the workforce with these specialized skills is crucial for ensuring that individuals can participate in and benefit from the growth of the green economy.³⁸

3.3.2 Skills Required for the Green Economy

The term “green jobs” encompasses a diverse array of occupations that contribute to preserving or restoring the environment. Green skills contribute to preserving or restoring environmental quality for a sustainable future and include jobs that protect ecosystems and biodiversity, reduce energy, and minimize waste and pollution.³⁹ According to the International Labour Organization (ILO), green jobs can be found in both traditional industries undergoing eco-friendly transformations and emerging green sectors, but they are not solely defined by the production of environmentally friendly goods and services. They can also be identified by their role in making production processes more sustainable, such as reducing water usage, improving waste management systems, or adopting cleaner technologies.^{40, 41}

While this report is not about green skills *per se*, there is a high degree of overlap between digital skills and green skills (Table 3.8). The featured jobs are separated into two groups: existing positions that are changing as a result of the creation of the green economy, and new positions emerging as a result of the digital and green transitions.

³⁷ <https://static1.squarespace.com/static/6197797102be715f55c0e0a1/t/66562d16136b916731176f97/1716923674120/Skills%2Bfor%2Ba%2BSustainable%2BFuture.pdf>

³⁸ https://unesdoc.unesco.org/in/documentViewer.xhtml?v=2.1.196&id=p::usmarcdef_0000245646&file=/in/rest/annotationSVC/DownloadWatermarkedAttachment/attach_import_da754df5-85a2-4d57-9f75-86732c83d6f1%3F_%3D245646eng.pdf&locale=en&multi=true&ark=/ark:/48223/pf0000245646/PDF/245646eng.pdf#%5B%7B%22num%22%3A83%2C%22gen%22%3A0%7D%2C%7B%22name%22%3A%22XYZ%22%7D%2Cnull%2Cnull%2C0%5D

³⁹ https://www.oecd.org/cfe/leed/Greener%20skills_Highlights%20WEB.pdf

⁴⁰ <https://unevoc.unesco.org/home/TVETipedia%2BGlossary/show=term/term=Green%2Bjobs>

⁴¹ <https://www.iberdrola.com/sustainability/what-are-green-jobs>

Table 3.8 - Intersection of Digital and Green Skills

Green Jobs Digital Jobs	Engineering and technology	Science	Operational Management	Regulation and Monitoring
	Evolving Jobs			
Data Analytics and AI	Environmental data analysis	Climate modeling		
	Environmental big data analysis	Ecological modeling		
		Biodiversity informatics		
		Bioinformatics for green biotechnology		
IoT and Sensor Technologies				Environmental monitoring systems
				Carbon emissions monitoring
Geospatial Technologies	Geospatial analysis			
	Sustainable transportation system modeling			
Simulation and Modeling	Renewable energy system design			
	Green building modeling			
	Eco-friendly material design software			
	Green biotech simulation software development			
Specialized Software Development	Environmental impact assessment tools		Energy management systems	Compliance tracking software
			Circular economy software platforms	Regulatory reporting platforms
				Environmental permit management software
Digital Twin Technology			Digital twins for operations	
Supply Chain Management Software			Supply chain optimization	
			Sustainable supply chain tracking	
Computational Biology		Computational biology		

Green Jobs Digital Jobs	Engineering and technology	Science	Operational Management	Regulation and Monitoring
Others	Environmental technician	Environmental scientist	Waste management specialist	Automated compliance auditing
	Solar energy consulting			Environmental impact assessment tools
				Health safety environment officer
New/Emerging Jobs				
AI and Machine Learning		AI for climate prediction		AI-powered regulatory compliance advisor
	Environmental crime analytics	Ecological AI modeling specialist		AI-powered environmental impact prediction
Data Analytics and Visualization	Climate data visualization		Smart grid management systems/smart grid analytics	
Internet of Things (IoT)				Real-time air quality monitoring
				Environmental IoT sensor network specialist
				Environmental DNA monitoring
Blockchain technology			Blockchain for supply chain traceability	
			Circular economy blockchain solutions architecture	
Digital Twin Technology	Digital twin designer for renewable energy systems			
3D Modeling and Simulation	Sustainable construction 3D modeling			
	Green transportation simulation			
	Microgrid modelling			
Geospatial Technologies				Geospatial AI modeling for sustainable land use
Quantum computing		Quantum computing for molecular modeling		

Green Jobs Digital Jobs	Engineering and technology	Science	Operational Management	Regulation and Monitoring
Specialized Software Development		Synthetic biology software development		Automated environmental auditing software development
		Synthetic biology for bioremediation		
Advanced Engineering Software	Hydrogen fuel cell design			
	Carbon capture technology			
	Vertical farming system design			
Predictive Analytics				Predictive maintenance for renewable assets
Industrial Networking			Industrial symbiosis platforms	Environmental crime analytics

Sources: OECD 2019; WEF 2023; ILO 2019; US Department of Energy 2021; Teller and Habans 2022; CEDEFOP 2019; S4YE 2023.

3.3.3 Skills Required for the Blue Economy

Developing the green economy is not the only transformation that most nations must envisage; countries with a seashore should also think seriously about the opportunities that the blue economy can give them to complement their transition to the green economy. The World Bank (2017) defines the blue economy as the sustainable use of ocean resources for economic growth, improved livelihoods, and jobs while preserving the health of ocean ecosystems. Table 3.9 lists the principal economic activities that can be undertaken to expand the blue economy.

Table 3.9 - Activities of the Blue Economy

Area	Activities
Fisheries and Aquaculture	• Sustainable harvesting of fish and other marine life. • Fish farming practices that do not harm the environment.
Marine Biology	• Use of marine organisms for new products and medicines. • Research and development in marine genetic resources.
Marine Resource Extraction	• Responsible extraction of marine resources (oil, gas, and minerals). • Reliance on extraction processes that do not cause long-term harm to marine ecosystems.
Renewable Energy	• Production of energy from ocean resources such as wind, waves, and tides. • Offshore wind farms and other marine renewable energy projects.
Carbon Sequestration	• Harnessing the ocean's natural ability to absorb carbon dioxide to mitigate climate change. • Protecting and restoring blue carbon ecosystems like mangroves, seagrasses, and salt marshes.
Conservation and Sustainable Management	• Protecting marine ecosystems and biodiversity. • Implementing measures to reduce pollution and manage marine resources sustainably.
Marine Spatial Planning	• Careful use of marine spaces to balance environmental, economic, and social objectives. • Ensuring that different activities in marine areas do not conflict with each other.
Shipping and Maritime Transport	• Improving the fuel efficiency of maritime transport. • Reducing the environmental impact of shipping activities.
Tourism	• Promotion of eco-friendly and responsible tourism activities. • Support of coastal communities through sustainable tourism practices.

Source: World Bank 2017.

Table 3.10 gives a list of jobs at the intersection of digital and blue skills. As in the case of the intersection between digital and green skills, the table distinguishes between new jobs and positions that need to evolve as countries try to develop the blue economy.

Table 3.10 - Intersection of Digital and Blue Skills

Blue Jobs Digital Skills	Engineering and Technology	Marine Science	Ocean Resource Management	Marine Policy and Governance
	Emerging Jobs			
Data Analytics and AI	AI-powered ship design engineer	Marine ecosystem AI modeler	Predictive fisheries analyst	AI-assisted policy analyst for ocean governance
			Oceanographic data analyst	
	Marine data scientist		Fisheries data analyst	
Internet of Things (IoT) and Sensors	Autonomous vessel systems integrator	Smart ocean sensor network designer	IoT-based fish farm manager	Marine pollution IoT monitoring specialist
	Aquaculture IoT specialist			
Virtual and Augmented Reality	VR maritime training Simulator Developer	AR-assisted marine species identifier	VR ocean farm designer	VR ocean policy scenario planner
			Marine GIS analyst	
Cybersecurity	Maritime cybersecurity architect	Marine research data protection specialist	Blockchain fish supply chain manager	International maritime cyber law specialist
	Offshore wind farm robotics technician			
	Evolving jobs			
Data Analytics and AI	Smart ship systems engineer	Data-driven marine biologist	Digital aquaculture manager	Marine protected area digital coordinator
	Marine engineer		Oceanographer	
Internet of Things (IoT) and Sensors	Marine IoT security specialist	Underwater IoT maintenance technician	Digital fisheries equipment technician	Smart port operations coordinator
	Aquaculture technician			
Virtual and Augmented Reality	AR-assisted ship maintenance technician	VR coral reef restoration planner	AR fishing fleet manager	AR-enhanced Coast Guard officer
		Marine Biologist	Fisheries Manager	
Cybersecurity	Ship network security Officer	Secure ocean data transmission expert	Digital seafood traceability auditor	Port cybersecurity compliance officer
	Offshore wind farm engineer			

Sources: OECD 2019; WEF 2020; ILO 2019; US Department of Energy 2021; Teller and Habans 2022; CEDEFOP 2019; S4YE 2023.

3.4 Transversal Skills

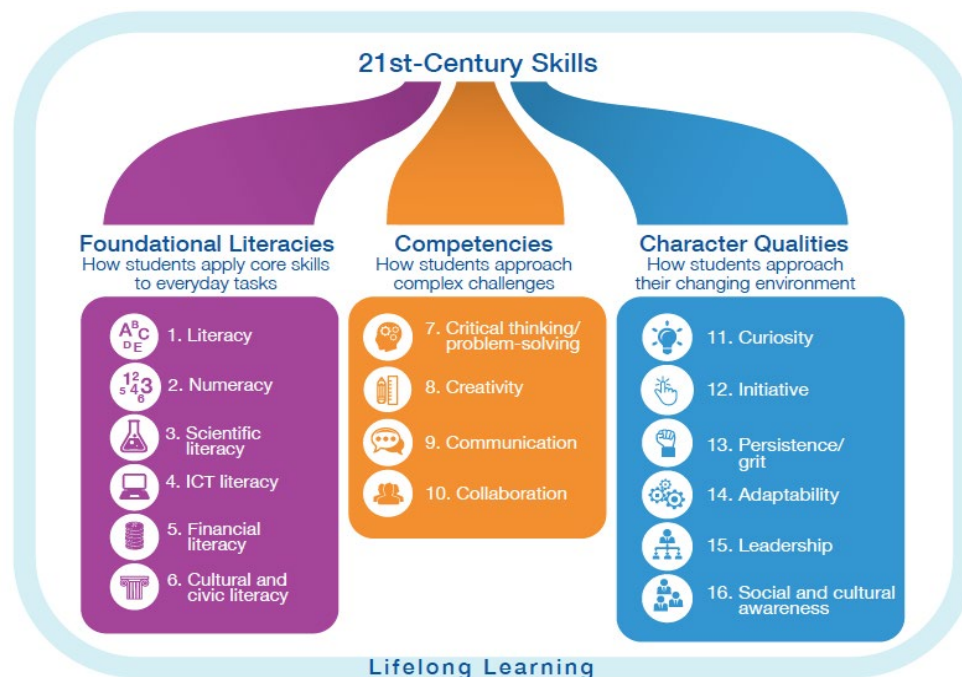
Digital skills are part of a broader skills framework that also includes cognitive and socioemotional skills. These transversal skills help to make digital skills work, especially when it comes to using AI effectively. They go beyond technical know-how and enable people to adapt, collaborate, and think critically in a rapidly evolving digital world. Transversal skills help people understand and evaluate the information proposed by AI platforms and are therefore important for interacting effectively with AI and for making ethical and socially responsible decisions.

3.4.1 Complex Competencies

A meta-analysis of transversal skills carried out by the WEF found that, in addition to acquiring the professional and technical skills needed by the changing labor market, university graduates must also master *complex competencies* to be able to contribute effectively to the production of goods and services (WEF 2015). The four key complex competencies are (i) critical thinking and problem solving, (ii) creativity, (iii) communication, and (iv) collaboration. Critical thinking is the ability to find and analyze relevant information to make a diagnosis of complex situations and formulate adequate responses and solutions. Creative people can imagine and design new, innovative ways of viewing and solving problems through the application, synthesis, or repurposing of knowledge. This skill is of course crucial in creative industries, but it is also indispensable in any industrial or service activity where innovative processes and products can be applied to increase productivity or to find new solutions. Communication is the ability to listen, understand, and explain complex phenomena and to convince others through oral, nonverbal, visual, and written means. Finally, collaborative skills comprise the ability to work well in teams or within networks toward a common goal.

Furthermore, the ability of individuals to become successful professionals and active citizens in their rapidly changing environment is determined by their *character qualities*, also called socio-emotional skills, and commonly misnamed “soft skills.” These include (i) curiosity, (ii) initiative, (iii) persistence, (iv) adaptability, (v) leadership, and (vi) social and cultural awareness. Curiosity, an important determinant of the motivation of learners, is the willingness to ask questions and be open-minded. Initiative is the ability to seek new tasks or new goals in a proactive way. Persistence is the capacity to sustain interest and efforts. Adaptability is the capacity to modify views, methods, plans, or goals in light of new information. Leadership is the ability to inspire, guide, and direct others to achieve a common goal. Finally, social and cultural awareness is the capacity to interact with other people and with the environment in a socially, culturally, and ethically appropriate manner. Figure 3.3 illustrates how the various sets of skills, including the foundational skills imparted at the primary and secondary education levels, are articulated.

Figure 3.3 - Skills for the 21st Century



Source: WEF 2015, 5.

Howard Gardner, who developed the concept of multiple intelligences in the early 1980s, proposed in 2009 an analytical framework encompassing the “five minds for the future” that embody many of the complex competencies and character qualities presented in Figure 3.3:

- The disciplined mind: the need to train and acquire the skills to become an expert in a specific professional area
- The synthesizing mind: the ability to understand, evaluate, use, and communicate information from various sources in a coherent way
- The creating mind: the ability to think outside the box, break new ground, bring out new ideas, ask unfamiliar questions, and conjure up new ways of thinking
- The respectful mind: the capacity to accept and defer to the ideas of diverse groups
- The ethical mind: the capacity to do the right thing under all circumstances (Gardner 2009).

This framework is highly relevant to understanding how AI enhances—but does not replace—human capabilities. It offers a nuanced way to analyze where AI can assist and where human intelligence remains irreplaceable.

3.4.2 Lifelong Learning

Linked to the need for young people to acquire complex competencies is the necessity to prepare them for a lifelong education experience. Lifelong learning enables individuals to keep pace with rapid change

technological and social change, ensuring that they remain relevant and productive in their respective fields.⁴² Lifelong learning should become an essential part of the configuration and operation of tertiary education systems and institutions so that they offer adult learners opportunities to learn through modalities and at times that are convenient for them.⁴³

In a labor market evolving at an unprecedented rate, individuals must adapt constantly, which requires not only a culture of continuous competency and skills development but also a “growth mindset.” The work of Carol Dweck, one of the foremost researchers in this area, has demonstrated that students with a “fixed mindset” react to failure as proof of their lack of ability (Dweck 2007). As a result, failure becomes a self-fulfilling prophecy. By contrast, students and adults with a “growth mindset” take poor learning outcomes as an incentive to work harder on improving their performance. They are also more curious and open to exploring new ideas and learn new methodologies.

*In a fixed mindset, students believe their basic abilities, their intelligence, their talents, are just fixed traits. They have a certain amount and that’s that, and then their goal becomes to look smart all the time and never look dumb. In a growth mindset, students understand that their talents and abilities can be developed through effort, good teaching and persistence. They don’t necessarily think everyone’s the same or anyone can be Einstein, but they believe everyone can get smarter if they work at it.*⁴⁴

Table 3.11 contrasts the main features of the fixed and growth mindsets as envisaged by Dweck.

Table 3.11 - Principal Features of Mindsets

Fixed Mindset	Growth Mindset
Intelligence is static	Intelligence can be developed
Avoids challenges	Embraces challenges
Gives up easily when facing obstacles	Persists despite obstacles
Sees efforts as fruitless	Sees efforts as path to mastery
Ignores useful feedback	Learns from criticism
Threatened by others’ success	Inspired by others’ success

Source: Dweck 2007.

⁴² <https://www.weforum.org/agenda/2024/01/lifelong-learning-past-100/>

⁴³ <https://nuvola.corriere.it/2018/05/19/le-learning-per-la-formazione-continua/>

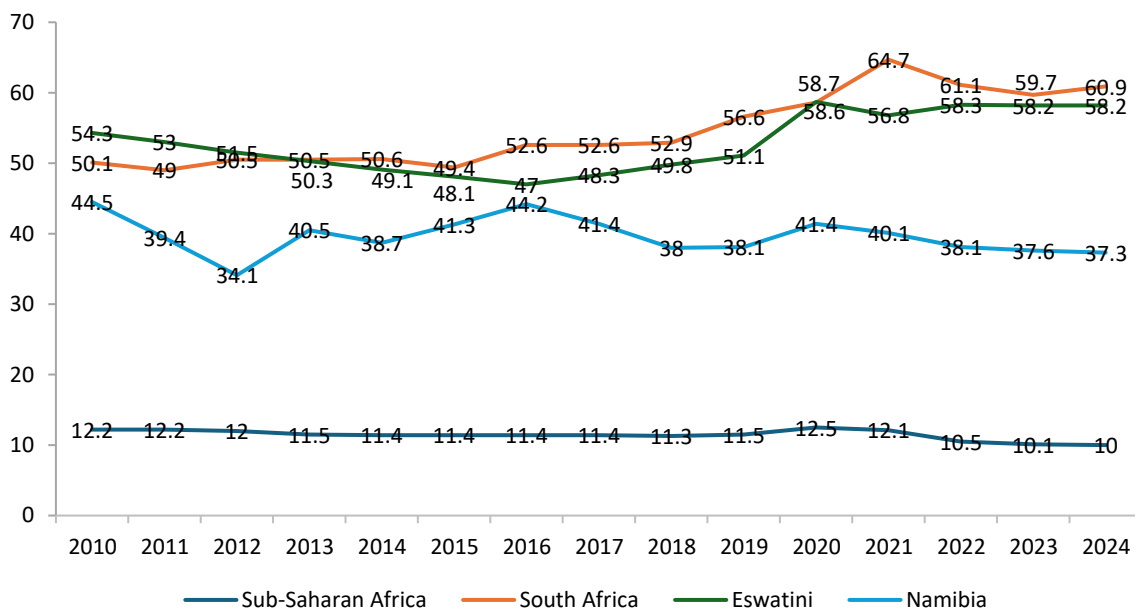
⁴⁴ Interview of Carol Dweck by James Morehead, reported in “Stanford University’s Carol Dweck on the Growth Mindset and Education,” OneDublin.org, June 19, 2012.

4. Seizing Digital Transition Opportunities in Sub-Saharan Africa

4.1 Economic and Social Challenges of Sub-Saharan Africa

Countries in Sub-Saharan Africa face several economic and social challenges, including famine, conflict, natural disasters, and epidemics. Two critical issues have compounded these challenges, namely unemployment and inflation. More recently, the adverse impact of COVID-19 on unemployment and the cost of living has worsened this socioeconomic crisis. Data from the World Bank and ILO show that Sub-Saharan Africa, for example, experienced an unemployment rate of about 6.5 percent in 2019; the rate increased to 6.7 percent in 2020 and 6.9 percent in 2021. This average rate varied across countries as shown in Figure 4.1, which looks at youth unemployment in selected countries before and during the pandemic. The youth unemployment rates of these countries were more than 100 percent higher than the regional average, and some are among the highest globally.⁴⁵ Over 30 percent of youth in these countries do not have incomes and are likely to fall into poverty, especially after the COVID-19 pandemic.

Figure 4.1 - Countries with High Youth Unemployment Rates (age 15–24, percent) in Sub-Saharan Africa



Source: World Bank database.

⁴⁵ <https://www.mercycorps.org/blog/youth-unemployment-global-crisis>

Sub-Saharan Africa continues to grapple with the effects of the pandemic, especially on the long-standing challenge of unemployment. The region's per capita GDP contracted by –1.9 percent in 2020. Although the crisis adversely affected all world regions, Sub-Saharan Africa had the worst experience on record: the slowest growth rate in the world since 2021. The International Finance Corporation (IFC) estimates that per capita GDP in many countries in Sub-Saharan Africa will not reach pre-COVID-19 levels, widening the economic gap between the region and the rest of the world.⁴⁶ The ILO estimates that informal workers, who account for 56 percent to 65 percent of total urban employment, lost about 81 percent of their earnings.

In this context, the high youth population is considered as both a dividend and a potential constraint. The World Bank estimates that Africa's working-age population will grow by approximately 450 million people—about 3 percent per year—between 2015 and 2035, and that by 2050, Africa will have 362 million young people between the ages of 15 and 24 years old (Filmer and Fox 2014). Thus, Sub-Saharan Africa is experiencing a slow demographic transition with a declining death rate, which could lead to a substantial demographic dividend in the economic growth that can result from having a larger proportion of the population in the working-age group relative to the dependents.⁴⁷ The region will continue to experience a growing working-age population (15–64 years), from approximately 643 million people in 2022 to 1.3 billion in 2050.⁴⁸ Based on the estimated youth dividend, a World Bank team projects that if Sub-Saharan African countries made adequate investments in education and training, the skill share of Africa's labor supply could double from 25 percent to about 50 percent, which could expand the regional economy by an additional 22 percent by 2030 (Ahmed, et al. 2014).

However, the current trajectory of Sub-Saharan Africa suggests that the youth dividend could turn into a curse if the right policies are not implemented, especially if the high youth unemployment rates are not reduced. Using skilled human capital for development would require preventing the export of talent, reducing the uncertainties of labor market outcomes, and improving working conditions.

The mismatch between this demographic dividend and the preparedness to accommodate youth for development explains the large flows of youth leaving the region for better opportunities in Europe or elsewhere. According to the African Union, about 70,000 skilled professionals emigrate from Africa yearly.⁴⁹

Inflation remains a serious issue for most SSA countries. The inflationary pressures that the region experiences have worsened in recent years due to climate change, food insecurity, armed conflicts,

⁴⁶ <https://www.imf.org/en/News/Articles/2021/04/12/na041521-six-charts-show-the-challenges-faced-by-sub-saharan-africa>

⁴⁷ <https://thedocs.worldbank.org/en/doc/6e828910dabf285651ff47d684276df7-0010012023/original/002-Africas-Moment-The-Promise-of-Demographic-Dividend.pdf>

⁴⁸ <https://thedocs.worldbank.org/en/doc/6e828910dabf285651ff47d684276df7-0010012023/original/002-Africas-Moment-The-Promise-of-Demographic-Dividend.pdf>

⁴⁹ https://au.int/sites/default/files/newsevents/workingdocuments/32718-wd-english_revised_au_migration_policy_framework_for_africa.pdf

supply chain disruption, and rising commodity prices. According to the International Monetary Fund (IMF), before the pandemic the median inflation rate for the region was 5 percent. It reached an average of 9 percent in July 2022 as advanced economies increased interest rates to fight inflation and international investors grew wary of risks in many Sub-Saharan African countries. In Nigeria, food inflation rose to 32.8 percent as of November 2023.⁵⁰ Similarly, Ghana's inflation rate reached 31.5 percent in 2022, a 10-point increase from 2021, the effect of rising food and energy prices and depreciating local currency.⁵¹

Faced with these multiple challenges that call for urgent solutions, countries in Sub-Saharan Africa can leverage the opportunities offered by the digital revolution to diversify their economies by moving away from agriculture and natural resource exports to accelerate the growth of promising sectors such as technology, finance, and services. Economists have studied the relevance of digitalization in connection with human capital, innovation, economic growth, and productivity. According to research by Bhorat et al. (2023), an increase of 50 percent in the digitization index of a given economy leads to an increase in GDP per capita by 62 percent, other things being equal. For the evidence that digitalization improves human capital, Shrivastava and Shrivastava (2022) found that the ability of digital technologies to transform the education systems and skills ecosystem in India enhances teaching and learning, research, and governance that improves economic growth. Other studies also suggest that digitization is instrumental to the development of systems that reduce information asymmetry, making information more accessible and affordable. Accessibility to information and financial markets improves productivity (Bai et al. 2016; Gao and Huang 2020).

The digital transition can help lower barriers to entry for entrepreneurs, enabling the creation of new businesses and jobs. Digital tools can improve productivity across many sectors and facilitate improved access to essential services such as education, healthcare, and financial services. Finally, embracing digital transformation can enhance the global competitiveness of Sub-Saharan African economies. By adopting advanced technologies and fostering a digital-savvy workforce, the region can attract more foreign investment and integrate itself more effectively into global value chains.

4.2 Level of Digitalization of Sub-Saharan Africa

What is the level of digitalization in Africa, and how does it compare with the rest of the world? The World Bank proposes five dimensions of digitalization; digital infrastructure, digital entrepreneurship, digital finance, digital public platforms, and digital skills (Table 4.1). Bashir and Miyamoto (2020) define these dimensions as follows:

- **Digital Infrastructure** is the tools and equipment required for individuals to engage in digital activities through the availability of widespread, high-quality broadband.

⁵⁰ <https://www.reuters.com/world/africa/nigeria-inflation-2820-yy-november-statistics-office-2023-12-15/>

⁵¹ <https://www.afdb.org/en/countries/west-africa/ghana/ghana-economic-outlook>

- **Digital Entrepreneurship** is the ability of entrepreneurs to easily explore new products and opportunities in the digital space.
- **Digital Finance** is the ability of individuals and households to access and use financial services to pay, save, and borrow.
- **Digital Public Platforms** are systems by which governments provide public services using digital channels of communication and engagement.
- **Digital Skills** are the skills and education required to actively participate in the digital ecosystem.

Table 4.1 - Indicators for Measuring the Five Dimensions of Digitalization

Digitalization Dimension	Indicators
Digital Infrastructure	(i) Fixed telephone subscriptions (per 100 people) (ii) Mobile cellular subscriptions (per 100 people) (iii) Secure internet servers (per 1 million people) (iv) Individuals using the internet (percent of population)
Digital Entrepreneurship	(i) Venture capital availability (ii) Ease of access to loans (iii) ICT services exports (percent of exports in balance of payments)
Digital Finance	(i) Account ownership at a financial institution or with a mobile money-service provider (percent of population age 15+) (ii) Used the internet to pay bills or to buy something online in the past year (percent of population age 15+) (iii) Made or received digital payments in the past year (percent of population age 15+)
Digital Public Platforms	(i) Online service index (ii) E-participation index value
Digital Skills	(i) Secondary gross enrollment ratio (percent) (ii) Tertiary gross enrollment ratio (percent) (iii) Mean years of schooling (iv) Internet access in schools

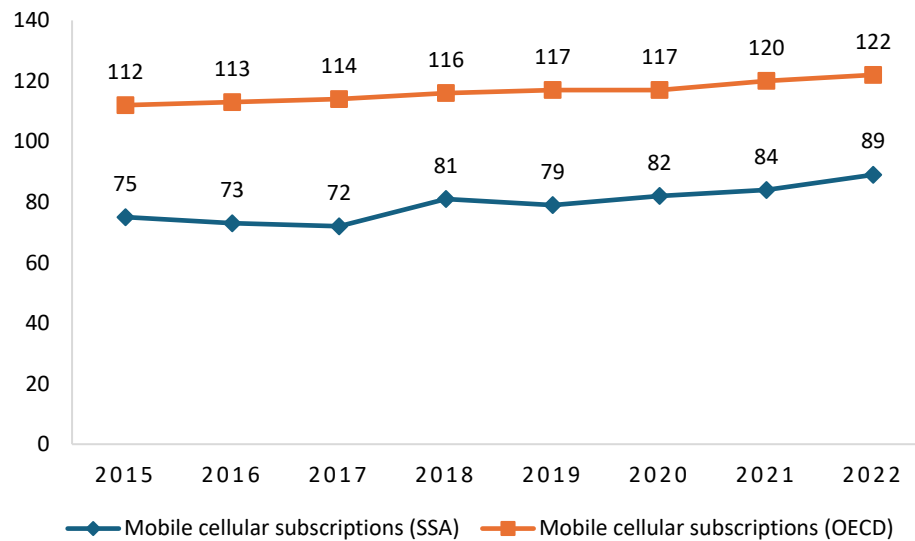
Source: Bhorat et al. 2023.

Note: Authors use other related indicators as proxies in this paper, based on availability of data.

Despite the growing priority given to the digital economy in Sub-Saharan Africa in recent years, the region is still far from fully leveraging the dividends of digital technology services and products. The charts below compare the state of five key indicators in Sub-Saharan Africa and OECD countries. Mobile cellular subscriptions are used as a proxy measure of digital infrastructure (Figure 4.2); automated teller machines (ATMs) as a proxy of digital finance (Figure 4.3); individuals using internet as a proxy to measure basic digital skills (Figure 4.4); secure internet servers as a proxy to measure digital platforms (Figure 4.5); and patents as a proxy to measure digital entrepreneurship (Figure 4.6). The comparison of results between Sub-Saharan Africa and OECD countries across the indicators reveals that Africa is

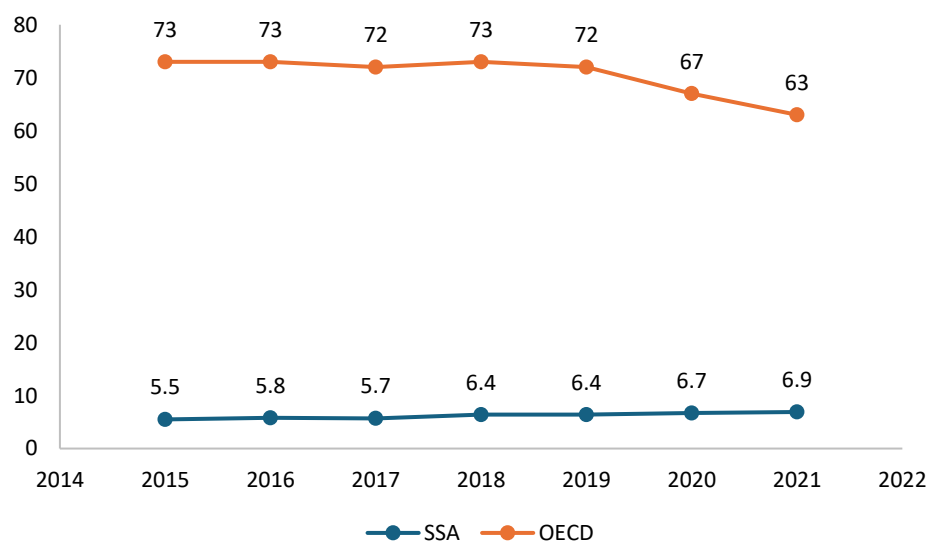
underperforming in digitalization compared to other regions of the world. The charts show the extent to which the digital ecosystem of Sub-Saharan Africa is falling behind other regions of the world. The gap corresponds approximately to a 15–20-year interval.

Figure 4.2 - Comparing Mobile Cellular Subscription in Sub-Saharan Africa (SSA) and OECD Countries (per 100 people)



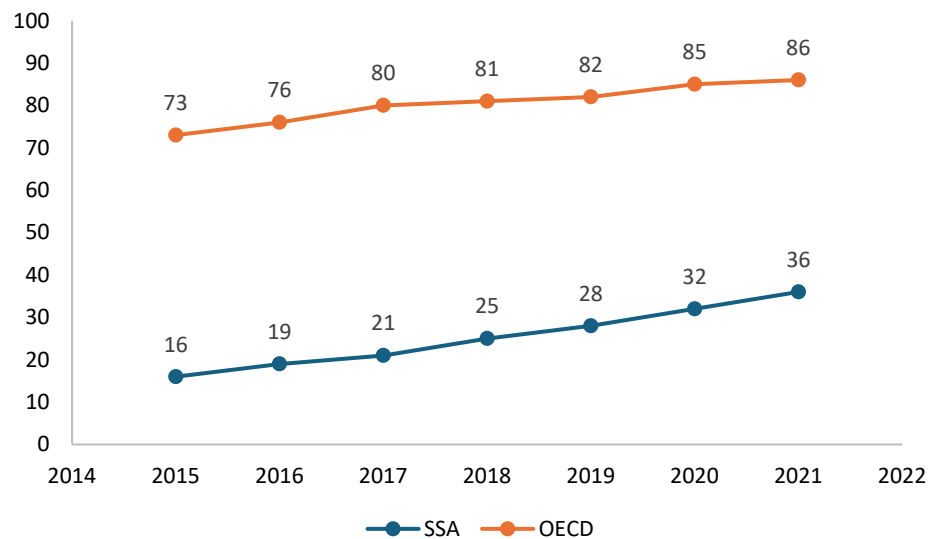
Source: World Bank data.

Figure 4.3 - Comparing ATMs in Sub-Saharan Africa (SSA) and OECD Countries (per 100,000 adults)



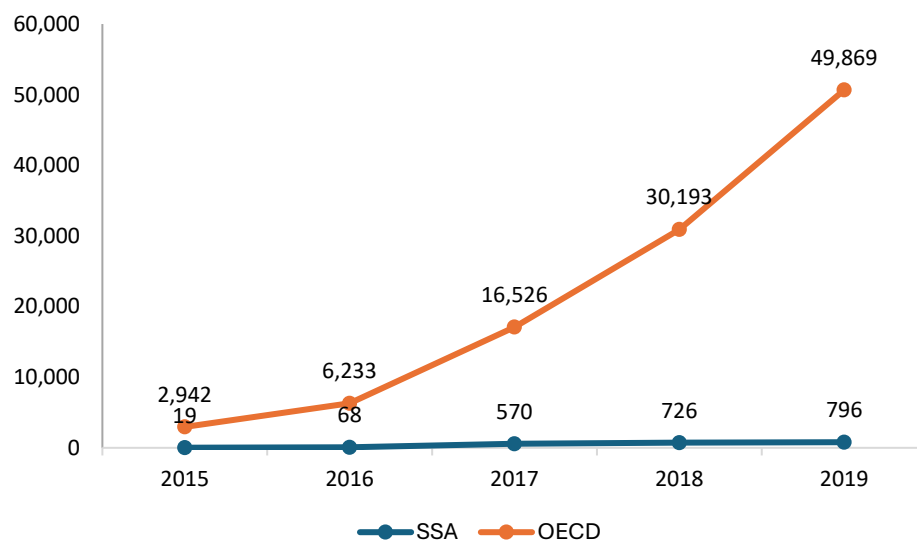
Source: World Bank data.

Figure 4.4 - Individual Internet Usage in Sub-Saharan Africa (SSA) and OECD Countries (percent of population)



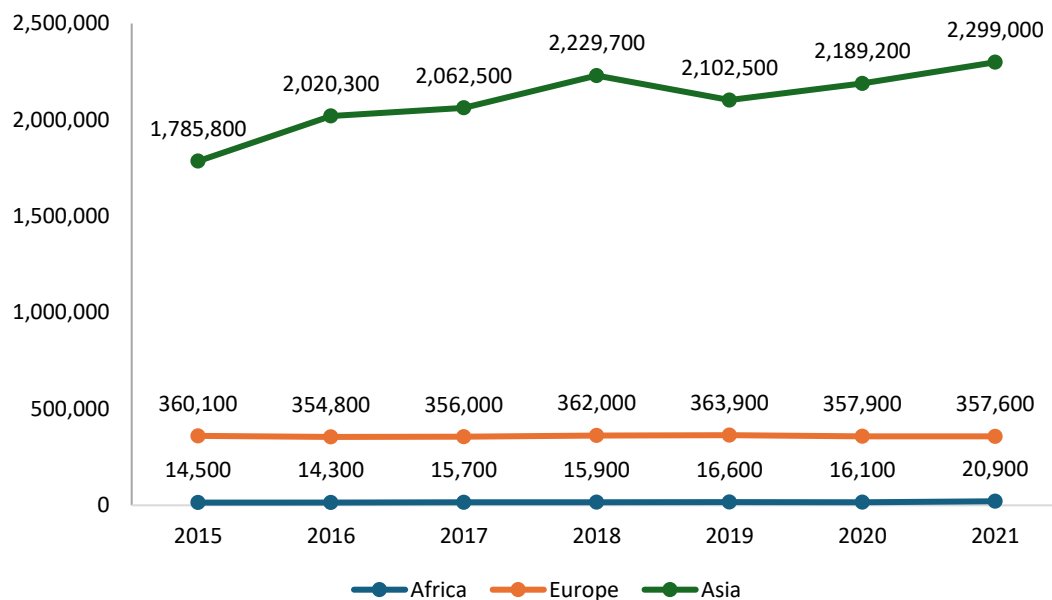
Source: World Bank data.

Figure 4.5 - Comparing Secure Internet Servers in Sub-Saharan Africa (SSA) and OECD Countries (million people)



Source: World Bank data.

Figure 4.6 - Comparing the Number of Patents in Africa, Europe, and Asia

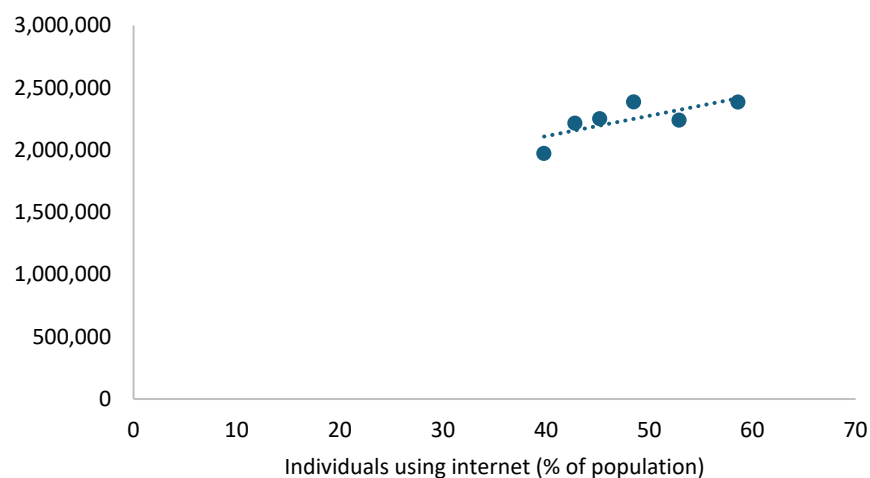


Source: WIPO IP Statistics. <https://www.wipo.int/en/ipfactsandfigures/patents>.

Notwithstanding the lag between Sub-Saharan Africa and the rest of the world, two positive aspects are worth mentioning as they are related to digital skills, innovation, and entrepreneurship. Mobile phone usage and internet penetration have shown a significant increase in coverage between 2010 and 2021. Regarding mobile phone subscription, even though the region has fallen behind OECD countries, there appears to be a meaningful change in the number of subscriptions. For example, from 2005 to 2014, the region observed a 600 percent increase in the number of users per 100 people, from 12 to 69. A similar trend can be observed in internet usage. Between 2000 and 2009 the region did not experience any rapid change in the use of the internet, but 2010 to 2021 shows a big jump. More than half the population is now using the internet. The level of access to cellular connections and the internet on the phone is seen by experts as an indicator of possible digital leapfrog in Sub-Saharan Africa. More than 160 million Africans gained broadband internet access between 2019 and 2022, a 115 percent increase in internet users between 2016 and 2021, and 191 million additional individuals made or received a digital payment between 2014 and 2021.

The study takes an additional look at how access to the internet correlations with patents, which are the proxy for digital entrepreneurship in this paper. The assumption is that the increased internet access will have a positive correlation with patents in the region. The positive correlation presents a case for the relevance of digital skills to innovation and entrepreneurship. Figure 4.7 indicates a high positive correlation of 74 percent between internet usage and patents.

Figure 4.7 - Correlation between Individuals Using Internet and Patent Production



Source: World Bank data.

4.3 Projection of Digital Skills Needs in Sub-Saharan Africa

4.3.1 Overview of the Demand in Sub-Saharan Africa

What is known about the demand for digital skills in Sub-Saharan Africa? The digital and technology sectors are marked for rapid growth. The rate of internet penetration in the region is three times the rate at which other regions are experiencing internet expansion. Global estimates project that Africa's digital economy will reach US\$180 billion by 2025, and US\$712 billion by 2050. One of the main drivers of this expansion is the vibrant innovation ecosystem in areas like mobile financial services, telemedicine, and e-commerce. Many entrepreneurs in these fields lead SMEs⁵² The digital economy of the region had more than 600 technology hubs offering facilities and support for digital innovation, and technology start-ups reached a little over US\$700 million investment in 2020, compared to US\$492 million in 2019 (IFC 2021).

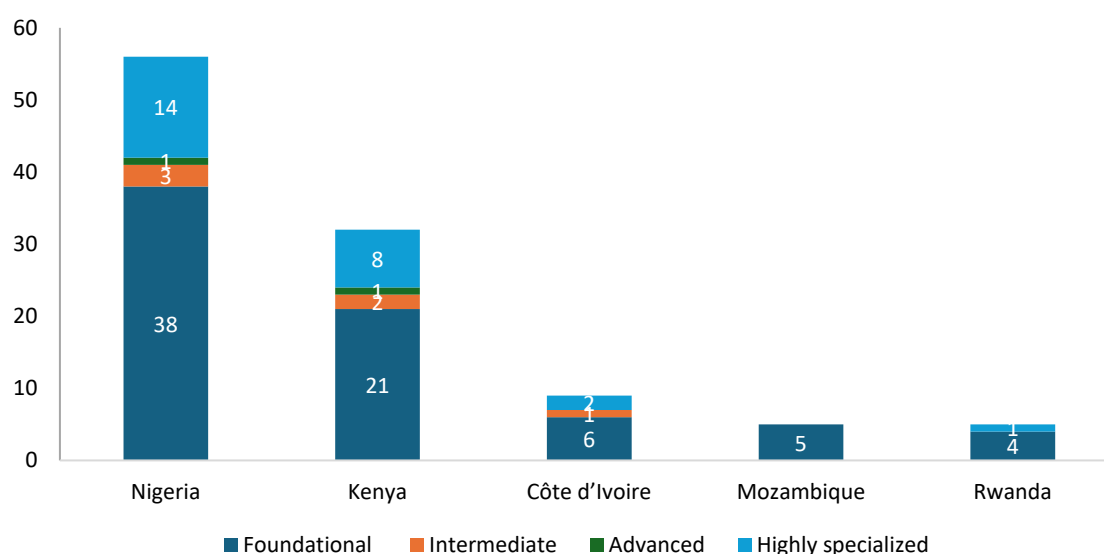
The continent already has 10 unicorns (start-ups valued at over \$1 billion), most of which are fintech businesses. Capturing over 60 percent of venture capital investments in Africa, these firms have the potential to expand into large firms or be acquired by large multinational firms to accelerate development.⁵³ Moreover, because of the digital landscape of their jobs, there will likely be a boost in the demand across Africa. The global job placement network for software developers, Andela, is a positive example of how technology can be leveraged to expand the digital labor economy and exchanges between Africa and other continents. Andela has a community of over 1,000 developers.

⁵² <https://www.bcg.com/publications/2022/africas-opportunity-in-digital-skills>

⁵³ <https://www.forbes.com/sites/alexlarow/2023/09/26/5-reasons-the-future-of-tech-is-african/?sh=4f29c9a82360>

According to the US Bureau of Labor Statistics (2023), 153,900 openings for software developers, quality assurance analysts, and testers were projected for 2024, with an expected yearly growth of 25 percent still 2032. For Sub-Saharan Africa, the World Bank estimates that automation in agriculture, manufacturing, and services will translate into high demand for digital skills. Over 230 million jobs will require digital skills by 2030, resulting in almost 650 million training opportunities in Sub-Saharan Africa; in Ghana alone, over 9 million jobs will require digital skills by 2030. There is a large opportunity for revenue and jobs in digital skilling, and the estimation is about US\$130 billion in potential revenue through 2030 in Sub-Saharan Africa and about US\$4 billion in through 2030 in Ghana (IFC 2019). According to Figure 4.8, other African countries, especially Nigeria, show promising levels of demand for digital skills. Although the demand for foundational skills remains high across Nigeria, Kenya, Côte d'Ivoire, Mozambique, and Rwanda, there is high demand for specialized digital skills in Nigeria and Kenya.

Figure 4.8 - Percentage of Demand, by Country and Level of Digital Skill (2019–30)

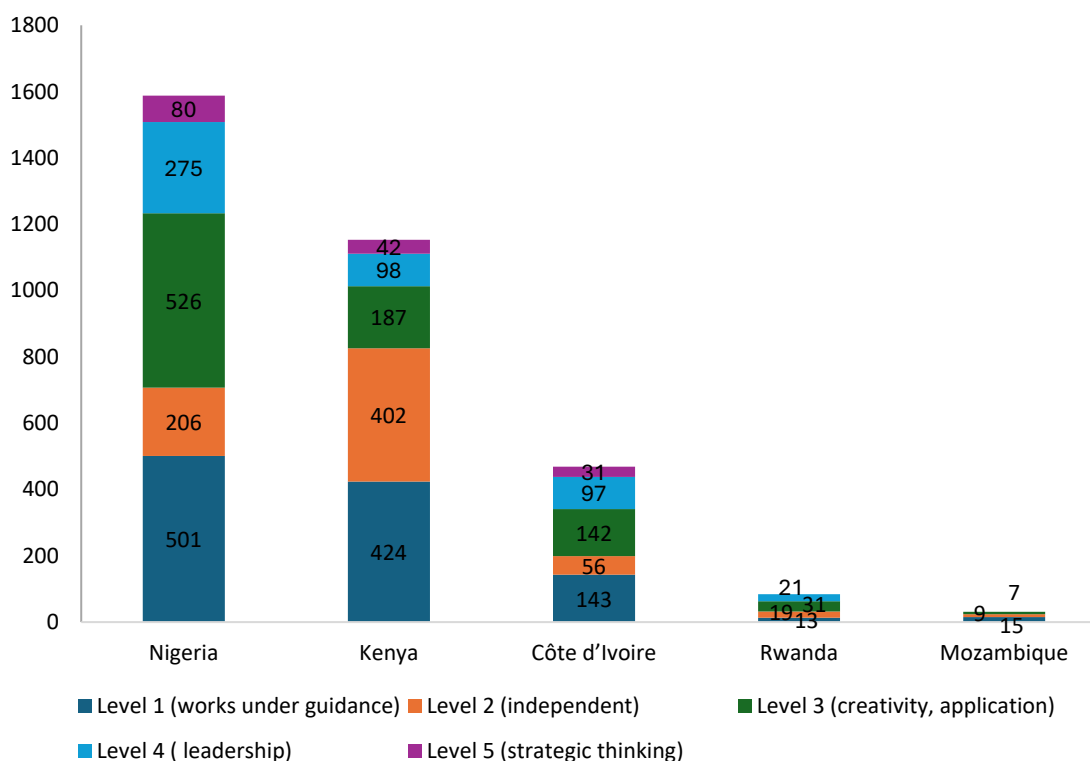


Source: IFC 2021.

The demand for digital skills in other Sub-Saharan African countries is also promising, as illustrated by the results of a study conducted by IFC in 2021 in Côte d'Ivoire, Kenya, Mozambique, Nigeria, and Rwanda (Figure 4.9). It showed that the COVID-19 pandemic accelerated the demand for digital skills, and it estimated that by 2030, digital skills will be required by 50–55 percent of all jobs in Kenya, 35–45 percent of all jobs in Côte d'Ivoire, Nigeria, and Rwanda, and 20–25 percent of jobs in Mozambique. Second, the study revealed that the demand for digital skills would come from occupations outside ICT specialties, that is, from enterprises adopting digital technologies. About 70 percent of the expected demand for digital skill will be for foundational ICT skills and 23 percent will be for non-ICT intermediate skills (Figure 4.10). Third, the study found that there was potential for a total training market of US\$11.1 billion across these five countries through 2030. About US\$5 billion would be for training the new

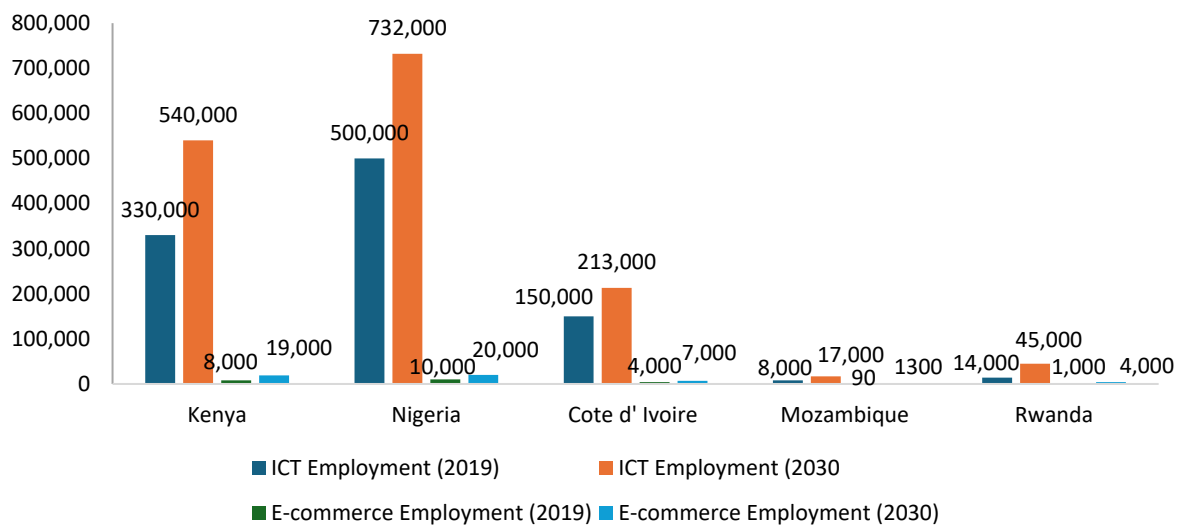
workforce, and US\$6.1 billion for reskilling existing workers. Most of these training opportunities will involve business-to-business, business-to-government, and public-private collaboration.

Figure 4.9 - Workforce Demand, by Country and Level of Digital Skill (2019–30)



Source: IFC 2021.

Figure 4.10 - Expected Demand for Jobs in ICT and E-commerce by 2030



Source: IFC 2021.

4.3.2 Results of Country Surveys

The overview presented in the previous section can be complemented by an analysis of the results of a recent survey of job offerings in Kenya, Nigeria, South Africa, and Uganda, undertaken in partnership with Lightcast, a leading firm specializing in labor market analytics. Tables 4.2 through 4.5 show the evolution of job postings between 2020 and 2024.

Table 4.2 - Trends in the Top 10 Job Titles for Postings with Digital/Advanced ICT Skills in Kenya

2020	2021	2022	2023	2024
Accountant	Accountant	Accountant	Accountant	Accountant
Finance Officer	Software developer	Accountant	Data analyst	Finance manager
Data Analyst	Software engineer	Data analyst	Graphic designer	Graphic designer
Graphic designer	Data analyst	Graphic designer	Finance manager	Accounts assistant
Digital marketer	Finance officer	Finance manager	Save	Data analyst
Communications officer	Data scientist	Business analyst	Communications officer	Senior accountant
Finance manager	Electrician	Data scientist	Software developer	Finance officer
Product manager	Finance manager	Finance officer	Business analyst	Digital marketer
Project manager	Graphic designer	Senior accountant	Devops engineer	Accountant in Kenya
Business manager	Devops engineer	Senior software engineer	Data engineer	Business analyst

Source: World Bank analysis of Lightcast job vacancy data.

Three of the top 10 positions are for digital jobs in Kenya. This proportion has not changed over the past five years.

Table 4.3 - Trends in the Top 10 Job Titles for Postings with Digital/Advanced ICT Skills in Nigeria

2020	2021	2022	2023	2024
Accountant	Accountant	Accountant	Accountant	Accountant
Digital marketer	Digital marketer	Digital marketer	Digital marketer	Social media manager
Graphics designer	Graphics designer	Business manager	Social media manager	Digital marketer
Social media manager	Social media manager	Social media manager	Graphics designer	Graphics designer
Graphic designer	Graphic designer	Full stack developer	Graphic designer	Graphic designer
Data analyst	Full stack developer	Electrical engineer	Data analyst	Full stack developer
Account officer	Business manager	Data analyst	Business manager	Business manager
Digital marketing manager	Digital marketing executive	Finance manager	Finance manager	Finance manager
Senior software engineer	Software developer	Graphics designer	Marketing manager	Marketing manager
Web developer	Finance manager	Graphic designer	Senior accountant	Electrical engineer

Source: World Bank analysis of job vacancy data by Lightcast.

With half of the top positions being for digital jobs, Nigeria has a higher share than Kenya.

Table 4.4 - Trends in the Top 10 Job Titles for Postings with Digital/Advanced ICT Skills in South Africa

2020	2021	2022	2023	2024
Financial manager	Financial manager	Financial manager	Financial manager	Financial manager
Java developer	Java developer	Business analyst	Financial accountant	Financial accountant
Senior Java developer	Business analyst	Java developer	Accountant	Accountant
Financial accountant	Financial accountant	Data analyst	Business analyst	Bookkeeper
Accountant	Senior Java developer	Financial accountant	Data analyst	Financial controller
Management accountant	Software developer	Senior Java developer	Bookkeeper	Business analyst
Graphic designer	Accountant	Software developer	Data engineer	Finance manager
C developer	Data analyst	Accountant	Software developer	Electrical engineer
Business analyst	Full stack developer	Electrical engineer	Project manager	Data analyst
Software developer	Devops engineer	Graphic designer	Electrical engineer	Java developer

Source: World Bank analysis of job vacancy data by Lightcast.

Four of the top positions are for digital positions in South Africa. The proportion is lower in 2024 than it was in 2020, possibly because of higher demand at the beginning of the pandemic.

Table 4.5 - Trends in the Top 10 Job Titles for Postings with Digital/Advanced ICT skills in Uganda

Accountant	Accountant	Accountant	Accountant	Data Analyst
Web designer	Finance officer	Finance officer	Finance manager	Electrical engineer
Finance officer	Finance manager	Senior accountant	Communications officer	Accountant
Data analyst	Database administrator	Data engineer	Finance officer	Meal manager
IT security manager	Senior accountant	Communications officer	Financial controller	Head of sales
Regional finance officer	Data analyst	Business analyst	Data analyst	Country communication officer
Data engineer	Monitoring and evaluation officer	Finance assistant	Graphic designer	Data scientist
IT solutions specialist	Credit analyst	Data scientist	Database administrator	Finance and budget officer
Accountability advisor	Civil engineer	Data evaluation officer	Software engineer	Program officer
Business intelligence analyst	Communication officer	Project manager	Marketing manager	Deputy country finance manager

Source: World Bank analysis of job vacancy data by Lightcast.

As in South Africa, the proportion of digital jobs decreased in Uganda since 2020.

The survey also provided information on job postings for AI specialists (Table 4.6) and data science specialists (Table 4.7). The data reveal a high degree of convergence for both job families across the four countries sampled. With regard to data science jobs, the labor market in South Africa appears to seek more specialized graduates.

Table 4.6 - Top Artificial Intelligence Skills Requirements

Kenya	Nigeria	South Africa	Uganda
Machine learning	Machine learning	Machine learning	Machine learning
Data mining	Data mining	Data mining	Data mining
Artificial intelligence	Google Cloud Platform	Artificial intelligence	Artificial intelligence
Google Cloud Platform	Artificial intelligence	Google Cloud Platform	TensorFlow
Deep learning	TensorFlow	TensorFlow	PyTorch (Machine Learning Library)
Machine learning algorithms	Machine learning algorithms	Deep learning	Keras (Neural Network Library)
TensorFlow	PyTorch (Machine Learning Library)	Machine learning algorithms	Google Cloud Platform
Natural language processing	Deep learning	PyTorch (Machine Learning Library)	Machine learning algorithms
PyTorch (Machine Learning Library)	Artificial neural networks	Natural language processing	Decision tree learning
Computer vision	Keras (Neural Network Library)	Artificial neural networks	Deep learning
Artificial neural networks	Computer vision	Keras (Neural Network Library)	Artificial Neural Networks
Decision Tree Learning	Natural Language Processing	Decision tree learning	Computer vision
Keras (Neural Network Library)	Decision tree learning	Computer vision	
Virtual training	OpenCV	Data profiling	
Data profiling	Machine vision	OpenCV	

Source: World Bank analysis of job vacancy data by Lightcast.

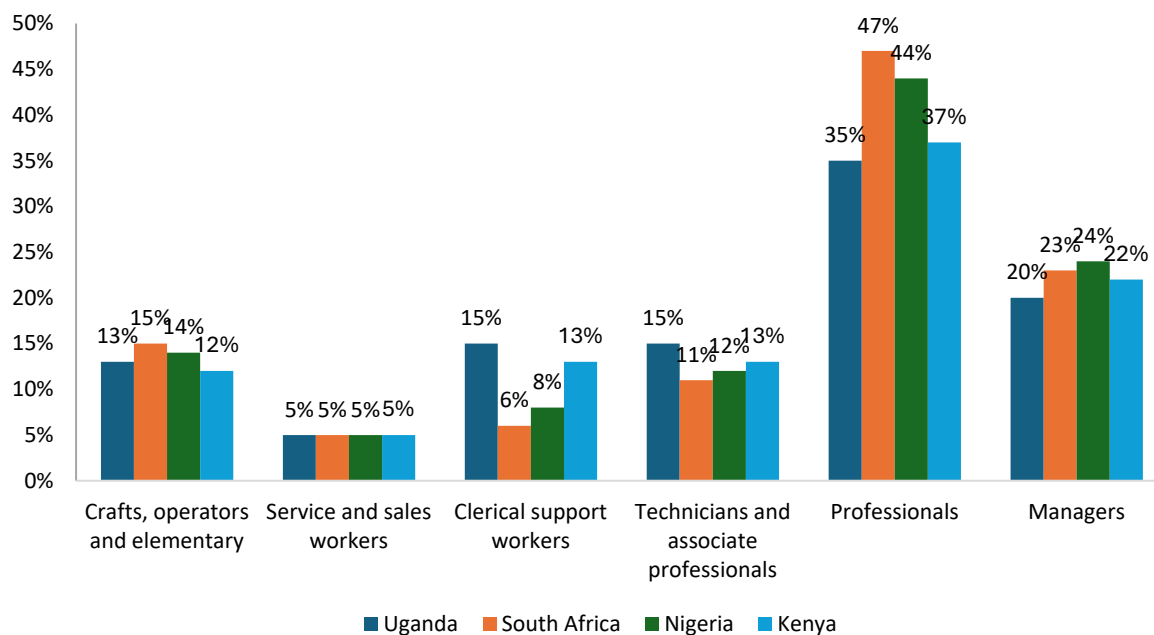
Table 4.7 - Top Data Science Skill Requirements

Kenya	Nigeria	South Africa	Uganda
Data analysis	Computer science	Computer science	Data analysis
Computer science	Forecasting	Forecasting	Computer science
Forecasting	Data analysis	Data analysis	Forecasting
Python (programming language)	Python (programming language)	Python (programming language)	Python (programming language)
Statistics	Analytics	Node.js (Javascript Library)	Statistics
R (programming language)	Google Analytics	Data modeling	R (programming language)
Analytics	Node.js (Javascript Library)	Object-Oriented programming	Data science
Data science	Object-Oriented Programming	Power BI	Tableau (business intelligence software)
Data Visualization	Statistics	Data Science	Data Visualization
Tableau (business intelligence software)	Web analytics	C++ (programming language)	Analytics
Data modeling	Data modeling	Analytics	Google Analytics
Google Analytics	Data science	R (programming language)	Statistical analysis
Power BI	Tableau (business intelligence software)	Data engineering	Power BI
Node.js (Javascript Library)	R (programming language)	Statistics	Data modeling
Statistical analysis	Power BI	Google Analytics	Big data

Source: World Bank analysis of job vacancy data by Lightcast.

Finally, Figure 4.11 presents the proportion of job postings that specifically indicate digital skill requirements across the four countries. Nigeria and South Africa appear to be the two countries where the demand for people with digital skills is highest.

Figure 4.11 - Share of Postings with Skill Requirements of Digital Categories



Source: World Bank analysis of job vacancy data by Lightcast.

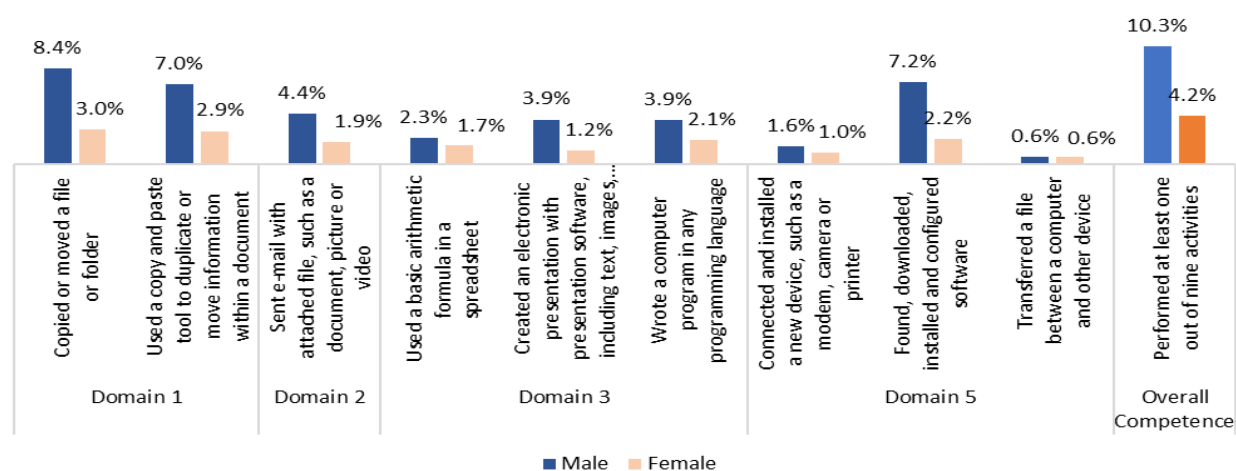
4.4 How Well is Sub-Saharan Africa Producing Digital Skills?

4.4.1 Overview of the Production of Digital Skills in Sub-Saharan Africa

Most African countries have begun to collect data on digital and ICT skills. UNESCO defines ICT as the set of technological tools and resources used to transmit, store, create, share, or exchange information. Examples of these technological tools and resources include different versions of computers, the Internet (websites and email), live broadcasting technologies (radio, television, and webcasting), recorded broadcasting technologies (podcasting, audio and video players and storage devices), and telephony (fixed or mobile, satellite, and vision/videoconferencing.). The degree to which people use these digital systems is an indicator of the level of digital skills.

Opportunities to use ICT in education determine the digital skills and competencies of citizens, especially children and youth. Because not many Sub-Saharan African countries have good data on the digital skills of their populations, Figure 4.12 shows the digital skills status of selected countries that have available data, including Central African Republic, Chad, Democratic Republic of Congo, The Gambia, Guinea-Bissau, Lesotho, Madagascar, Malawi, Togo, São Tomé and Príncipe, and Zimbabwe.

Figure 4.12 - Digital Skills of Youth in Sub-Saharan Africa



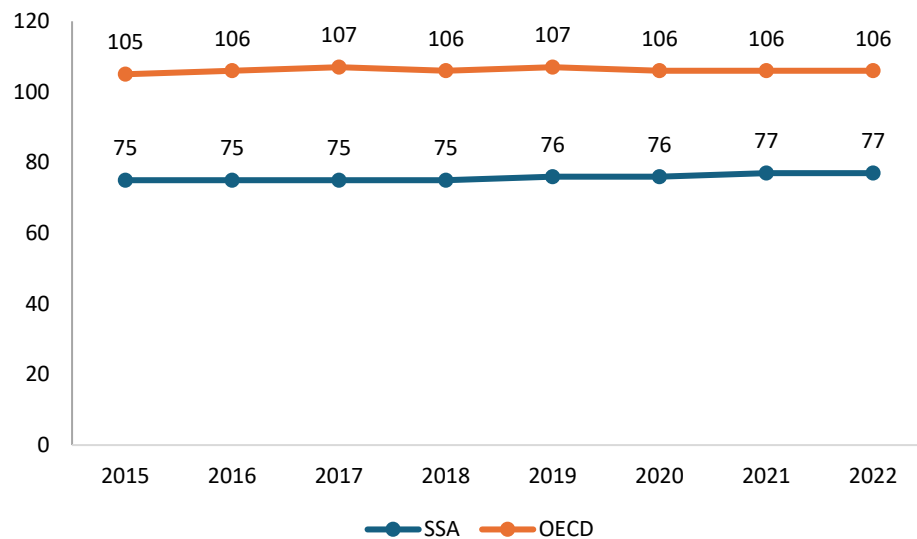
Source: UNICEF database.

According to the DigComp 2.2 framework domains elaborated by the European Commission, the low percentage of Sub-Saharan African youth with some form of digital skills is of concern (Vuorikari et al. 2022). Despite the gender differences, with higher digital skills among males, the overall levels are low compared to Europe and the rest of the world. The statistical office of the European Union indicates that in 2022, 96 percent of young people in the European Union made daily use of the internet, compared with 84 percent for the whole population.

Other important digital skills indicators such as the secondary gross enrollment ratio (Figure 4.13), the tertiary gross enrollment ratio (Figure 4.14), and the percentage of STEM graduates in tertiary education (Figure 4.15). The data presented in the three graphs clearly indicate that Sub-Saharan Africa is behind the rest of the world.

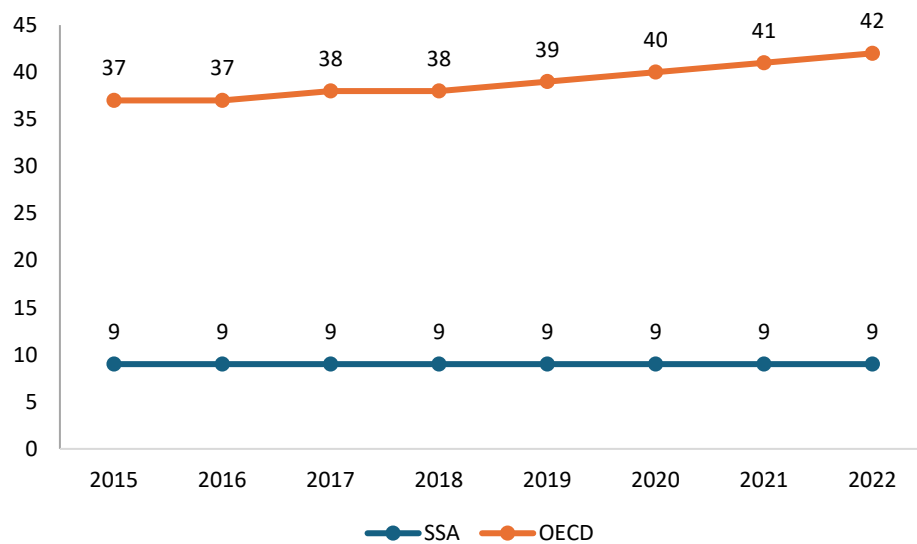
The number of STEM graduates from African universities is a useful predictor of the progress of higher education institutions in supplying advanced digital skills in the region. Using STEM to measure the supply of advanced digital skills is relevant because of the high level of digital skills needed to participate and complete STEM courses such as technology, engineering, and electronics. None of the countries that report STEM graduates have more the 50 percent in STEM. Rwanda has been the most successful country in boosting the proportion of STEM graduates, achieving 31 percent of STEM graduates. No other Sub-Saharan African country had achieved 30 percent STEM graduates as of 2022.

Figure 4.13 - Secondary Gross Enrollment Ratio (percent) in Sub-Saharan Africa (SSA) and OECD Countries



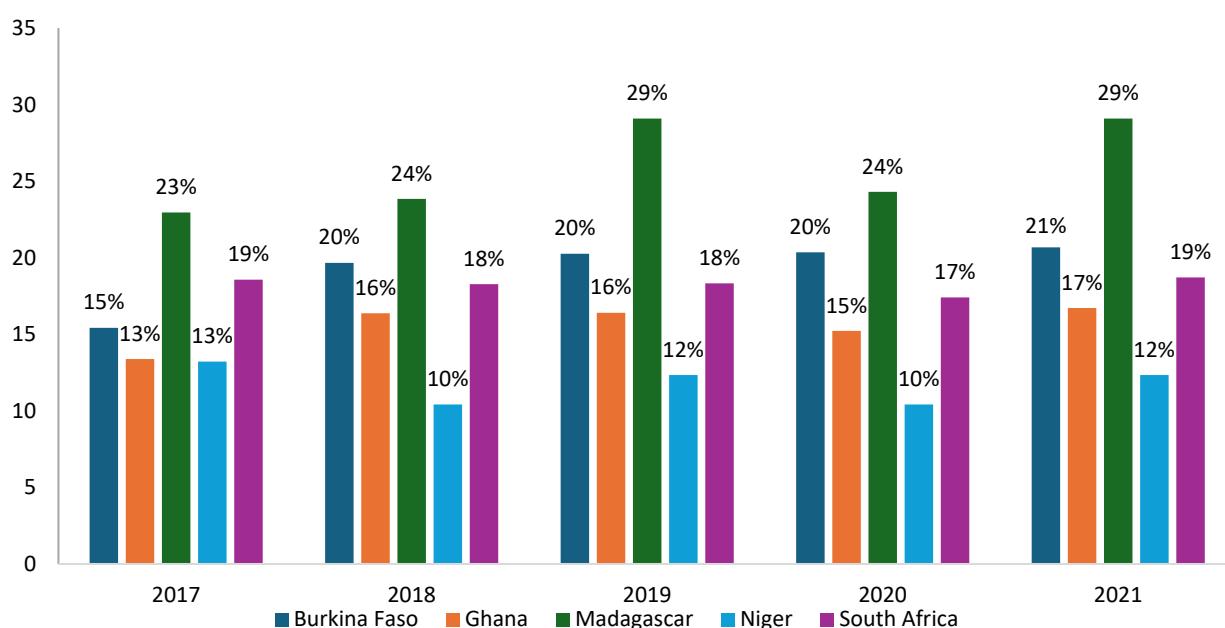
Source: World Bank data.

Figure 4.14 - Tertiary Gross Enrollment Ratio (percent) in Sub-Saharan Africa (SSA) and OECD Countries



Source: World Bank data.

Figure 4.15 - STEM Graduates in Tertiary Education (percent) in Sub-Saharan Africa



Source: UNESCO-UIS data.

4.4.2 Results of the 2024 Advanced Digital Skills Survey

Characteristics of Participating Institutions

To obtain a better picture of the capacity of higher education institutions in Sub-Saharan Africa to produce advanced digital skills, the World Bank conducted a survey of the supply of advanced digital skills in Sub-Saharan Africa between April and May 2024. The survey was distributed by email to all major university associations in Sub-Saharan Africa, including the Association of African Universities, the Inter-University Council of East Africa, and to beneficiaries of World Bank higher education projects, reaching about 1,000 higher education institutions. The survey sought both quantitative and qualitative data to provide an overview of the current landscape of advanced digital skills training. A total of 174 tertiary institutions responded with well-completed surveys (accounting for about 14 percent of the total number of Sub-Saharan African institutions), a fairly representative sample and a useful overview of the supply of advanced digital skills in the region. The survey explored which advanced digital courses are offered, access to digital resources, graduate outcomes, and the qualifications of lecturers in digital skills programs. The institutions surveyed were classified into three categories: traditional (comprehensive) universities, technical universities, and polytechnics.⁵⁴ The survey included public and private institutions, as well as public-private partnerships.

⁵⁴ Comprehensive universities are complex higher education organizations formally authorized to offer and confer advanced degrees in three or more academic disciplines or fields of study with a clear focus on research. Technical

The responding universities came from 29 Sub-Saharan African countries. Table 4.8 presents the distribution by subregion and country, while Figure 4.16 shows the distribution of participating universities by country income level. West Africa has the highest level of participation, with 77 institutions, and Central Africa has the smallest number of responses with only 5 countries. Fifty-seven institutions are from low-income countries, representing 33 percent of the total; 106 are from lower middle-income countries, accounting for 61 percent of the total, and 11 are from upper middle-income countries (6 percent of the total sample).

Table 4.8 - Number of Participating Tertiary Education Institutions by Country and Subregion

Subregions	West (44%)	East (18%)	Central (4%)	Southern (34%)
Number of Countries	10	8	4	7
List of Countries and Number of Tertiary Education Institutions	Benin (2) Burkina Faso (8) Côte D'Ivoire (2) Gambia (2) Ghana (10) Liberia (1) Nigeria (45) Senegal (3) Sierra Leone (2) Togo (2)	Burundi (2) Somali (6) Tanzania (5) Uganda (3) Ethiopia (3) Kenya (10) DRC (2) Mauritius (2)	São Tomé and Príncipe (1) Cameroon (2) Chad (1) Republic of Congo (1)	Angola (10) Botswana (4) Malawi (5) Mozambique (20) Zambia (6) Zimbabwe (9) South Africa (5)
Total (174)	77 Institutions	33 Institutions	5 Institutions	59 Institutions

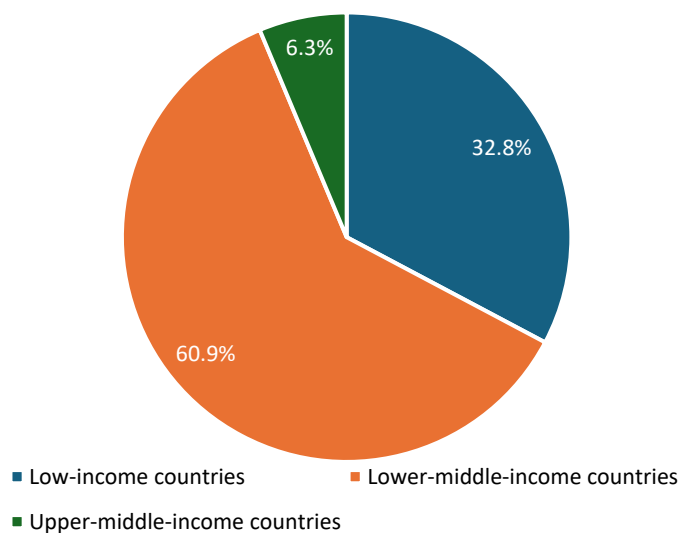
Source: World Bank survey 2024.

Figures 4.16 and 4.17 show the distribution of participating institutions by income level of host countries and by legal status. Almost 70 percent are public universities.

universities are institutions specializing in engineering and technology and combining advanced academic research with practical training through industry partnerships. Polytechnic universities are higher education institutions that primarily train students in skills central to the needs of industry.

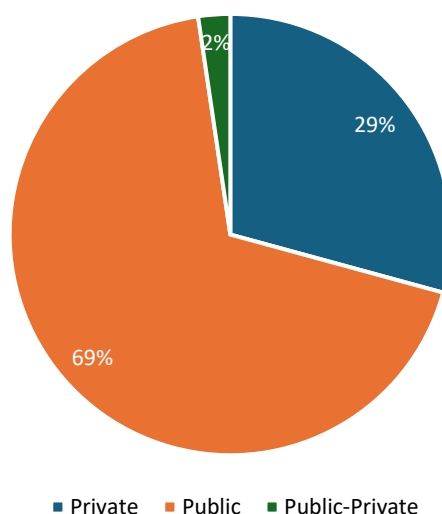
https://uis.unesco.org/sites/default/files/documents/uoe2016manual_11072016_0.pdf

Figure 4.16 - Distribution of Tertiary Education Institutions by Income Level of Host Country



Source: World Bank survey 2024.

Figure 4.17 - Distribution of Tertiary Education Institutions by Legal Status



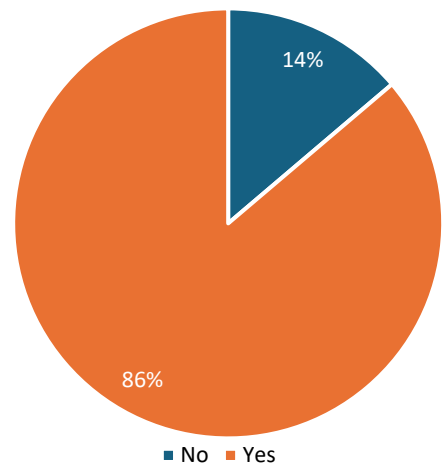
Source: World Bank survey 2024.

Types of Programs Offered

A first useful finding of the survey is that a large majority of institutions (86 percent) offer programs that provide additional foundational digital skills for all students at basic, intermediate, or advanced levels (Figure 4.18). This positive result is especially important in Sub-Saharan Africa because of the existing deficit in foundational skills at prior education levels. It means that tertiary education institutions can compensate for this deficit. The IFC projects a significant rise in the demand for foundational skills in

Sub-Saharan Africa, expected to make up 70 percent of the total digital skills required by 2030 (IFC 2021). These foundational skills are entry-level abilities necessary for the simple operation of digital tools and applications, allowing individuals to interact with digital technology.

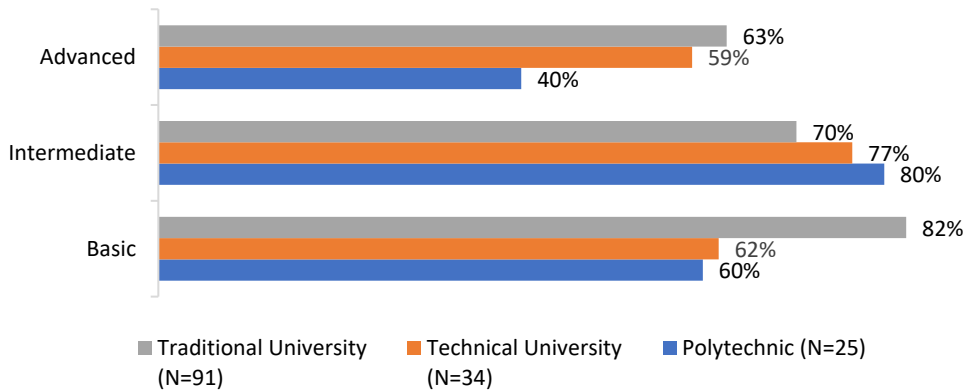
Figure 4.18 - Tertiary Education Institutions Offering Foundational Digital Skills Programs (percent)



Source: World Bank survey 2024.

Figure 4.19 shows at what level foundational skills courses are given for each type of institution. On average, 72 percent of comprehensive universities offer foundational programs at basic intermediary and advanced level. This is more than the average of 66 percent for technical universities and 60 percent for polytechnics.

Figure 4.19 - Foundational Skills Courses by Type of Institution (percent)



Source: World Bank survey 2024.

The survey investigates how tertiary education institutions in the region are offering specialized digital programs for students. The study operationalizes specialized digital skills programs according to the European Union’s Digital Competency Framework 2.2 (DigComp 2.2) that provides a common language

to identify key areas of digital competence and the e-Competence Framework 3.0 which provides a reference framework of competencies applied in the ICT professions. Using the same definitions, the survey looked at specialized digital skills programs as programs that offer learners the digital competencies to resolve complex problems involving few or several moving pieces, to guide others, to contribute to professional practice and propose innovative ideas to the field. These specialized programs require greater analytical skills as well as theoretical knowledge, which are typically needed in occupations with a high level of ICT intensity. Tertiary education institutions providing these programs can be at an advanced to a highly specialized level. Table 4.9 gives an overview of the proficiencies and competencies that such programs offer.

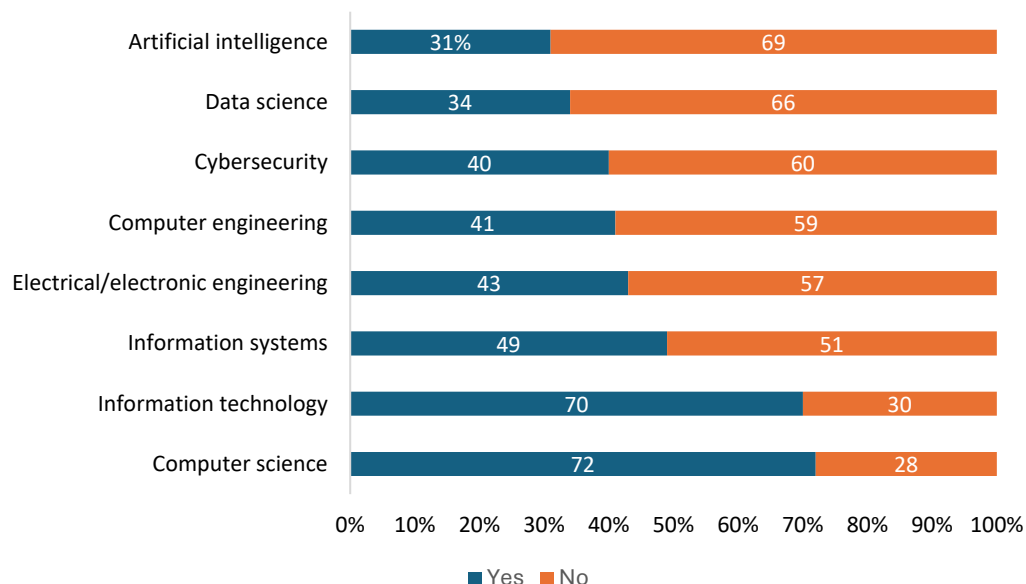
Table 4.9 - Key Features of Advanced and Specialized Digital Skills Proficiency at Advanced and Specialized Levels

	Advanced		Highly Specialized	
Granular levels	5	6	7	8
Complexity of tasks	Different tasks and problems	Most appropriate tasks	Resolve complex problems with limited solutions	Resolve complex problems with many interacting factors
Autonomy	Guiding others	Able to adapt to others in a complex context	Integrate to contribute to professional practice and to guide others	Propose new ideas and processes to the field
Cognitive domain	Applying	Evaluating	Creating	Creating

Source: DigComp 2.2.

The survey found eight specialized digital skills programs based on the closer relation of their theoretical content to electrical or electronic engineering, computer engineering, and technology programs offered as bachelor's, master's, or PhD degrees. The eight programs are computer science, computer engineering, information systems, information technology, cybersecurity, data science, electrical/electronic engineering, and AI. The survey asked tertiary education institutions to match the programs they offered with this framework of eight identified programs. The data show that, on average, 47.5 percent of the 174 tertiary institutions offer all 8 advanced/specialized digital skills programs. Figure 4.20 shows that at the individual program level, 72 percent of institutions offer computer science, 70 percent offer information technology, and 49 percent offer information systems, making these programs the top three programs offered in tertiary education in Sub-Saharan Africa. Only 31 percent offer AI, 34 percent offer data science, and 40 percent offer cybersecurity.

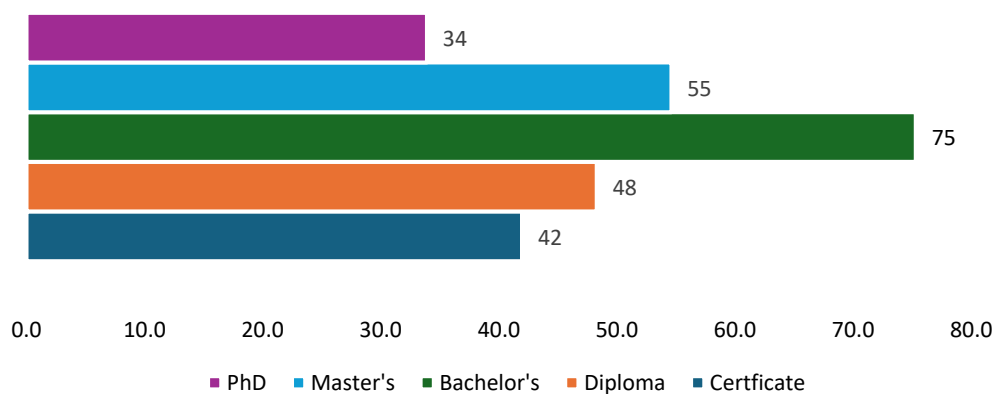
Figure 4.20 - Proportion of Tertiary Education Institutions Offering Advanced Digital Skills Programs by Specialization (percent)



Source: World Bank survey 2024.

Figure 4.21 shows the distribution of advanced/specialized digital programs by degree level. Overall, 75 percent of the institutions offer at least a bachelor's degree in one or more of the eight programs compared to other postgraduate levels at either the master's or PhD level.

Figure 4.21 - Advanced/Specialized Programs at Different Academic Levels (percent)

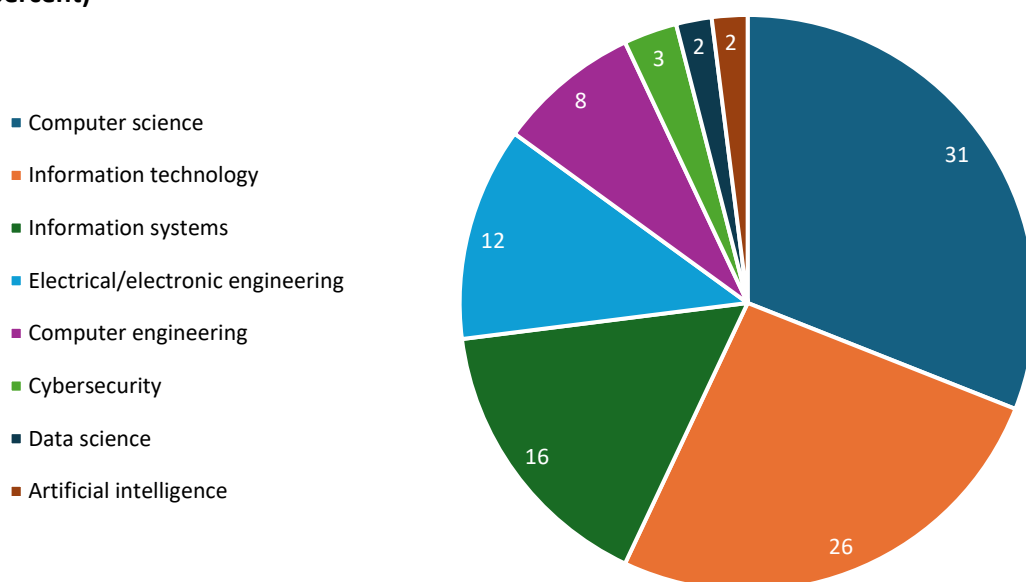


Source: World Bank survey 2024.

Student Enrollment and Graduation Rates

The survey investigated the distribution of enrollments and graduation rates for the eight programs of interest. Overall, the study shows a high enrollment in computer science: 30.5 percent of students enrolled into a computer science program in the 2023 academic year (Figure 4.22). The lowest enrollment was in AI programs with only 1.5 percent enrolled in the 2023 academic year. Thus, on average, 12.5 percent of students in tertiary education institutions enrolled into a digital skills program at an advanced or specialized level.

Figure 4.22 - Distribution of Enrollment by Type of Advanced/Specialized Digital Skills Programs (percent)

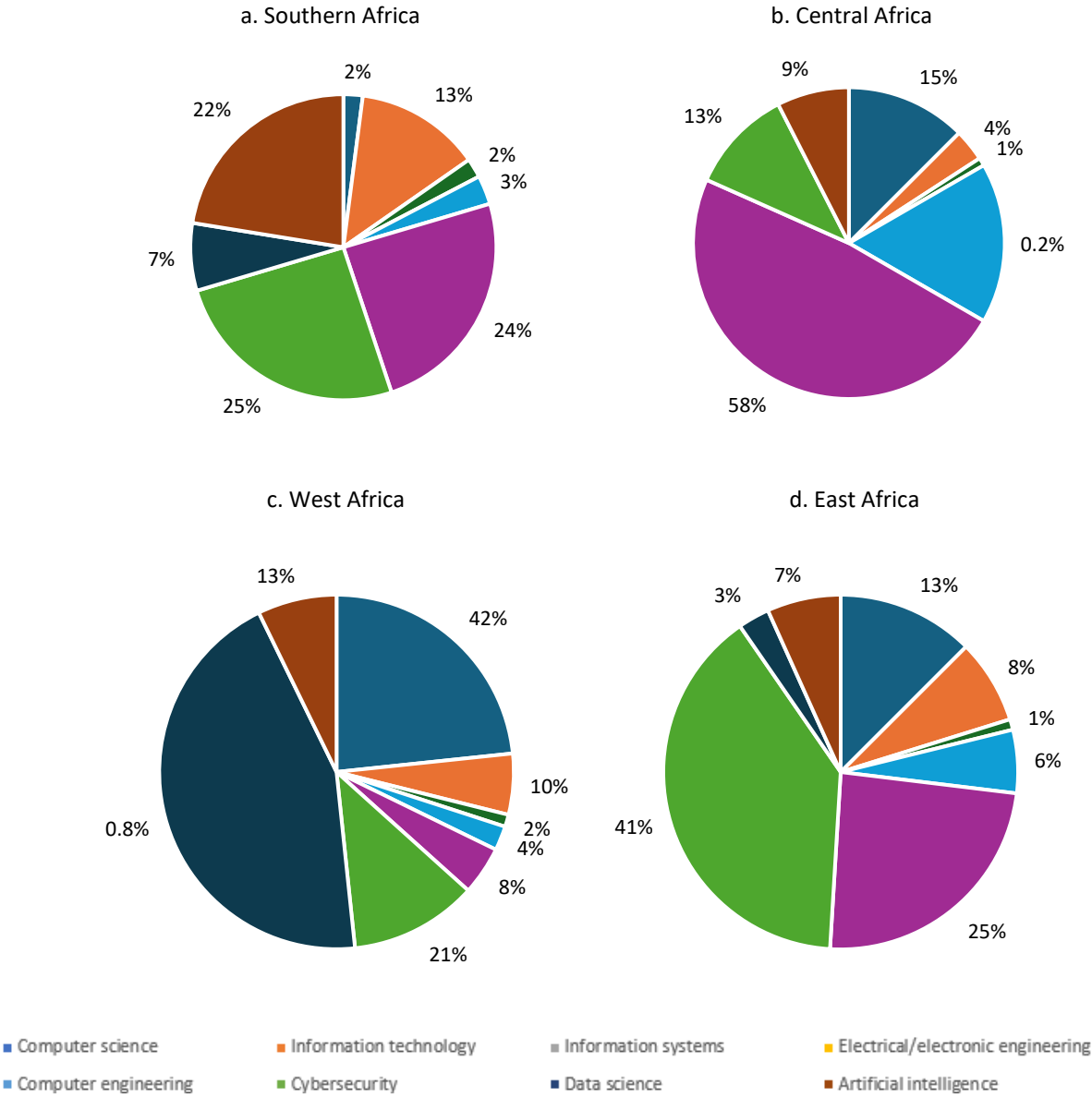


Source: World Bank survey 2024.

Additional analysis of available data on enrollment in tertiary education in Sub-Saharan Africa, based on UIS data, shows estimated enrollments of 12,925, 223 in tertiary education in 2023. The 267,557 students enrolled in advanced digital skills for the 2023 academic year make up only 2 percent of total tertiary enrollment in Sub-Saharan Africa in 2023.

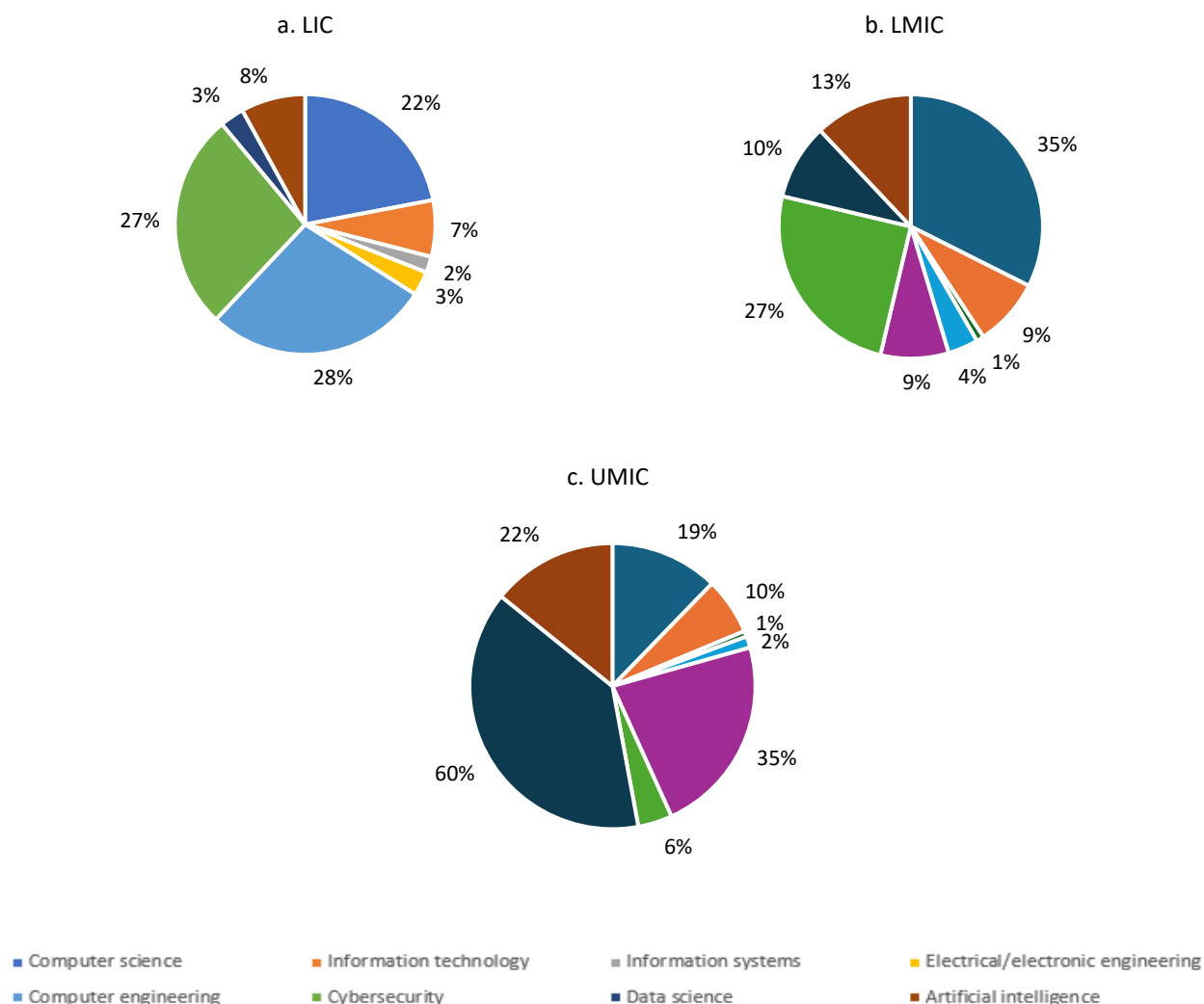
The results of the survey also have valuable information to compare subregions and country income groups in terms of enrollment in digital skills training (Figures 4.23 and 4.24). The evidence shows that the highest enrollment in digital skills programs is observed in West Africa, where the average was 55 percent in 2023. However, the region has only 12 percent enrollment in data science compared to 41 percent and 38 percent in Southern and East Africa, respectively. Despite the overall low average of 3.3 percent enrollment in digital skills from Central Africa, which amounts to only five participating tertiary institutions, the region has a significant enrollment of 14 percent in information systems programs. Figure 4.23 shows that with a 1.9 percent enrollment, Central Africa outperforms Southern Africa, which had only 0.9 percent enrollment in computer science.

Figure 4.23 - Enrollment in Advanced/Digital Skills Programs by Sub-Saharan Africa Regions



Source: World Bank survey 2024.

Figure 4.24 - Percentage of Enrollment in Advanced/Digital Skills Programs by Country Income Level (percent)

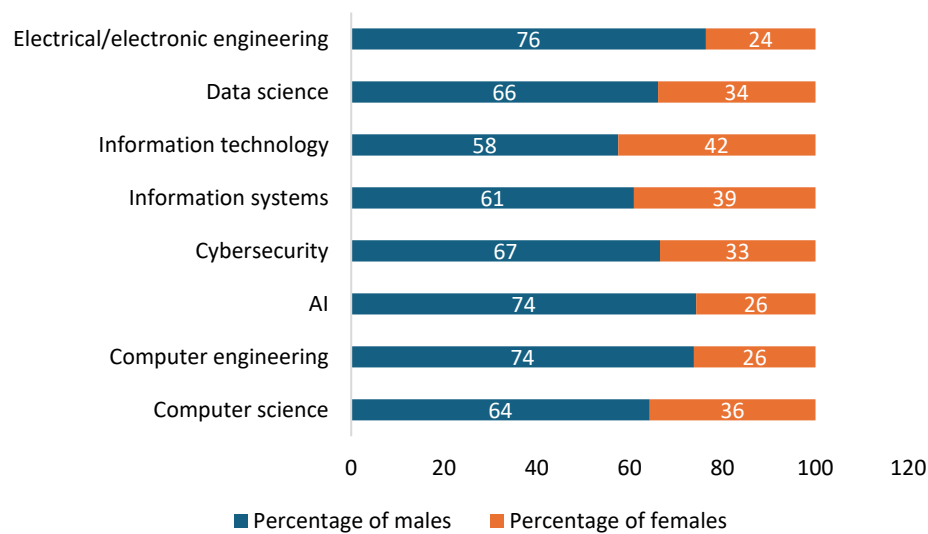


Source: World Bank survey 2024.

Note: LIC = low-income country; LMIC = lower-middle income country; UMIC = upper-middle income country.

As expected, the survey results reveal a wide gender gap in enrollment. The overall distribution is 67.5 males enrolled in advanced digital skills programs in Sub-Saharan Africa for 32.5 females. Figure 4.25 shows that the highest gender gap can be found in electrical/electronic engineering: 76.4 percent males compared to 23.6 percent females. Information technology is the program with the best gender balance, relatively (57.5 percent males versus 42.5 percent females).

Figure 4.25 - Student Enrollment by Gender (percent)

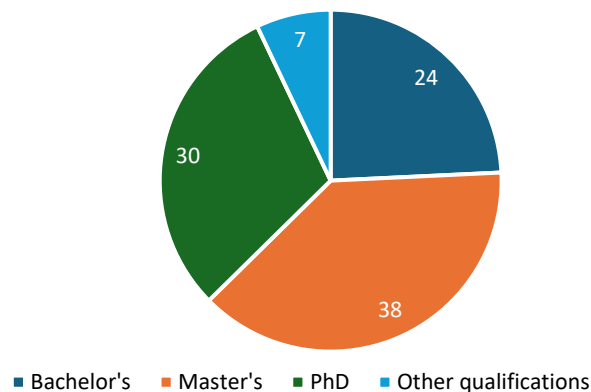


Source: World Bank survey 2024.

Teaching Staff for Advanced/Specialized Digital Skills Programs

The caliber of educators is critical in nurturing digital competencies across Africa for a multitude of reasons. To begin with, educators with high qualifications possess an extensive comprehension of digital technologies and are adept at transferring skills that align with the demands of the job landscape. Such educators are at the forefront of fostering innovation and creativity, inspiring students to engage in critical thinking and address real-life challenges. This training prepares students to make meaningful contributions to the economy. The survey provides information about the qualifications of lecturers teaching advanced digital skills, the gender balance among lecturers, and student-teacher ratios. Figure 4.26 shows the distribution of teaching staff by degree achieved. Only 30 percent are PhD holders, with a further 38 percent having stopped at a master's degree.

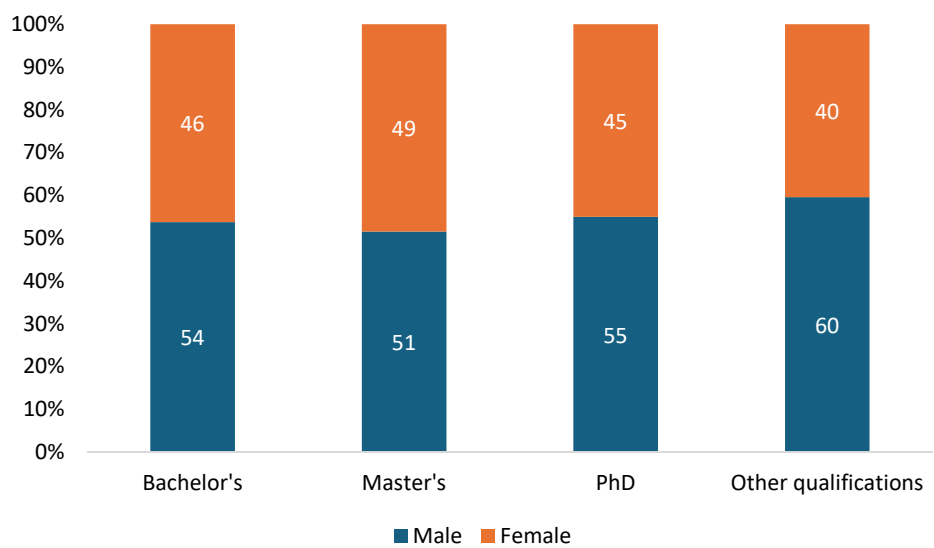
Figure 4.26 - Level of Qualification of Teaching Staff (percent)



Source: World Bank survey 2024.

As expected, there were significant gender differences across all qualification types; the highest gap observed was in the “other qualification” category with 19.2 percent more male lecturers than female lecturers (Figure 4.27). The category with the smaller gender gap is lecturers with a master’s degree.

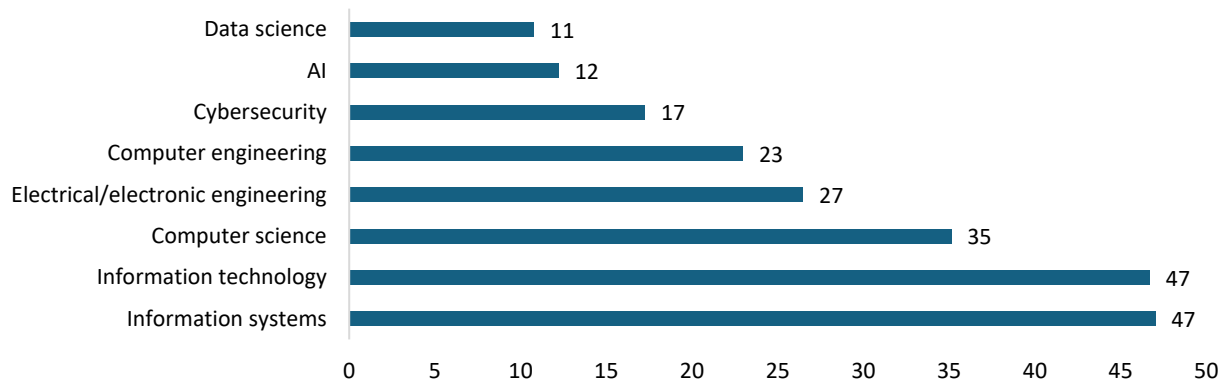
Figure 4.27 - Qualifications of Teaching Staff, by Gender



Source: World Bank survey 2024.

The survey investigates the student-lecturer ratio as a proxy of the quality of teaching and the likely degree of interaction between teachers and students. Figure 4.28 compares the ratio across the various types of programs. It reveals very high ratios for the most programs with the highest enrollment, such as computer science, IT, and information systems. For instance, the student-lecturer ratio for information systems, information technology and computer science are 47, 47, and 35 respectively. This is a worrisome result, as it may reflect a low degree of interaction with the teachers.

Figure 4.28 - Student-Teacher Ratio by Type of Program

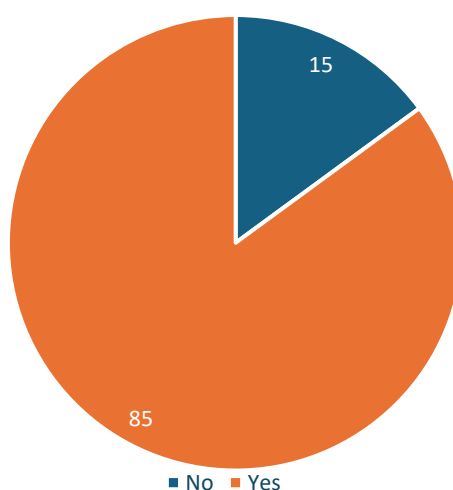


Source: World Bank survey 2024.

Quality infrastructure is fundamental to the development of advanced digital skills in Africa for several reasons. Teachers and students need robust digital infrastructure, including stable power, for fast and widespread internet access and connectivity. Well-equipped digital labs are indispensable for advanced digital skill programs. The results of the survey provide relevant information on these requirements.

The first critical element to look at is access to a reliable and stable power supply to ensure uninterrupted operation of the computer infrastructure and the scientific labs. Considering the frequency of power cuts in many SSA countries, it is reassuring to observe that 96 percent of the participating institutions have some form of power back-up system. With respect to specialized labs for digital education, the survey reveals that 85 percent of all institutions do have specialized IT labs (Figure 4.29). However, the 15 percent of institutions without such labs raises serious concerns about the quality and relevance of the training received by students enrolled in their advanced digital education programs.

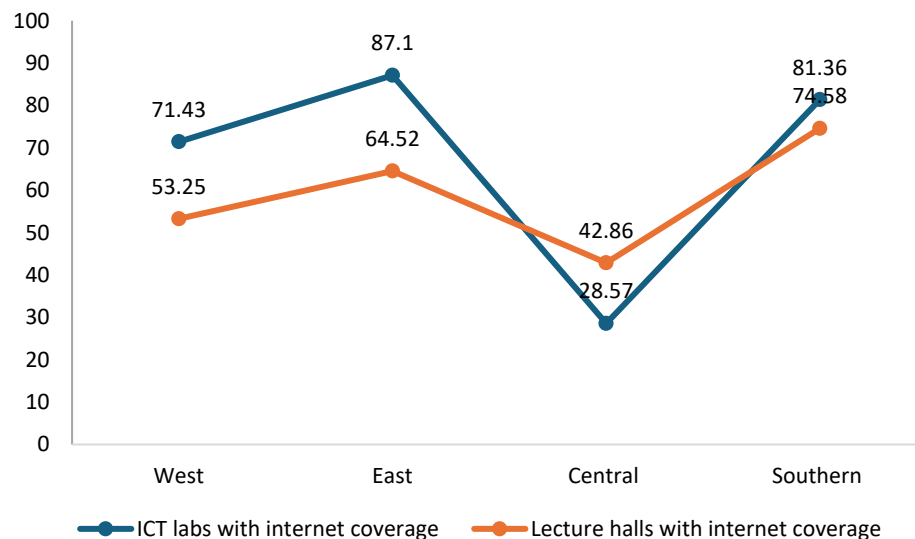
Figure 4.29 - Percentage of Institutions with Specialized ICT Labs (percent)



Source: World Bank survey 2024.

The next infrastructure of interest was internet connectivity for teaching and learning digital skills (Figure 4.30). The survey asked tertiary education institutions about the availability of internet access in lecture hall and ICT laboratories. The results across the subregions indicate that 41.2 percent do not have access to internet in lecture rooms and 32.9 percent do not have internet access in ICT laboratories. On average, 64.3 percent of tertiary education institutions in Central Africa do not have internet access in lecture halls and ICT laboratories.

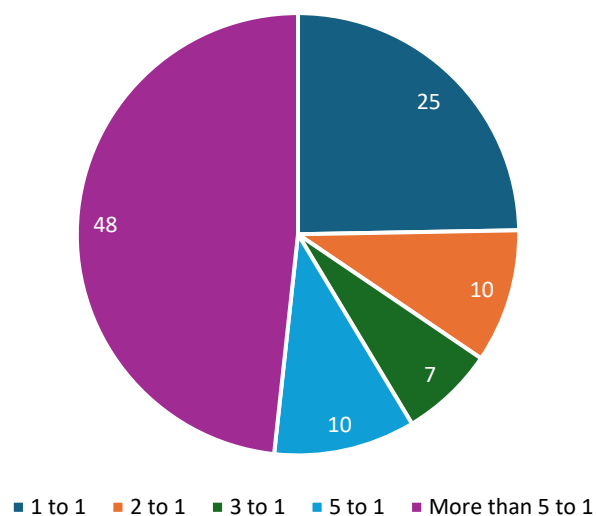
Figure 4.30 - Tertiary Institutions in Africa with Internet Connectivity in Lecture Halls and ICT Labs (percent, by region)



Source: World Bank survey 2024.

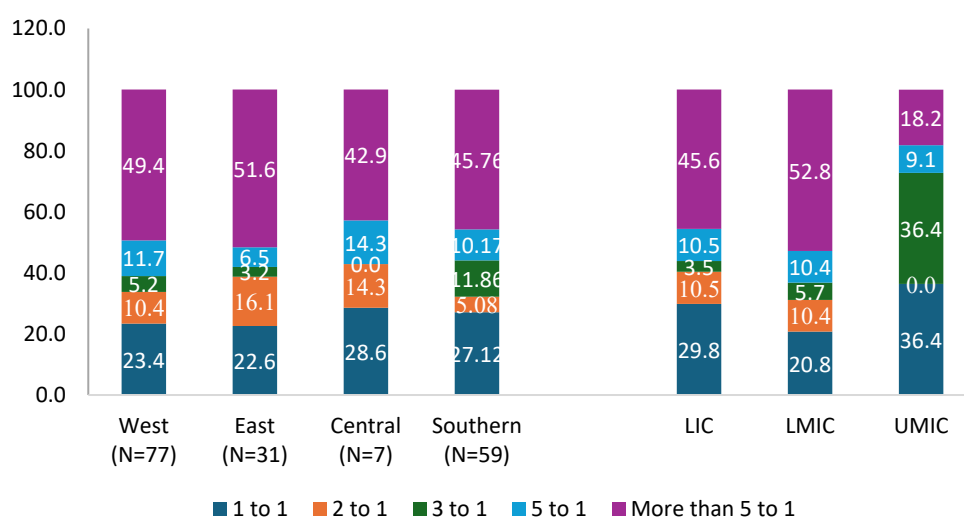
Finally, the survey collected information about the extent to which students have access to computers at their place of study. Figure 4.31 shows the proportion of students with various levels of access to computers: only 25 percent have their own computer or have access to a computer from the university on a one-to-one basis. Almost half of the students must share a computer with at least four other students. The survey also revealed significant variations by region and country income level (Figure 4.32).

Figure 4.31 - Overall Student - PC Ratio (percent)



Source: World Bank survey 2024.

Figure 4.32 - Student-Computer Ratio by Subregion and Country Income Level (percent)



Source: World Bank survey 2024.

Note: LIC = low-income country; LMIC = lower-middle-income country; UMIC = upper-middle-income country.

4.4.3 Range of Advanced Digital Programs

To complement the results of the survey, an analysis of the range of advanced digital programs was undertaken by looking at a small sample of universities in four countries: Ghana, Kenya, Rwanda, and South Africa. Except in South Africa, where private universities are not allowed to operate, the sample included a leading public university and a private one in each country. South Africa's flagship university, the University of Cape Town, was selected as reference university for Sub-Saharan Africa.

Tables 4.10–4.12 show the relevant programs at the bachelor's, master's, and PhD levels for the seven universities, respectively. Table 4.13 highlights diploma and microcredit programs in the same universities.

Table 4.10 - Advanced Digital Skills Programs at Undergraduate Level

Digital/ICT Bachelor's Programs	University of Ghana	Ashesi University	University of Rwanda	Carnegie Mellon University Africa	Moi University	Strathmore University	University of Cape Town
	Ghana	Ghana	Rwanda	Rwanda	Kenya	Kenya	South Africa
Computer Science	✓	✓			✓		✓
Information Technology	✓		✓				

Digital/ICT Bachelor's Programs	University of Ghana	Ashesi University	University of Rwanda	Carnegie Mellon University Africa	Moi University	Strathmore University	University of Cape Town
Computer Engineering	✓	✓	✓				✓
Information Systems		✓					✓
Electrical & Electronic Engineering	✓	✓			✓	✓	
Electrical Engineering							✓
Statistics & Data Science							✓
Electrical & Computer Science Engineering							✓
Electrical Power Engineering			✓				
Electronics and Telecommunications Engineering			✓		✓		
Informatics					✓	✓	
Applied Statistics with Computing					✓		
Education Computer Studies					✓		
Information Sciences					✓		
Computer Networks and Cybersecurity						✓	

Sources: University of Ghana -

https://admission.ug.edu.gh/applying/sites/default/files/documents/UG_Prospectus_2019_2020-sm%20.pdf

Ashesi University: <https://www.ashesi.edu.gh/academics/programmes.html>

University of Rwanda: <https://ur.ac.rw/spip.php?page=admissions>

Carnegie Mellon University Africa: <https://www.africa.engineering.cmu.edu/academics/index.html>

Moi University: <https://www.mu.ac.ke/index.php/en/2-uncategorised/108-list-of-programmes-offered.html>

Strathmore University: <https://strathmore.edu/courses/>

University of Cape Town:

https://uct.ac.za/sites/default/files/media/documents/uct_ac_za/49/2025_ug_prospectus.pdf

Table 4.11 - Advanced Digital Skills Programs at Master's Level

Digital/ICT Master's Programs	University of Ghana	Ashesi University	University of Rwanda	Carnegie Mellon University Africa	Moi University	Strathmore University	University of Cape Town
Computer Engineering	✓						
Information Systems	✓		✓			✓	✓
Computer Science	✓		✓	✓			✓
Computational Nuclear Sciences & Engineering	✓						
Artificial Intelligence				✓			✓
Commerce Informatics						✓	✓
Information and Communication Technologies (Operational Communications)			✓				
Internet of Things: Embedded Computing Systems (MSc in IoT: ECS)			✓				
IoT: Wireless Intelligent Sensor Networking			✓				
Information Technology				✓			✓
Electrical and Computer Engineering				✓			
Information Systems Security						✓	
Data Science and Analytics						✓	

Sources: University websites and prospectuses.

Most universities offer traditional programs in computer science, computer engineering, and electrical or electronic engineering at the bachelor's level. The most striking aspect at this level is that only one university (Strathmore) offers a program in cybersecurity, even though this has become a major priority for all countries in the world. Only UCT and Moi University in Kenya have programs related to data sciences.

At the master's level, the most common programs are computer science and information science. As could be expected, the University of Cape Town has the largest number of master's degree programs in advanced digital skills, followed by the University of Ghana. Only one institution, Strathmore University, has designed master's degree programs in information systems security and in data science and analytics, two priority topics that could have been expected to be offered by more universities. Carnegie Mellon University Africa and the University of Cape Town are the only ones offering a master's program in AI, another high priority. The University of Rwanda seems to be the only university in the group that has master's programs in IoT. Two universities—the University of Cape Town and Strathmore University—offer an informatics program directly linked to commerce. The University of Ghana has set up a master's in computational nuclear sciences and engineering.

Table 4.12 - Advanced Digital Skills Programs at the PhD Level

Digital/ICT PhD Programs	University of Ghana	Ashesi University	University of Rwanda	Carnegie Mellon University Africa	Moi University	Strathmore University	University of Cape Town
Computer Engineering	✓						
Information Systems	✓						✓
Computer Science	✓			✓		✓	✓
Computational Nuclear Sciences & Engineering	✓						
Software Engineering				✓			
Embedded Computing Systems				✓			

Sources: University websites and prospectuses.

The range of programs directly linked to advanced digital training at the PhD level is very narrow, concentrated, essentially, on computer science. The two exceptions are the University of Ghana consistently complementing its Master's in Computational Nuclear Sciences & Engineering with a PhD in the same area and the Carnegie Mellon campus in Rwanda offering PhDs in software engineering and embedded computing systems. It is surprising to observe that neither the University of Rwanda nor Ashesi University have PhD programs in these areas where demand is high.

Table 4.13 - Advanced Digital Skills Programs at Certificate/Diploma Level

Digital/ICT Certificate/Diploma Programs	University of Ghana	Ashesi University	University of Rwanda	Carnegie Mellon University Africa	Moi University	Strathmore University	University of Cape Town
Management in Information Systems (part-time diploma)							✓
Business Information Technology (diploma)						✓	
Computer Applications						✓	
Certified Ethical Hacking						✓	
Computer Hacking Forensics Investigator						✓	
International Computer Driving License						✓	
Certified Information Systems Auditor						✓	

Sources: University websites and prospectuses.

Strathmore University is the only university in the sample that offers microcertificates, with six such programs, including computer hacking forensics investigator (Table 4.13). This finding is worrisome,

because it suggests that most universities are missing out on this important development; they have neither positioned nor prepared themselves to become major contributors to lifelong learning at a time when upskilling and reskilling have become increasingly necessary for millions of workers and employees.

In summary, the review of the seven universities indicates that the range of offerings is still very limited, with computer science the only advanced digital skills program offered at the undergraduate, master's, and PhD levels.

4.4.4 Digital Skills for the Green Economy and the Blue Economy

In the absence of a systematic compendium of university programs at the intersection of digital and green/blue skills, an internet search was conducted to identify existing programs in Sub Saharan countries. While certainly incomplete, Table 4.14 illustrates the types of programs bringing advanced digital skills and green economy competencies together in an interdisciplinary manner. South Africa stands out as leading the way in this direction.

Table 4.14 - University Programs at the Intersection of Digital and Green / Blue Skills

Institution	Program
University of Ghana (Ghana)	Master's in Remote Sensing and GIS PhD in Remote Sensing and GIS Master of Science in Sustainable Development Management
Strathmore University (Kenya)	Master's in Sustainable Energy PhD in Sustainable Energy
University of Nairobi (Kenya)	Bachelor's, Master's, & PhD in Environmental & Biosystems Engineering Bachelor's and PhD in Geospatial Engineering Master's and PhD in Geographic Information Systems Master's in Climate Change Master's and PhD in Environmental Governance
University of Nigeria Nsukka (Nigeria)	Master's in Renewable Energy PhD in Renewable Energy
Durban University of Technology (South Africa)	PhD in Solar Thermal PhD in Wind / PV Hybrid systems PhD in Energy Management Systems PhD in Energy Audits PhD in Biogas and Biofuels PhD in Sea Wave Energy

Institution	Program
Stellenbosch University (South Africa)	Master's in Climate Change and Sustainable Development Master's in Bioinformatics and Computational Biology Bachelor in Geoinformatics Master's in Renewable and Sustainable Energy
University of Cape Town (South Africa)	Master's in sustainable urban development PhD in sustainable urban development Master's in Marine Resource Management PhD in Marine Resource Management
University of Pretoria (South Africa)	Bachelor's in Bioinformatics Bachelor's in Geoinformatics Master's in Bioengineering Master's in Environmental Engineering

Sources: University websites.

5. The Way Forward

African nations have paid close attention to developments in the international economy and the possible impact of the Fourth Industrial Revolution. The continent has embraced the vision of the former UN Secretary-General, Ban Ki-Moon, who in April 2014 articulated clearly the new opportunities that higher education systems and institutions could leverage as countries sought to move from traditional economic growth strategies, based on the exploitation and exportation of natural resources, to new approaches that seek to engage knowledge for development.⁵⁵

In response to the UN's Post 2015 Development Agenda for Education, the African Union proposed its own Agenda 2063, which calls for African societies to become knowledge societies. The first 10-year Action Plan, the Continental Strategy for Education recognizes that developing the human capital which is essential for this path cannot happen without the revitalization and expansion of tertiary education, research, and innovation to address continental challenges and promote global competitiveness.⁵⁶

The African Union's Digital Education Strategy and Implementation Plan for the period 2023–2028 is the official framework for accelerating the adoption of digital technologies in alignment with the Continental Education Strategy for Africa.⁵⁷ The plan proposes three main areas of focus, eight action areas, and fourteen measures:

1. Digital technology in education: accelerating the adoption of digital technologies for teaching, learning, research, assessment, and administration.
2. Education in digital technologies for digitally empowered citizens as well as for the digital economy and society: strengthening digital literacy and skills for all, especially for teachers and students.
3. Building the capacities of African Union member states in digital infrastructure (devices and networks). Infrastructure development is the primary strategic objective of the digital education strategy.

Although the plan outlines an expansion of access to digital devices by 20 percent for students and 50 percent for teachers by 2027, including persons with disabilities, its targets are not ambitious enough to put the continent in a position to leapfrog the global supply of digital skills in Sub-Saharan Africa.⁵⁸ With current tertiary enrollment at 9 percent in Sub-Saharan Africa, compared to 27 percent in South Asia and 42 percent in OECD countries, the region will need more than 20 percent enrollment in tertiary education to be able to produce the needed advanced digital skills, taking tertiary enrollment as a proxy

⁵⁵ Secretary-General's message to Conference on the Knowledge-based Economy and its Role in National Development, Riyadh, Saudi Arabia, April 24, 2014
[https://www.un.org/sg/en/content/former-secretary-general/statement/2014-04-24/secretary-generals-message-conference-the-knowledge-based-economy-and-its-role-national-development#:~:text=By%20shifting%20to%20a%20knowledge,in%20a%20more%20sustainable%20future.29958-doc-cesa - english-v9.pdf \(au.int\)](https://www.un.org/sg/en/content/former-secretary-general/statement/2014-04-24/secretary-generals-message-conference-the-knowledge-based-economy-and-its-role-national-development#:~:text=By%20shifting%20to%20a%20knowledge,in%20a%20more%20sustainable%20future.29958-doc-cesa - english-v9.pdf (au.int))

⁵⁶ [https://www.un.org/sg/en/content/former-secretary-general/statement/2014-04-24/secretary-generals-message-conference-the-knowledge-based-economy-and-its-role-national-development#:~:text=By%20shifting%20to%20a%20knowledge,in%20a%20more%20sustainable%20future.29958-doc-cesa - english-v9.pdf \(au.int\)](https://www.un.org/sg/en/content/former-secretary-general/statement/2014-04-24/secretary-generals-message-conference-the-knowledge-based-economy-and-its-role-national-development#:~:text=By%20shifting%20to%20a%20knowledge,in%20a%20more%20sustainable%20future.29958-doc-cesa - english-v9.pdf (au.int))

⁵⁷ <https://au.int/en/documents/20221125/digital-education-strategyand-implementation-plan>

⁵⁸ <https://au.int/sites/default/files/documents/42416-doc-1. DES EN - 2022 09 14.pdf>

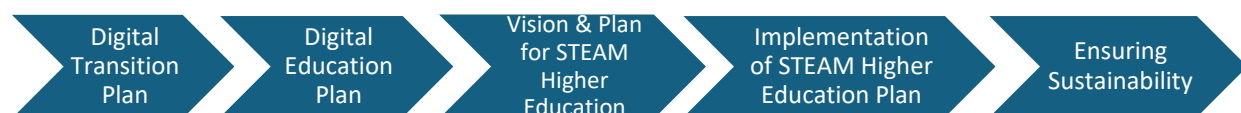
measure of the capacity to train graduates in these skills. It is therefore imperative that all Sub-Saharan African nations accelerate their efforts in this area.

The policies that will guide and implement the digital transition in Sub-Saharan Africa must work along several dimensions. This chapter first looks at national policies to orient and support tertiary education institutions for the development of advanced digital education programs. Second, it proposes a range of policies and measures at the institutional level. Third, it discusses the contribution of the Diaspora to the implementation of the digital transition agenda. And finally, the section outlines the potential role of donors in support of the digital transition in higher education.

5.1 National Strategies and Policies

Figure 5.1 proposes a sequence to help guide the design and implementation of a national plan to develop and strengthen advanced digital education programs in higher education.

Figure 5.1 - Strengthening Advanced Digital Education in Sub-Saharan African Countries



Source: Authors' own elaboration

5.1.1 Digital Transition Plan

The first step in the sequence is to formulate a national digital transition plan that outlines the vision and national targets to accelerate the digital transition as part of the overall economic and social development plan. Among the advanced industrial economies, Singapore and Estonia provide leading examples.

- **Singapore's** plans to become a Smart Nation by 2025 rely on a comprehensive strategy for undertaking digital transformation across all sectors. The main elements of the strategy are to (i) invest in advanced technologies such as artificial intelligence, the Internet of Things, and data analytics, and integrate them into existing infrastructure and processes; (ii) invest in education and training programs to develop a skilled talent pool proficient in cutting-edge technologies; (iii) expand 5G technologies as the backbone of innovative applications such as autonomous vehicles, smart grids, and remote healthcare services; (iv) scale up digital literacy and lifelong learning programs to empower citizens of all ages and backgrounds with the necessary digital

skills to fully participate in the digital economy and society; and (v) promote sustainable energy production and management.⁵⁹

- **Estonia** is renowned as a digital pioneer and the leading nation in Europe for digital services, based on the strength of its innovative e-governance solutions, including digital identity, e-residency, and secure digital signatures. The country's digital infrastructure has streamlined government operations, making it easier for citizens and businesses to interact with public services. Estonia's success story in digital transformation can be seen as a blueprint for nations looking to enhance their e-governance capabilities.⁶⁰

Rwanda and Senegal are among the first African countries that have formulated a clear and audacious digital transition strategy.

- **Rwanda's** Digital Transformation Strategy 2018–2024 focuses on (i) digital infrastructure to expand access to affordable internet and mobile broadband; (ii) digital literacy to equip citizens with the skills to use digital technologies effectively; (iii) e-government to make government services more efficient and accessible through digital platforms; (iv) innovation to create an enabling environment for tech start-ups and entrepreneurs; and (v) cybersecurity to develop a robust cybersecurity framework to protect critical infrastructure and data.⁶¹
- **Senegal's** 2025 Digital Plan (SDA 2025) emphasizes (i) digital foundations to build a secure and reliable digital infrastructure; (ii) digital inclusion to ensure equitable access to digital technologies for all citizens; (iii) digital transformation to digitize key economic and social sectors; (iv) e-government to modernize government services for improved efficiency and transparency; and (v) digital skills development to equip the workforce for the 21st century.⁶²

5.1.2 Digital Education Plan

The second phase consists in elaborating a digital education plan whose purpose is to ensure full alignment of the objectives and operation of the education system, at all levels, with the strategic aims of the national digital transition plan. Here again, Rwanda is among the leading nations in Sub-Saharan Africa. As early as 2016, Rwanda drafted a plan for ICT in Education to accompany the national digital transition strategy. The plan's main aim is "... to harness the innovative and cost-effective potential of world-class educational technology tools and resources, for knowledge creation and deepening, to push

⁵⁹ <https://www.tigernix.com/blog/digital-transformation-singapore-smart-nation-2025#:~:text=Achieving%20Singapore's%20Smart%20Nation%20plan,into%20existing%20infrastructure%20and%20processes>

⁶⁰ <https://blogs.iadb.org/administracion-publica/en/8-lessons-from-estonias-digital-transformation-for-latin-america-and-the-caribbean/>

⁶¹ <https://cenfri.org/research-themes/rwandan-economy-digitalisation-programme/>

⁶² <https://www.adie.sn/agence/cadre-strat%C3%A9gique#:~:text=La%20SN2025%20ambitionne%20de%20faire,social%20%C3%A0%20l'horizon%202025.&text=Ces%20pr%C3%A9requis%20et%20axes%20sont,innovant%20dans%20un%20%C3%A9cosyst%C3%A8me%20performant%20%C2%BB>

out the boundaries of education: improve quality, increase access, enhance diversity of learning methods and materials, include new categories of learners, foster both communication and collaboration skills, and build capacity of all those involved in providing education.”⁶³ Table 5.1 lists other countries in Sub-Saharan Africa that have a formally defined digital education strategy.

Table 5.1 - Examples of Digital Education Plans in Sub-Saharan Africa

Country	Name of Digital Education Plan
Burkina Faso	Cyber-stratégie Sectorielle e-Éducation
Ghana	The Ghana Information & Communications Technology in Education Policy
Kenya	Policy on Information and Communication Technology in Education and Training
Mali	Politique Nationale de l'Éducation en Matière de Technologie de l'Information et de la Communication
Mozambique	Plano Tecnológico da Educação
Rwanda	ICT in Education Policy
Seychelles	Information Communications Technology in Education and Training Policy
South Africa	National Digital and Future Skills Strategy
Uganda	Education Digital Agenda Strategy
Zimbabwe	ICT Policy for Primary and Secondary Education

Sources: https://burkina-ntic.net/ressources/assets/docP/Document_N0273.pdf;
[https://wikieducator.org/images/c/ce/Final draft ICT in Education policy.pdf](https://wikieducator.org/images/c/ce/Final_draft_ICT_in_Education_policy.pdf)
<https://www.education.go.ke/sites/default/files/2023-01/ICT%20IN%20EDUCATION%20AND%20TRAINING%20POLICY%202021.pdf>
https://www.mined.gov.mz/assets/docs/plano_tecnologico_educacao.pdf
https://planipolis.iiep.unesco.org/sites/default/files/ressources/rwanda_ict_in_education_policy_approved.pdf
https://planipolis.iiep.unesco.org/sites/default/files/ressources/seychelles_ict_education_policy.pdf

To be comprehensive and effective, digital education plans must not only consider the contribution of each subsector to the overall digital transformation strategy; they also must articulate linkages across sectors. For instance, the quality of primary education directly influences the quality of secondary education graduates who, in turn, are an essential determinant of the quality of advanced digital skills programs. Conversely, the quality of teacher training at the tertiary education level conditions the quality of basic education, especially in math and sciences. A recent World Bank article highlighted the

⁶³ https://planipolis.iiep.unesco.org/sites/default/files/ressources/rwanda_ict_in_education_policy_approved.pdf

major constraint represented by the low participation of youths in STEM subjects at the secondary education level, which results in a weak pipeline into advanced digital skills programs at the university level.

5.1.3 STEM and STEAM Higher Education Plans

The third step is the preparation of the specific vision and plan for the higher education subsector that offers specialized programs in advanced digital education. Consistent with its bold digital transformation aspirations, Rwanda was one of the first Sub-Saharan African countries to define clear targets to rapidly increase the share of STEM graduates from higher education institutions, with the very ambitious goal of achieving a 70 percent proportion of graduates in STEM programs. The University of Rwanda, the country's flagship university, has responded effectively to the national strategy to enlist science and technology for the country's development, with growth in the share of STEM students from 54 percent to 61 percent between 2013 and 2020. Ethiopia, Nigeria, and South Africa have also made substantial progress in making plans for the development of digital skills.

Sub-Saharan African countries keen on accelerating the development of their advanced digital skills programs ought to elaborate a vision and strategic plan for that purpose. The vision should be informed by a thorough diagnosis of the current results of the system in terms of production of graduates specialized in advanced digital skills, distribution of the supply of specialized science and technology higher education institutions and digital skills programs, quality and relevance of these programs, and gender balance in access and completion in these programs.

Formulating an audacious vision and defining clear targets for the development of advanced digital skills programs would involve policy decisions about the role and place of each type of institution in the national tertiary education system, bearing in mind the differential investment and operational costs in each case, and the philosophical preferences of each country's government with regard to the desirable growth of a healthy private sector. The plan should also outline the necessary reforms and measures that will establish adequate conditions for the effective operation of higher education institutions: supportive quality assurance mechanisms, favorable governance, and sustainable financing.

It would be advisable to adopt a wider approach that includes arts and humanities with science, technology, engineering and math (STEAM) rather than the narrow STEM (Box 5.1). In STEAM curricula, the inclusion of artistic and humanist competencies helps students leverage both hard and soft skills to solve problems through critical thinking and innovative ideas. It encourages the use of creativity and imagination to understand and address complex subjects. Including the "A" dimension of arts and humanities, which has been historically undervalued, not only helps STEM professionals learn to develop design thinking capability but could also make it easier to attract talented students who may not be drawn to the highly technical STEM programs.

Box 5.1 - Incorporating Humanities, Arts, Crafts, and Design into Curricula Makes Better Scientists

If you've ever had a medical procedure, chances are you benefited from the arts. The stethoscope was invented by a French flautist/physician named René Laennec who recorded his first observations of heart sounds in musical notation. The suturing techniques used for organ transplants were adapted from lacemaking by another Frenchman, Nobel laureate Alexis Carrel. The methods and some of the tools required to perform the first open-heart surgeries were invented by an African American innovator named Vivien Thomas, whose formal training was as a master carpenter.

But perhaps you're more of a technology lover. The idea of instantaneous electronic communication was the invention of one of America's most famous artists, Samuel Morse, who built his first telegraph on a canvas stretcher. Actress Hedy Lamarr collaborated with the avant-garde composer George Antheil to invent modern encryption of electronic messages. Even the electronic chips that run our phones and computers are fabricated using artistic inventions: etching, silk-screen printing, and photolithography.

STEM professionals with vocations such as wood- and metalworking, printmaking, painting, and music composition are more likely to file and license patents and to found companies than those who lack such experience. Likewise, authors who publish high-impact papers are more likely to paint, sculpt, act, engage in wood- or metalworking, or pursue creative writing. Members of the U.S. National Academies of Sciences and Engineering are about three to five times more likely to have a lifelong avocation involving arts, crafts, theater, or some type of creative writing than are average scientists, and Nobel Prize winners engage in such activities at 15 to 25 times the rate of average scientists. A 2013 survey of 225 scientists and engineers found that more than 60 percent could cite a direct impact of their artistic or handicraft activities on their STEM work, and over 80 percent recommended that these dimensions be a required part of STEM education.

Integration occurs best through the building of conceptual or methodological "bridges" between disciplines for the purpose of addressing well-defined multi- or transdisciplinary problems. Integration is not a goal in and of itself, but rather a skill that needs to be developed in order to respond to the connectedness of the real world. The late Charles M. Vest, president emeritus of the National Academy of Engineering and president emeritus of the Massachusetts Institute of Technology, concurred: "[Engineering] systems cannot be wisely envisioned, designed, or deployed without an understanding of society, culture, politics, economics, and communications—in other words, the very stuff of the liberal arts and also of the social sciences."

Source: Root-Bernstein (2019).

At the same time, it is important to recognize the need to promote quantitative and computational skills in all subject areas outside the STEM fields. The inclusion of computational thinking—problem-solving processes that include characteristics such as logically ordering and analyzing data and creating solutions using a series of ordered steps (or algorithms), and dispositions such as the ability to confidently deal with complexity and open-ended problems—across the curriculum is vital to promoting effective problem solving and critical thinking in all fields of study and future employment.

5.1.4 Implementation of STEAM Higher Education Plan

The fourth phase corresponds to the implementation of the plan for advanced digital skills education. The national authorities in charge of higher education should focus on the following three aspects:

- Putting in place a strong digital infrastructure to ensure access of all higher education institutions to fast, reliable, and reasonably priced internet;
- Offering financial incentives for expanding and improving advanced digital education programs, and reducing gender disparities in STEM programs; and
- Providing technical assistance to build the institutional capacity of science and technology universities and programs.

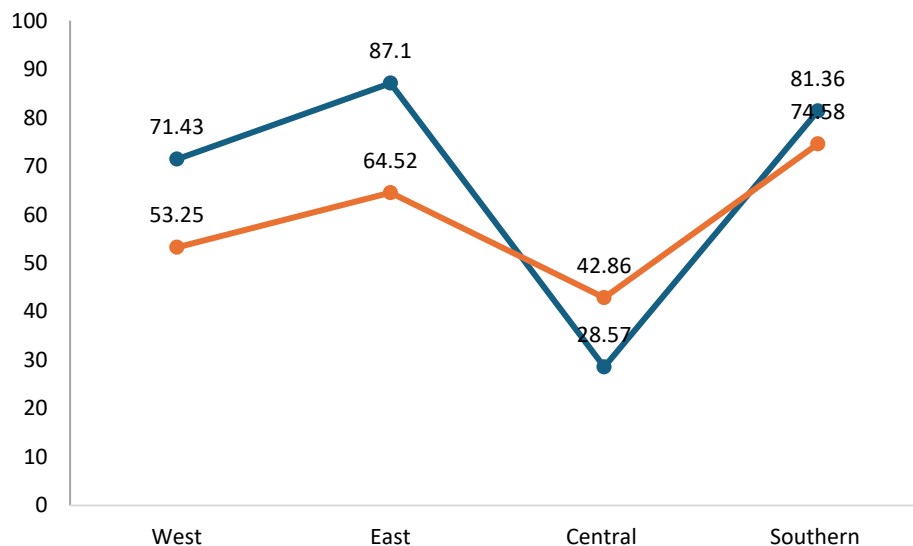
Digital infrastructure. As the World Bank has recommended, it is crucial to endow all higher education institutions, especially STEAM programs, with comprehensive and effective digital infrastructure to facilitate innovative teaching and learning practices (World Bank 2020). All campus units and academic departments must be included to connect faculty members and students to the internet from their mobile devices, tablets, laptops, and desktop computers.

Current levels of broadband connectivity are largely insufficient to support all but the most basic uses of digital technology. The 2024 survey presented earlier in this chapter indicated that, on average, 41 percent of students do not have access to internet in their lecture rooms and 33 percent do not have internet access in the ICT laboratories or their university. The results across subregions indicate that Central Africa and West Africa are the worst equipped (Figure 5.2).

The spread of undersea and terrestrial fiber optic lines from Europe to both West and East Africa and the development of new mobile and satellite-based technologies represent great opportunities for universities in Sub-Saharan Africa to leverage the abundance of data and wealth of digital resources and applications. Each African country should expand and strengthen its National Research and Education Network (NREN) to provide high-speed broadband access to all universities and other tertiary education institutions. Though the NRENs in North, East, and Southern Africa are more developed, much remains to be done in Central and West Africa, where they are not fully functional.

Recent experience in a few countries in Sub-Saharan Africa shows that, as universities acquire more bandwidth thanks to the development of NRENs, the constraints shift from availability at the national level to the campus network level, as many university networks are inadequate for their large user communities. It is therefore important to set up well-structured campus networks to optimize the use of bandwidth. Solving what are called “last mile” problems to increase widespread access and availability is as important as developing the national level NRENs.

Figure 5.2 - Tertiary Institutions in Africa with Internet Connectivity in Lecture Halls and ICT Labs (percent, by region)



Source: World Bank survey 2024.

Financial Incentives. National governments can decide to accelerate the growth and improve the quality of their advanced digital skills programs by providing financial incentives to interested universities. These can take two forms: (i) competitive funds, or (ii) performance contracts.

- Competitive funds have proven their strength and value as an effective and flexible resource allocation mechanism for transformative investment. Under this modality, institutions are invited to formulate project proposals for the creation, development, and strengthening of advanced digital skills programs. The proposals would be reviewed and selected by committees of peers according to transparent procedures and criteria. Positive experience in countries as diverse as Chile, China, Ethiopia, and Tunisia has shown the advantages of competitive funds to help improve quality and relevance, promote curricular and pedagogical innovations, and foster stronger linkages between universities and industry (Saint 2006; Salmi 2017). In some countries (Chile for example), governments allow accredited private universities to join the competition for these funds.
- Performance contracts are nonbinding regulatory agreements, negotiated between governments and higher education institutions, defining a set of mutual obligations. In this case, the “contracts” would aim at setting up new advanced digital skills programs or consolidating and expanding existing ones. In return for the participating universities’ commitment to meeting the performance targets established in the agreement, the government provides additional funding. The agreements may be with several or all institutions in the higher education system, or with a single institution. All or a portion of the funding may be conditional upon the participating institutions meeting the requirements in the contracts. The agreements can be

prospectively funded or reviewed and acted upon retrospectively. The World Bank is currently supporting performance agreements in Angola through a new higher education project.

To complement these approaches, some governments, for example Malaysia, Qatar, and the United Arab Emirates, have provided financial resources to attract foreign universities to set up a local campus or enter into a partnership with national institutions. Sub-Saharan African nations could follow the example of Rwanda, which invited Carnegie Mellon University and then subsidized its setting up of a campus in Kigali in 2011 that offers graduate-level programs in advanced digital skills.

Another option is to encourage partnerships among the leading providers of advanced digital skills in each country. Too often, local universities tend to compete, especially public and private institutions, instead of exploring ways of pooling their resources and working together for the greater good of the nation. In Switzerland, the top two engineering universities, EPF Zurich and EPF Lausanne, launched in early 2023 an initiative called the Coalition for Green Energy and Storage, led by ETH Zurich and EPFL, that brings together partners in politics, science, and industry to develop solutions for the storage and transport of renewable energy.⁶⁴ The federal government has provided subsidies to match the polytechnics own resources devoted to this initiative.

Finally, from a gender equity perspective, it is vital that governments in Sub-Saharan Africa ensure that the digital and green transitions do not predominantly benefit male students and professionals. It is therefore essential to put in place well-funded scholarship schemes to facilitate the participation of female students in advanced digital education programs in both public and private universities. International experience indicates that scholarships are a powerful tool to increase opportunities for qualified female students, not only by eliminating the financial barriers that prevent many of them from enrolling in the first place, but also by providing adequate support to boost the female students' chances of succeeding in their master's or PhD program (Salmi 2018).

Capacity Building. To build the capacity of science and technology universities and advanced digital skills programs in comprehensive universities, Sub-Saharan African governments could organize programs to promote a culture of continuous improvement. This would involve supporting higher education institutions in identifying areas for improvement and implementing effective strategies to enhance the quality of teaching, learning, and student experience. The relevant government agency would provide guidance, resources, and good practice examples through publications, workshops, webinars, and online resources to help institutions identify areas for improvement and implement effective strategies. The agencies would facilitate the sharing of good practices and innovative approaches to teaching and learning among institutions. This exchange of ideas would help institutions learn from each other and adopt effective methods to introduce innovations in their advanced digital skills programs. It would also provide professional development opportunities for staff and academic leaders through training programs, conferences, and networking events to enable staff to enrich their skills and stay updated on good practices.

⁶⁴ <https://www.swissinfo.ch/eng/sci-tech/swiss-universities-launch-green-energy-coalition/48577382>

5.1.5 Ensuring Sustainability

This educational transformation must be sustainable. The three drivers of sustainability of higher education systems and institutions are adequate governance, robust quality assurance, and stable funding (Salmi 2017).

- Good governance. International experience shows that universities that are fully autonomous are better positioned to become innovative and be responsive to rapidly changing external conditions and evolving labor market needs. At the same time, all higher education institutions that receive government subsidies should be fully accountable for the appropriate use of public resources through independent audit mechanisms and clear measures of improved performance.
- Quality assurance. The most effective way of promoting improvements in higher education programs is not by controlling and assuring quality at the national level, but by helping higher education institutions to develop a robust internal quality assurance culture based on standards and procedures owned throughout the institution. Therefore, it would make a lot of sense for the national agency in charge of higher education to support the development and strengthening of internal quality assurance units in all higher education institutions, which are essential to the development of a genuine and effective quality assurance culture. This could be complemented by the formulation of quality enhancement frameworks and methodologies to guide higher education institutions in their improvement efforts. These frameworks would support a structured approach to identifying priorities, setting targets, implementing changes, and evaluating outcomes as a rigorous approach to continuous improvement.
- Financial sustainability. A recent independent evaluation of the African Centers of Excellence, sponsored jointly by the World Bank and the French Development Agency (AFD), found that the new Centers, designed as regional institutions, had achieved impressive results. They have rapidly built the capacity to offer high quality advanced training in multidisciplinary fields and conduct leading-edge applied research in partnership with local industry. The evaluation found, at the same time, that the Centers face a major challenge in terms of financial sustainability in the medium to long term. Sub-Saharan African countries engaged in upgrading and expanding their advanced digital education programs should carefully study the results of this evaluation and work on strengthening the financial sustainability of their higher education systems. This would involve the following steps: (i) defining clear expansion and quality improvement targets; (ii) translating these targets in short-, medium-, and long-term financing requirements; (iii) exploring ways of mobilizing additional public resources; (iv) encouraging public higher education institutions to diversify their revenue sources; and (v) promoting the development of good quality private higher education and public-private partnerships to complement the public higher education sector.

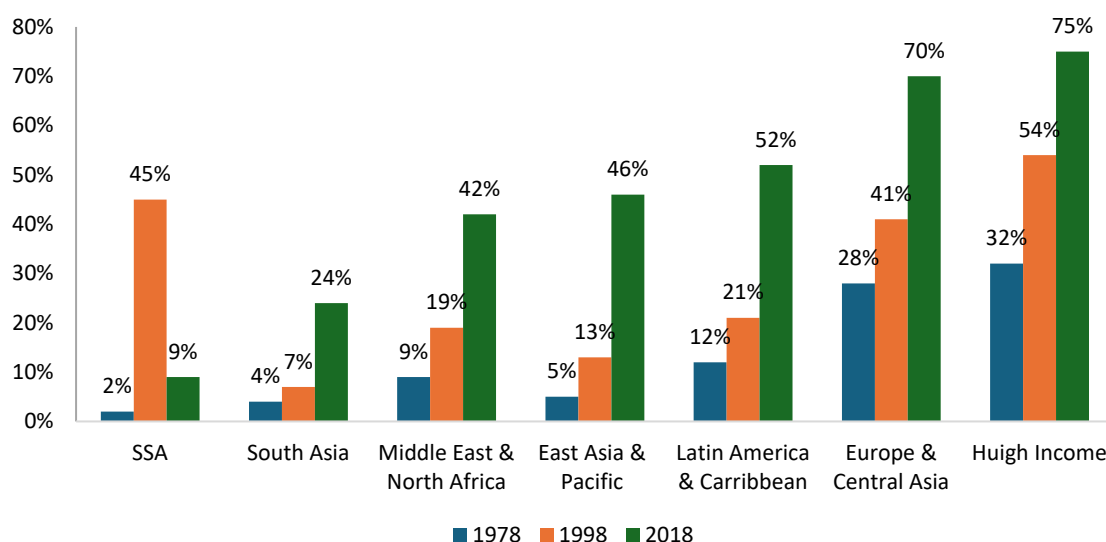
5.2 Institutional Policies and Programs

5.2.1 Present Challenges

With an average tertiary enrollment rate of 10 percent—the lowest in the world—serious issues of low quality and relevance, and an embryonic research capacity, the Sub-Saharan Africa’s universities and other higher education institutions have, by and large, failed to become engines of development.

Quantitative Expansion and Disparities. Between now and 2035, 74 percent of the expected global population growth for the 18–23 age group will be concentrated in 10. Eight of these countries are in Sub-Saharan Africa: Angola, the Democratic Republic of Congo, Ethiopia, Kenya, Niger, Nigeria, Uganda, and Tanzania. However, despite several decades of investment to expand their higher education systems, and even though the subregion’s enrollment rates have doubled every 20 years since 1978, few countries in Sub-Saharan Africa have been able to make significant progress. As a matter of fact, Sub-Saharan Africa has the lowest participation rate in tertiary education in the world and has fallen further behind compared to the other regions (Figure 5.3).

Figure 5.3 - Gross Tertiary Enrollment Rates by Region



Sources: World Bank, World Development Indicators 2018; UNESCO Institute for Statistics.

In most Sub-Saharan African countries, the growth of enrollment has not been widely spread across all income groups. The disparity index, measured as the Gross Enrollment Rate (GER) for the richest quintile over the GER for the poorest quintile, remains very high in several countries (Table 5.2). For example, among the West African countries for which data are available, only Burkina Faso, Niger, Côte d'Ivoire, Liberia, and Mauritania have a relatively small degree of inequality in tertiary-level enrollment from a

social origin viewpoint. Benin, the Republic of Congo, Guinea, Kenya Nigeria, and Sierra Leone are the most unequal countries.

The situation is not substantially better in other parts of Africa. In Kenya, young people from the richest income quintile are 49 times more likely to enroll in university than those from the poorest quintile. In South Africa, for instance, almost 70 percent of university tuition subsidies benefit students from households in the three wealthiest income deciles (World Bank 2019a). In Senegal, students from the poorest quintile receive only 6 percent of total education expenditures, while those from the richest quintile get 53 percent of the total education benefits,

Gender is the other main dimension of disparity. Sub-Saharan Africa is one of two regions in the world (the other is South Asia) that have not yet achieved gender balance in higher education enrollment yet. The most recent UNESCO statistics show the proportion of female students in higher education in Sub-Saharan Africa at 42 percent. Furthermore, girls are less likely to choose STEM fields. In Ghana, for example, women comprised only 1 percent and 4 percent, respectively, of graduates finishing programs in ICT and engineering in 2019. Though the situation is not so dire in Tanzania; female students account only for 15 percent of engineering students (World Bank 2021). A survey of 17 African countries showed that women represented less than 30 percent of STEM PhD students (Fischer et al. 2020).

Table 5.2 - Disparity Index in Selected Sub-Saharan African Countries

Most Equal (5 to 14)	Average (15 to 44)	Most Unequal (45 to 170)
Burkina Faso	The Gambia	Guinea
Niger	Guinea Bissau	Nigeria
Côte d'Ivoire	Togo	Republic of Congo
Liberia	Ghana	Benin
Mauritania	Gabon	Sierra Leone
	Cameroon	Kenya
	Chad	
	Senegal	
	Mali	

Source: Household surveys (most recent available year).

Quality and relevance. Measuring the quality and relevance of higher education programs is a challenging endeavor. Unlike what happens at lower levels of education, where ministries of education

can use widely accepted metrics like PISA to assess learning outcomes from an international perspective, no such instrument yet exists for higher education. Furthermore, few African nations regularly collect comprehensive data about their graduates' employment, even though the labor market results of graduates are an essential indicator of the quality and relevance of training programs. The limited evidence and data available reveal serious shortcomings that adversely affect the quality and relevance of higher education in Sub-Saharan Africa and explain the high levels of graduate unemployment experienced in many countries. In Ghana, for example, a 2017 survey found that no more than 10 percent of students found a job within the first year after graduating.⁶⁵ Graduate unemployment reached 32.6 percent in South Africa in 2022.⁶⁶ The contributing factors include outdated curriculum and weak linkages to industry; poor teaching and learning infrastructure; high student-teacher/faculty ratios; low quality of teachers/faculty; and lack of adequate data to keep policy makers and institutions accountable for their performance. Higher education institutions are often not agile enough to respond in a timely fashion and adequately to the changing nature of work. A few country vignettes can illustrate this situation.

In Nigeria, for example, the 2018 Blueprint document, written by a group of experts appointed under the authority of the National Universities Commission, found evidence of poor quality throughout the system. The ratio of students to faculty is close to 150:1 in the top federal universities, and a 2018 employment survey indicated tertiary education graduates' employment rates from 37–68 percent (for all but one private university).

"In many ways, very little has changed in the content and manner educational materials have been delivered to students in many Nigerian universities over the years... Curricula taught are hardly reviewed in decades to reflect current realities, advances in new knowledge and practice as well as priority areas for national growth and global developmental trajectories ... (NUC 2018, 19)."

The situation is no better in Francophone West African and Central African countries. In Burkina Faso, for instance, rapid enrollment growth has not been matched by rising numbers of faculty, resulting in severe overcrowding in public universities. The student-to-faculty ratio is around 112:1, way above the UNESCO standard of 25:1, with negative consequences for the quality of teaching and learning. Poor working conditions and low remuneration have prompted many professors to leave the profession or moonlight in private universities and other consulting opportunities, and account for the reluctance of new PhDs with degrees acquired overseas to return to Burkina Faso to teach (World Bank 2018a). In Côte d'Ivoire, the quality of teaching and learning is poor, according to a recent World Bank report: "Most higher education institutions are not fulfilling their mission of training high-quality professionals to meet the demand of the labor market. Efficiency appears to be low in public universities, where about 40 percent of students have been in the system for more than 10 years" (World Bank 2018b, 14).

⁶⁵ <https://www.isser.ug.edu.gh/research-impact/only-10-graduates-find-jobs-after-first-year-%E2%80%93-isser#:~:text=Data%20from%20the%20Institute%20of,first%20year%20of%20completing%20school>

⁶⁶ <https://www.dailymaverick.co.za/article/2022-06-16-youth-are-starved-of-opportunities-say-experts-ahead-of-youth-day/#:~:text=A%20recent%20report%20by%20Statistics,for%20those%20aged%2025%2D34>

To take one example from East Africa, a study on the quality of higher education in Kenya (World Bank 2019b) found that rapid enrollment growth in the university sector has come at the expense of quality. Pedagogical practices continue to be very traditional, with overreliance on rote learning and outdated curricula that tend to be excessively theoretical. The public budgets allocated to the universities have not kept pace with student numbers, meaning that the capacity to fund the needed human and educational resources has not been sustained. Government statistics indicate that the number of academics teaching at public universities grew by only 13 percent in total between 2011 and 2018, while student numbers rose fivefold.

Research output. Africa's footprint scientific output is also small, apart from the few research-intensive universities operating in South Africa and in North Africa. To assess in a comparative perspective the research output of some of the largest African economies, Egypt, Nigeria, and South Africa, Table 5.3 presents the change in the number of citable documents relative to the population between 2010 and 2020, corresponding to the quantitative dimension of research production, and the H-index, which measures the quality and impact of that research.⁶⁷

Table 5.3 - Research Output of Selected Sub-Saharan African Countries (2010 and 2021)

Country	Citable Documents per 1 million inhabitants (2010)	Citable Documents per 1 million inhabitants (2021)	Increase from 2010 to 2021	H-Index
Ethiopia	9.1	342.5	3,764%	193
Ghana	30.0	955.2	3,184%	191
Kenya	36.2	836.8	2,312%	310
Nigeria	31.7	597.2	1,884%	260
Rwanda	13.1	367.6	2,806%	107
Senegal	29.8	740.2	2,484%	146
South Africa	224.9	5,673.5	2,523%	567
Tanzania	17.6	359.3	2,042%	205
Uganda	25.4	500.5	1,971%	209

Source: SCImago. SJR — SCImago Journal & Country Rank. <https://www.scimagojr.com/countryrank.php>.

⁶⁷ The H-index is a bibliometric index developed in 2005 by Professor Jorge Hirsch, a University of California physicist. A researcher's H-index score is the maximum number of publications for which each publication is cited at least that many times. The index is based on the set of the scientist's most cited papers and the number of citations that they have received in other publications. The H-index is better than many other bibliometric measures in that it considers both productivity and impact, is not biased by a small number of very successful articles, discounts the value of papers that are not influential and uses only publicly available data (Usher 2012).

South Africa is the outlier in the region; the research results of most other Sub-Saharan Africa countries are not very satisfactory. After South Africa, Nigeria has one of the most extensive university networks, but its performance is quite average from an international perspective. Even though its scientific output doubled over the past decade, the H-index for Nigeria is about three times lower than India's, indicating poor performance in quality and impact of research.

5.2.2 The Brighter Side

Notwithstanding the magnitude of the challenges outlined in the previous section, it is equally important to recognize the dynamism of those African higher education systems and institutions whose transformative efforts have shown good results, as illustrated by the following examples.

High returns to higher education. Among all the regions in the world, higher education graduates in Sub-Saharan Africa achieve the highest rates of return to investment in their education (Table 5.4). These high returns reflect the high demand for advanced skills and the insufficient supply in the subcontinent.

Table 5.4 - Educational Rates of Return by Region

Region	Primary	Secondary	Tertiary	Countries
Sub-Saharan Africa	14.4	10.6	21.0	33
South Asia	6.0	5.0	17.3	7
Latin America and Caribbean	7.8	5.4	15.9	23
East Asia	13.6	5.3	14.8	13
Middle East and North Africa	15.0	4.5	10.5	10
Europe and Central Asia	13.9	4.7	10.3	20
All Countries	11.5	6.8	14.6	130

Source: Montenegro and Patrinos 2014.

South Africa

The South African higher education system has a unique, almost paradoxical configuration: its top universities are the most advanced on the African continent, operating as high-caliber institutions, offering excellent graduate degree programs and achieving a steady output of internationally recognized

research. They are leaders in offering advanced training and conducting applied research for the digital, green, and blue transitions.⁶⁸

And yet, the country's tertiary education system remains among the most segmented and unequal in Africa, despite the steady efforts of successive governments since the end of apartheid in 1994 to reduce the legacy of inequality and exclusion. Black South Africans make up 80 percent of the total population, but only 16 percent of young black South Africans go to college, compared to 55 percent of whites. Meanwhile, official reports indicate that a significant number of institutions fail to provide adequate learning conditions and lack the human and financial resources necessary to provide a quality education (World Bank 2019a).

Ashesi University

In Ghana, Ashesi University has received international recognition for its innovative multidisciplinary curriculum aiming at developing critical thinking, leadership skills, ethical reasoning, and effective communication skills.⁶⁹ Since graduating its first batch of 30 students in 2002, the new private, not-for-profit institution has grown to a total enrollment of about 1,300 students. Ashesi University was among the first African higher education institutions combining the liberal arts and sciences with professional majors, with the purpose of educating entrepreneurial leaders with a strong ethical commitment. In 2017, it was awarded the WISE education prize by the Qatar Foundation in recognition of its innovative curriculum. At the heart of the Ashesi experience is an interdisciplinary core curriculum, a strong emphasis on experiential learning, and a campus culture emphasizing ethical behaviors, leadership, and sustainability.

Other Pioneering Initiatives

In Rwanda, a branch of Carnegie Mellon University (CMU) was established in 2011 in partnership with the Government of Rwanda to address the critical shortage of high-quality engineering talent needed to accelerate development in Africa. CMU-Africa's vision is to educate and empower the next generation of African leaders and innovators by delivering a world-class educational experience. Its mission is to produce creative and technically strong engineers, trained in the African context, who can be expected to have a transformative impact in their communities and region. As of May 2020, CMU-Africa had trained close to 300 engineers in Rwanda. Almost all of them have found a job (96 percent within six months of graduation) and have stayed in Africa (98 percent), with an employer satisfaction rate of 95 percent.⁷⁰

⁶⁸ https://www.universityworldnews.com/post.php?story=20230322202257227&utm_source=newsletter&utm_medium=email&utm_campaign=GLNL0732

⁶⁹ <http://www.ashesi.edu.gh/academics/the-ashesi-education.html>

⁷⁰ <https://www.africa.engineering.cmu.edu/alumni-impact/index.html>

In Niger, the recently launched African Development University is positioning itself as an innovative not-for-profit university dedicated to the education of ethical leaders with the needed knowledge, skills, and commitment to contribute to the future of Sahel nations (Box 5.2).

Box 5.2 - African Development University in Niger

The African Development University in Niger's capital, Niamey, is the result of the vision of a young man, Kader Kaneye, who started dreaming 12 years ago about how to empower youth in his country through quality higher education. Following in the footsteps of the founder of Ashesi University in Accra, Patrick Awuah, Kaneye's vision matured at Harvard University, where he partnered with one of his classmates from the Kennedy School of Government, Meredith Segal.

After graduating in May 2017, Kaneye and Segal spent three months working night and day touring buildings in Niamey that were potential sites for his new university. Finally, they settled on an old building that was donated to them but required massive repairs. "Thereafter, we recruited a group of dedicated volunteers and solicited partners from around the world." They opened this not-for-profit university – the country's first – in 2017, but their ambition is bigger than the creation of a single university: they want to literally transform Niger's higher education system.

Kaneye started thinking about founding a university in 2007 while teaching at a private university in Niamey, where the owner expected him to teach a masters-level course in finance in a quarter of the time it needed. "I was being asked to teach the course in just 30 credit hours to students that were not as strong as the students in France that took the course in 120 credit hours," said Kaneye. When he noticed the problem was widespread in Niger, he decided there was a need for a more ethical higher education institution.

Having established the university in 2017, Kaneye is now determined to transform it into a world-class institution that prepares talented youth to enter the workforce equipped with the knowledge, leadership and critical thinking, ethics, and collaborative mindset necessary to design and drive the Nigerien economy and the Sahel region in general.

This investment has clearly paid off. Kaneye has put the African Development University on its feet with the aim of educating young people, regardless of their financial means. In his own words, Kaneye is looking for students who are committed to academic excellence, prepared to work hard and committed to serve their communities. "We have students from all backgrounds, lots of them from rural areas of Niger and surrounding countries." At present, 70 percent of students at the African Development University are women, and 90 percent of students receive some sort of financial aid.

The university has fashioned a unique academic program that includes a three-year undergraduate degree that prepares students to become ethical leaders. A two-year specialized master's program is available to career professionals and a one-year MBA is also on offer.

To circumvent the shortage of good lecturers, e-learning is one of the university's key delivery formats. "Massive open online courses, MOOCs, are embedded in our learning experience and technology is a big piece in our strategy because finding qualified professors is difficult here in Niger, as is the case in most universities in Sub-Saharan Africa."

Source: Kigotho (2019).

African Centers of Excellence

A recent evaluation of the first wave of African Centers of Excellence (ACEs), which were launched in 2014 with support from the World Bank has found that this initiative has created synergies in higher education across Sub-Saharan Africa by optimizing limited resources and deepening cooperation between countries, while equipping young people with highly relevant skills and strengthening the research capacity and output of the host universities. The ACEs were designed to address specific common regional development challenges in Sub-Saharan Africa. Several of the new Centers, which are specialized in select multidisciplinary areas (health, environment, education, agriculture, etc.), have demonstrated the capacity to tackle important development issues facing the region through graduate training in masters, PhD, and short-term courses, and through applied research in the form of partnerships and collaborations with other institutions and the private sector. Some of the Centers led major health initiatives during the Ebola epidemic and the COVID-19 pandemic. For example, the Africa Center of Excellence for Genomics of Infectious Diseases hosted by Redeemer University in Nigeria, and the West African Centre for Cell Biology of Infectious Pathogens at the University of Ghana, illustrate how regional higher education integration can help generate innovative solutions to the most serious problems faced by African societies (World Bank 2021b).

The International Institute for Environment and Water (2iE), based in Ouagadougou (Burkina Faso), is one of the most successful institutions among the ACEs established in Francophone Sub-Saharan Africa. Created in 2008, the Institute has the highest proportion of regional students among all ACEs (63 percent), including many master's students. It has built a robust research capacity and become a strong performer in publications and citations (first among Francophone ACEs and second among all ACEs in its share of publications in highly cited journals). Its research has also had a positive impact on the region. For instance, 2iE has developed a new water collection basin technology to better sustain crops in low-moisture environments. A collaboration with the state company SOIFTEX aims to make use of this technology to help grow cotton. The institute has also been working with the state water company in Burkina Faso on developing new ways to filter arsenic.

Besides thriving as centers of research and teaching excellence, many ACEs are helping to build the capacity of their host universities to provide quality postgraduate education that is relevant to the labor market as well as helping them conduct high-quality applied research that seeks ingenious solutions to key development priorities. Furthermore, to generate greater impact, most Centers have developed partnerships with other academic institutions, nationally, regionally, and internationally, and with industry and the private sector. Thus, the Centers are gradually becoming role models for other higher education institutions in Sub-Saharan Africa by delivering excellent teaching and research.

Finally, in many countries, the pandemic has provided the opportunity for increased collaboration among tertiary education institutions that would otherwise be competing. This has been facilitated by the proliferation of software and platforms that enable collective and collaborative work. In Senegal, for instance, the Virtual University played a crucial role in helping all the country's other universities during the early stages of the pandemic.

5.2.3 Expanding and Strengthening Advanced Digital Skills Programs

The leaders of higher education institutions seeking to develop their advanced education programs must take the following six dimensions into consideration:

- Strategic selection of programs
- Innovations in curriculum, pedagogy, and assessment
- Close linkages with employers
- Lifelong perspective
- Deep partnerships with foreign universities
- Promotion of gender equity

Strategic Selection of Programs

Each university should (i) review existing advanced digital education programs to assess their continuing relevance and the need for updating or adjusting, and (ii) explore which new programs should be designed and launched to prepare graduates for the jobs of the future. This would involve setting up a small unit tasked with undertaking a systematic scanning and mapping of relevant labor market trends internationally and nationally to identify areas of growth in relation to the country's development priorities.

Innovations in Curriculum, Pedagogy, and Assessment

Adopting innovative curricular, pedagogical, and assessment practices is the best way to align the quality and relevance of advanced digital education programs with the national digital transition strategy and the needs of employers. In 2018, MIT published the findings of a major study of the evolution of engineering education. The study could help Sub-Saharan African universities of science and engineering think about relevant innovations in their own technology programs as they attempt to transform the education experience of their students more experiential (Box 5.3).

As a result of this study, MIT has established a new interdepartmental, project-based program called NEET (New Engineering Education Transformation) that gives students the opportunity to select explicitly multidisciplinary projects during the four years of their degree while still learning the fundamentals in departmentally offered subjects.⁷¹ The four key objectives of the program are to (i) focus the curriculum on the machines and systems of the future rather than those of the past, (ii) prepare students to become discoverers or makers, (iii) organize the educational experience around the way students best learn, and (iv) teach them to think and learn independently. Students can enroll in one of the following four thematic threads: advanced materials machines, autonomous machines, living machines, and low-carbon energy systems.

⁷¹ <https://neet.mit.edu/about>

Box 5.3 - The Future of Engineering Education

The trend in engineering education is a move toward socially relevant and outward-facing engineering curricula. Such curricula emphasize student choice, multidisciplinary learning and societal impact, coupled with a breadth of student experience outside the classroom, outside traditional engineering disciplines, and across the world. Many of these educational features appear within engineering programs at the ‘current leader’ institutions, they are often “bolt-on” activities and are isolated within the curriculum. As a result, much of the benefit of these experiences remains unexploited because they are unconnected with other curricular components and students are not encouraged to reflect upon and apply what they have learned in other areas of the degree program.

In contrast to the current leaders, many institutions identified as emerging leaders in engineering education typically deliver distinctive, student-centered curricular experiences within an integrated and unified educational approach. In most cases, their curricula were designed from a blank slate or were the result of a recent systemic reform. Experiences such as work-based learning and societally relevant design projects are embedded into the programs in a way that provides a solid platform for student self-reflection and a pathway for students to both contextualize and apply the knowledge and skills they have gained elsewhere in the curriculum. However, many of these ‘emerging leader’ exemplars – such as at Olin College of Engineering and Iron Range Engineering – cater to relatively small cohort sizes. The key innovations that are likely to define the next chapter for engineering education are the mechanisms by which such features can be integrated across the curriculum at scale: that is, delivered to large student cohorts under constrained budgets.

Source: Graham (2018), iii, iv.

This evolution has substantial implications for universities in Sub-Saharan Africa with advanced digital education programs, if they want to support the development of the green and/or blue economy. As they contemplate introducing new programs to reflect the evolution of labor markets, they should not operate in silos with digital skills in one side of the institution and skills for the green/blue economy in another part of the institution. They should carefully consider the intersections among the various sets of skills and opportunities for putting in place leading-edge multidisciplinary programs that would bring all aspects of the digital transition together.

Effective labor market feedback mechanisms, such as tracer surveys and regular consultations with employers and alumni, are indispensable for adjusting curricula to meet the changing needs of the economy. All Sub-Saharan African universities could benefit greatly from setting up a unit that is responsible for systematically monitoring the labor market trajectories of all graduates and the trends in job postings. This unit could use data analytics to map out future labor market needs and influence the shaping of the curriculum, following the example of the city of Manchester, which has tried to chart the competencies, skills, and attributes in demand in the Greater Manchester area by analyzing 600,000 LinkedIn profiles of people working in the region. The British Council supported a project to use big data for the same purpose in Africa. A pilot survey of graduates of pharmacy programs at the University of Ghana, the University of Lagos, and the University of the Western Cape was successfully conducted to test the potential of mobile phones for the collection of labor market results data (Yeld 2018).

Sub-Saharan African universities that have many advanced digital education programs may consider establishing cooperative learning programs that alternate on-campus learning periods and regular in-firm internships, following the example of Waterloo University in Ontario, Canada (Box 5.4).

Box 5.4 - Lessons from Co-operative Programs

Co-operative education is a model that alternates academic studies with relevant work experience in a field directly related to a student's academic or career goals. The advantages of this model are considerable: it allows students to gain relevant work experience, apply theoretical knowledge gained in the classroom and clarify career plans. It also helps students to build contacts with employers and establish networks to facilitate finding employment upon graduation. Working as part of the studies program helps finance education; it is also useful for learning on how to behave on the job and in general to develop the skills which employers want. The advantages for employers are also significant, because they have "access to well-prepared short-term workers, flexibility to address human resource needs, cost-effective long-term recruitment and retention, partnerships with Schools, and cost-effective productivity."^a

Waterloo University in Ontario, Canada, is home to the world's largest co-op program, with 15,800 undergraduate co-op students (more than 56 percent of the university's full-time undergraduate population and more than twice as many students as the next largest program in the world) and 3,500 partner employers around the world (StudyinCanada.com).^b A Co-op student at Waterloo graduates with the same number of study/academic terms as a non-co-op student, plus up to two years of work experience in different professional areas. The student has four to six work terms (usually four months long each), to try out a variety of careers before graduating. On average, by the time the student graduates, he/she has already earned from \$25,000 to \$74,000, resulting in smaller student loan debt than other students and a greater capacity to repay it. Graduates of Waterloo's co-op programs earn about 15 percent more upon graduation than graduates of non-co-op programs (University of Waterloo).^c Furthermore, Waterloo University offers the Enterprise Co-Op program, where students obtain support (advice of experienced professionals and, in some cases, funds) to develop their own businesses.

Sources: The World Association for Cooperative Education (WACE); The National Commission for Cooperative Education; StudyinCanada.com; University of Waterloo, Canada.

a. The National Commission for Cooperative Education (NCCE) is dedicated to advancing cooperative education throughout the United States. <http://www.co-op.edu/aboutcoop2.html>

b. StudyinCanada.com. "University of Waterloo." <http://www.studyincanada.com/english/schools/profile.asp?SchoolCode=uwatl08&ProfileType=University&URL=index>

c. University of Waterloo, Canada. "Co-op at Waterloo." <http://findoutmore.uwaterloo.ca/coop/>

Complementing efforts to align the content of programs with the world of work, the focus of pedagogical innovations should be on providing a stimulating learning experience for the students and increasing learning efficiency. Several universities of science and technology in Sub-Saharan African countries have started to move away from traditional teaching methods to make teaching and learning more interactive, collaborative, and experiential. Today's cohorts of young students—sometimes described as the e-generation or Renaissance kids—have grown up with the Internet and have been learning since their earliest youth from computer screens, websites, and visual media. Traditional ways

of teaching have been found increasingly counterproductive in engaging and motivating the e-generation. Mounting evidence provided by the cognitive and learning sciences indicates that interactive pedagogical approaches facilitate an effective learning experience (Box 5.5).

Box 5.5 - Twilight of the Lecture: “Active Learning” Overthrowing the Style of Teaching That Has Ruled Universities for 600 Years

In 1990, after seven years of teaching at Harvard, Eric Mazur was delivering clear, polished lectures and demonstrations and getting high student evaluations for his introductory Physics 11 course, populated mainly by pre-med and engineering students who were successfully solving complicated problems. Then he discovered that his success as a teacher “was a complete illusion, a house of cards.”

The epiphany came via an article in the *American Journal of Physics* by Arizona State professor David Hestenes. He had devised a very simple test, couched in everyday language, to check students’ understanding of one of the most fundamental concepts of physics—force—and had administered it to thousands of undergraduates in the southwestern United States. Astonishingly, the test showed that their introductory courses had taught them “next to nothing,” says Mazur: “After a semester of physics, they still held the same misconceptions as they had at the beginning of the term.”

Mazur tried the test on his own students. To his consternation, the simple test of conceptual understanding showed that his students had not grasped the basic ideas of his physics course: two-thirds of them were modern Aristotelians. “The students did well on textbook-style problems,” he explains. “They had a bag of tricks, formulas to apply. But that was solving problems by rote. They floundered on the simple word problems, which demanded a real understanding of the concepts behind the formulas.”

Some soul-searching followed. “That was a very discouraging moment,” he says. “Was I not such a good teacher after all? Maybe I have dumb students in my class. There’s something wrong with the test! How hard it is to accept that the blame lies with yourself.”

Serendipity provided the breakthrough he needed. Reviewing the test of conceptual understanding, Mazur twice tried to explain one of its questions to the class, but the students remained obstinately confused. “Then I did something I had never done in my teaching career,” he recalls. “I said, ‘Why don’t you discuss it with each other?’” Immediately, the lecture hall was abuzz as 150 students started talking to each other in one-on-one conversations about the puzzling question. “It was complete chaos,” says Mazur. “But within three minutes, they had figured it out. That was very surprising to me—I had just spent 10 minutes trying to explain this. But the class said, ‘OK, We’ve got it, let’s move on.’”

“Here’s what happened,” he continues. “First, when one student has the right answer and the other doesn’t, the first one is more likely to convince the second—it’s hard to talk someone into the wrong answer when they have the right one. More important, a fellow student is more likely to reach them than Professor Mazur—and this is the crux of the method. You’re a student and you’ve only recently learned this, so you still know where you got hung up, because it’s not that long ago that you were hung up on that very same thing. Whereas Professor Mazur got hung up on this point when he was 17, and he no longer remembers how difficult it was back then. He has lost the ability to understand what a beginning learner faces.”

Box 5.5 (continued)

This innovative style of learning grew into “peer instruction” or “interactive learning,” a pedagogical method that has spread far beyond physics and taken root on campuses nationally. Interactive learning triples students’ gains in knowledge as measured by the kinds of conceptual tests that had once deflated Mazur’s

spirits. “In a traditional physics course, two months after taking the final exam, people are back to where they were before taking the course,” Mazur notes. “It’s shocking.” Peer-instructed students who’ve actively argued for and explained their understanding of scientific concepts hold onto their knowledge longer.

Such pedagogical invention isn’t just a trial-and-error endeavor. Rigorous evaluations using statistical analysis can help distinguish the most promising innovations. For his part, Mazur has collected reams of data on his students’ results. End-of-semester course evaluations he dismisses as nothing more than “popularity contests” that ought to be abolished. “There is zero correlation between course evaluations and the amount learned,” he says. “Award-winning teachers with the highest evaluations can produce the same results as teachers who are getting fired.” He asserts that he is “far more interested in learning than teaching,” and envisions a shift from “teaching” to “helping students learn.” The focus moves away from the lectern and toward the physical and imaginative activity of each student in class.

Source: Lambert (2012).

Problem-based learning, a student-focused method in which students learn about a topic and acquire competences by working in groups to solve open-ended problems, has shown great results. The rationale of this approach is that it raises students’ motivation by challenging them to solve a problem, thereby making the learning experience more stimulating and effective. As they are confronted with a new problem, the students must take stock of the information and tools they need to learn to be able to find a solution. Project-based learning is generally organized as a group activity.

Business schools were perhaps the first institutions to use some kind of problem-based approach through the case studies written up as a platform for simulating real-life situations and getting the students to learn by analyzing and resolving real problems. In the past decades, a growing number of universities have adopted project-based learning as their main educational approach, especially in medical and engineering education. McMaster University and Sherbrooke University in Canada were among the first ones to apply project-based learning training the training of medical doctors, followed by Maastricht in the Netherlands and Roskilde University in Denmark. Established in 1974 as the Netherlands’ newest university, Maastricht University rapidly expanded the problem-based approach from medical education to all fields, including economics and business, law, psychology and neuroscience, humanities, natural sciences, arts, and social sciences.

Franklin W. Olin College of Engineering, a new private university located in Wellesley, Massachusetts, operates a comprehensive design-based educational model. It is perhaps one of the best examples of an institution embodying the radical transformation that interactive, collaborative, and experiential learning call modalities for. Olin College opened its doors in 1999 with an audacious charter: offering an experimental laboratory for remaking engineering education. Starting from the observation that STEM

education is in crisis in the United States because it fails to attract the right students, because it is teaching the wrong curriculum, and because it is using methods that are known to be largely ineffective, the main purpose of Olin is to train the engineer of the 21st century, “a person who envisions what has never been and does whatever it takes to make it happen” (Buderi 2014).

Olin College operates with several innovative features. To identify future innovators and leaders, it recruits its students not primarily on the basis of their test scores and grades but through face-to-face interviews in multiple settings, including team exercises. Learning is primarily organized around project-based and design-based activities performed by students working in teams. Olin College has no academic departments and does not offer tenure to its faculty members, resulting in an academic culture emphasizing interdisciplinary learning and educational innovation. A typical program will involve several teachers from different disciplines providing integrated courses with interdisciplinary material. The curriculum combines engineering, entrepreneurship, and humanities in a unique way. Every Olin student must start and run a business to graduate and must complete a year-long senior design project sponsored by industry. The students are also expected to acquire leadership and ethical competencies through social sciences and humanities courses. For that purpose, Olin students cross-enroll at Babson College and Wellesley College for entrepreneurship and humanities courses, respectively. To ensure that all Olin graduates are successful at communicating in a professional setting, every student is required to present some aspect of their academic work in a public setting at the end of every semester.

Fifteen years after the project was launched, Olin College can boast impressive results. In 2014, *Forbes* magazine ranked Olin eighth in the United States for highest SAT scores of incoming students. Based on a survey of 130,000 students, Princeton Review placed Olin in the top 20 in 15 categories, including 3rd for students studying the most, and 19th for the happiest students in the nation. The testimony of a typical Olin student reflecting on the learning culture of the College would be, “I’ve never worked this hard in my life and there’s nothing else I’d rather be doing” (Buderi 2014). Olin has been particularly successful in attracting young women into engineering education. While the proportion of women in engineering education is about 20 percent in the United States, it ranges from 40 percent to 50 percent at Olin. Olin graduates have outstanding career opportunities. According to a recent survey, 97 percent of Olin alumni were either employed—in a company or in a business they started themselves—or attending graduate school (22 percent of these were at Harvard, Stanford, or MIT). Companies sponsoring senior-year projects often recruit the students involved as permanent employees after they graduate.

Several African universities have introduced project-based learning to enrich their students’ learning experience. In partnership with the Finnish University of Aalto, three flagship institutions, in Kenya (University of Nairobi), Tanzania (Dar es Salaam University), and Uganda (Makerere University), are collaborating to implement project-based learning in a multidisciplinary mode. They see this project as vital to their transformation “from teaching universities to innovation universities.”⁷² The project aims to support the development of sustainable innovation ecosystems by building the capacity of university

⁷² <https://www.aalto.fi/en/news/new-project-develops-problem-based-learning-in-east-african-universities>

academics and students to find innovative solutions to the challenges faced by East Africa. In addition to organizing multidisciplinary project-based learning courses in their universities, the partners are establishing regional networks to support their innovation work.

Along similar lines, the PBL-BioAfrica project, which involves several Kenyan and Zambian universities, seeks to integrate project-based teaching and learning methods into bio-entrepreneurship education to equip graduates with practical and entrepreneurial skills. Participating faculty members are being trained on the use of project-based methods for climate-smart agriculture programs.⁷³ In South Africa, Walter Sisulu University has adopted an innovative curriculum based on project-based learning and community-based education to improve the practical and problem-solving skills of its medical students.⁷⁴ The University of Burundi has recently signed a partnership agreement with Maastricht University to introduce project-based learning at its newly set up National Digital Institute.

Aligned assessment methods. Curricular and pedagogical innovations can transform learning in an effective way only if the assessment criteria and processes are fully aligned with the educational experience of the students. For instance, traditional end-of-semester exams are not an adequate way of evaluating the learning outcomes of students who participated in problem-based courses organized around group work and peer learning. Similarly, during the Covid-19 pandemic, it became clear that online teaching and learning required new assessment approaches emphasizing more continuous assessment than one-off exams.

Therefore, to support students' acquisition of transversal skills, universities need to implement assessment strategies that are substantially different from the ranking and classifying practices that are commonly applied. Two innovative practices have emerged in recent years in the design and use of assessment in university settings. The first one is a progressive shift towards a competency-based education model, in contrast to the traditional content-based model of course design and delivery (Henri et al. 2017).

The second practice, triggered by the increasing reliance on competency-based evaluation, is the move away from high-stakes summative evaluations to a formative assessment model (Gomez-Garibello and Young 2018). Assessments are formative when the information that they generate is used to adapt the instruction process to student needs. Advanced technological tools, such as AI and social learning platforms, allow students to obtain immediate feedback from the formative assessment conducted by the instructor. The MOOC provider Coursera, for example, uses software that alerts the instructor when a large proportion of students submit wrong answers to homework assignments and provides students with hints to get at the correct answer.

⁷³ www.pbl-bioafrica.net; <https://unlimited.hamk.fi/ammattillinen-osaaminen-ja-opetus/challenges-of-using-problem-based-learning-in-africas-higher-education-institutes-and-the-way-forward>

⁷⁴ <https://safacts.co.za/universities-that-offer-medicine-in-south-africa/>

This type of system helps to fill in the gaps in explanation that can occur in courses and helps to ensure that all students are building the same conceptual foundation. Rather than waiting to hear back from the professor, students get immediate feedback that helps them to understand a concept and remember how to do it correctly the next time around (Teachthought 2018).

The main forms of social learning platforms that support the use of formative assessment are student response systems, online student peer-review systems, and online teamwork feedback systems.

As demonstrated by the disrupting effects of generative AI platforms such as ChatGPT, AI has the potential of revolutionizing teaching, learning, and assessment. To begin with, it can unburden faculty members from routine academic tasks. Grading software for multiple choice examinations is used in many universities. Technical University of Berlin, for instance, has developed “chatbots”—computer programs using natural language to conduct a conversation through auditory or textual methods—capable of grading assignments and responding to questions from students on a variety of topics, including how to plan their course of studies.

Of greater potential impact are adaptive learning virtual assistants and cognitive tutors that can teach students independently and guide them through more personalized learning. Carnegie Mellon University has been a pioneer in this area. Through its Open Learning Initiative, it has developed AI-based cognitive tutors that leverage AI algorithms to deliver content adapted to student needs based on their performance and engagement with the subject matter. Its course on statistics, for example, which is conducted with minimal contact with a human instructor, achieved comparable learning outcomes for students requiring fewer hours of study to master course content. In one course at the Georgia Institute of Technology, students could not tell the difference between feedback from a human being and feedback from a chatbot.

In pursuit of greater personalization in higher education, thought leaders such as Bill Gates champion AI tutors. Providing thorough feedback on writing assignments, for example, is an extensive and time-consuming process for instructors; virtual tutors can transcend checking for surface-level errors to analyze meaning, themes, and arguments to provide granular feedback to students. In online classrooms, the tutors can interrupt video lectures to ask questions directly to learners, replaying snippets of the video if it is clear the student is struggling to understand specific subject matter. This kind of omnipresent support and mentoring can fill in gaps, particularly for large introductory courses where it is challenging for instructors to give their pupils one-on-one attention. Researchers at the National School of Engineers of Sousse in Tunisia are investigating an AI tutoring system that recognizes facial expressions as students engage in science experiments in remote and virtual labs (NMC 2017, 47).

From a psychological and motivational viewpoint, interacting with AI-based software makes it easier for students to learn by trial and error without fear of failure. It helps them experiment and learn in a judgment-free environment, rather than running the risk of failing in front of the other students and the teacher. AI does not criticize the students but makes suggestions on how to improve and learn better. At the same time, it is important to consider the philosophical and psychological questions about human

reactions, behaviors and incentives that arise from increased reliance on AI, including the risk of academic dishonesty; that is, increased cheating and plagiarism.

Concluding comments. Three final observations are called for. First, improving the qualifications of academics will be critical to enhance the quality of advanced digital education programs. To meet the growing demand for qualified academics and the shortfall in PhD holders that most countries in Sub-Saharan Africa are facing, universities can strive to (i) attract qualified academics from the diaspora, (ii) expand their master's and doctoral programs and hire their own graduates as teaching staff; (iii) expand international training opportunities for their academics; and (iv) allow academic staff to work on a contract basis at other universities in addition to their primary employer. Increasing the share of qualified female academics could greatly enhance the quality of teaching, learning, and research.

Second, the establishment of well-resourced teaching and learning centers in science and technology universities should become a priority, for supporting active learning (design-based or problem-based learning, gaming, simulations, role playing, peer-to-peer learning, AI software for independent learning, etc.). These centers can rely on a range of training activities, including capacity building workshops and mentoring, to support the development of innovative pedagogical approaches among the teaching staff. Adequate time should be allotted to allow academics to participate in these important professional development activities. It will also be important to offer appropriate incentives (performance bonus, promotion, etc.) for teaching excellence that are on par with outstanding research.

Third, the introduction of innovative teaching and learning practices that promote interactive and collaborative learning also implies remodeling the physical infrastructure and environment of universities. From the flipped classroom, where the professor does not teach but essentially guides and facilitates self-learning and peer learning, to studios and open-space classrooms designed to support design-based learning in teams, the new learning facilities represent a flexible learning environment that breaks away from the traditional classroom and lecture hall.

Close Linkages with Employers

Strengthening linkages with the productive sectors is the most effective way of increasing the relevance of advanced digital skills programs. Sub-Saharan Africa's universities can rely on a variety of mechanisms for that purpose, including the participation of industry professionals in the redesign of program and course content, internships for undergraduate students, in-company placements of research students and academics, and the use of practitioners from industry as visiting lecturers. Box 5.6 summarizes the experience of UK universities in making employer engagement a core dimension of their curriculum development practice, while Box 5.7 shows a relevant example of linkages from Korea.

A few universities in Sub-Saharan Africa have pioneered the practice of placing academic staff in industry. It would be desirable to extend this positive approach in all departments offering advanced digital education programs. Along the same lines, it is imperative to strengthen existing career advisory centers to better inform students about career prospects and coordinate internships for students, as

well as in-firm placement of academics. A smooth university-to-work transition can be supported by targeted career and networking support over the study lifecycle, role models for students, and strong mentoring programs.

Box 5.6 - Good Practices of Employer Engagement

for Curriculum Improvement Purposes

A 2015 study in the United Kingdom identified four main categories of employer engagement in tertiary education (course development and delivery):

- Giving accurate and up-to-date information, advice, and guidance to students about the knowledge and skills needed to enter particular industries and professions;
- Facilitating and supporting work placements and internships to provide students with valuable work experience;
- Developing curricula, pedagogy, learning materials, and learning-related research projects; and
- Establishing bespoke learning and teaching facilities where students can acquire the specialist skills, they need in the workplace, often with financial support from firms.

Experience shows that successful and sustainable partnerships require specialist staff, ongoing relationship management, and significant development time. Typically, this engagement will take place with companies that are located near the university. While research and knowledge transfer activities are often administered centrally and thus highly visible in universities, employer engagement activities tend to be managed at faculty level or below.

The five case studies documented in the report yielded the following findings:

- Collaborations should be designed to respond to a strategic need recognized by all partners. This need will often be a shortage of graduates with the skills required by a particular company or group of companies, but it may encompass areas of research, particularly in advanced manufacturing or engineering. There may also be more specific needs, such as identifying innovative delivery methods.
- Collaborations require strong leadership from the senior teams of all the organizations involved, including the recognition that developing and implementing projects of this kind will be time-consuming and that engagement will need to be sustained indefinitely to keep curricula current.
- Co-location of staff and joint appointments can support the culture change required to work together effectively and speed up decision making.
- External funding streams can be important to give initial impetus to the partnership and give all organizations the confidence to release their own funds.
- Benefits to business can include the availability of graduates with relevant skills, recruitment efficiencies, and access to other university/business services. Benefits to universities include the development of an up-to-date and relevant curriculum, which will increase student recruitment and progression outcomes and enhance the university's reputation.

Source: UK University Alliance (2015).

Box 5.7 - Close Collaboration between Korean Universities and Firms

Yonsei University and Korea University, along with other universities in Korea, are rushing to open new departments in cooperation with Samsung Electronics or SK Hynix to groom future engineers in the field of system semiconductors.

The move comes amid a serious unemployment crisis in tandem and fears of brain drain in the industry. It is also in line with the Korean government's plan to nurture 3,400 professional personnel in the sector through 4-year undergraduate programs by the end of 2030, as need grows for chipmakers to expand their presence in the non-memory chip market.*

Sungkyunkwan University has already operated a similar course in cooperation with Samsung Electronics since 2006, enjoying great popularity among students and parents. During the 2019 admission period at the university, 1,387 students applied for the department's 55 openings.

Seoul National University and the Korea Advanced Institute of Science and Technology are also discussing opening their own departments.

Samsung Electronics will hire 50 students who major in system chips at Yonsei University, and SK Hynix will recruit 30 who study at Korea University. The chipmakers will also award scholarships to students of the new departments and cover the operating expenses of the university departments.

Source: IFC (2019).

* Semiconductor chips that do not store data permanently or temporarily, unlike traditional memory chips like RAM or flash storage.

Finally, incorporating training for entrepreneurship into advanced digital education programs could also help bring the programs closer to the productive sectors, thereby boosting their ability to nurture young entrepreneurs. Investing in incubators, innovation hubs, and start-up support programs fosters entrepreneurship and innovation ecosystems. These initiatives provide practical opportunities for young people to apply their creativity, collaboration, and problem-solving abilities.

Many of the new African Centers of Excellence have attained good results in incorporating entrepreneurship training into their master's-level courses. A 2019 report prepared by the European University Association explains that the key factors to promote entrepreneurship at university are collaboration, knowledge sharing, and allowing students to show initiative (Reichert 2019). "It is about interdisciplinarity in the classroom, project-based learning, teamwork, and developing soft skills. But it is also outside the classroom, allowing students to develop student-led activities" (Boyer King 2019). Besides the well-known examples of universities that have traditionally been successful in developing entrepreneurship mindsets and skills among its students, such as MIT or Stanford, several newer

institutions have also distinguished themselves in recent years, among them KU Leuven in Belgium, Aalto University in Finland, and Haifa Institute of Technology in Israel.

By setting up their own incubators and/or linking up closely with industrial parks under development, the strongest universities in Sub-Saharan Africa could contribute innovative ways of producing goods and services. Many African Centers of Excellence have achieved good results. Universities would need to make systematic efforts to undertake industry-oriented applied research and seek opportunities for technology commercialization. Conducting research that results in patents and licenses that allow firms to make new products and develop new lines of business is important, but it is not the only way to do technology transfer. Firm-strengthening ideas pass between the academic world and companies through other forms of collaboration.

The contribution of Sub-Saharan African universities to technology upgrade and absorption can best be achieved in two ways. First, involving employers in curriculum design, as suggested earlier, and having them take on students as interns strongly increase the probability that firms will employ qualified graduates. These graduates, in turn, will be agents of technology transfer, bringing new techniques and know-how to firms, especially to SMEs. At the end of the day, the best conduit for moving ideas back and forth between universities and firms is through the students and graduates themselves.

Second, by opening their doors to representatives of firms and organizing technology information and diffusion events, universities can act as knowledge exchange platforms which, despite the often informal character of interaction between academics and industry people, can have a significant technology transfer influence on firms.

Universities can support the digital and green transitions in several ways. Table 5.5 provides a summary of the principal modalities of collaboration on knowledge transfer and technology commercialization that universities in Sub-Saharan Africa with advanced digital education programs could consider.

Table 5.5 - Most Effective Knowledge- and Technology Transfer Mechanisms

University-Industry Linkages	Facilitating Role of National and/or Local Authorities	Comments
Public space function for networking and dissemination	Develop and fund programs to create and support clusters	With education and training, this function is seen by firms as the most important contribution of universities
Human capital formation (students and firm employees)	Priority setting and incentives for establishment of new programs Targeted scholarships Funding and tax incentives to facilitate insertion of PhD graduates	Primary role of universities in support of innovation

Research	Matching grants and tax incentives Criteria for evaluating the performance of researchers Support for cluster formation	Increased returns at the intersection of traditional disciplines
Problem-solving and consulting	Targeted assistance to SMEs	
Sharing of technical infrastructure	Funding	Need for clear revenue-sharing arrangements among researchers, departments, and university overall
Knowledge commercialization	Appropriate intellectual property legal framework Technical assistance Financial autonomy of public universities	More likely to happen in biotechnology, nanotechnology, new materials, and IT

Source: Authors' elaboration.

Lifelong Learning

*... Our world is changing so quickly that we can only begin to imagine what the future will hold. But we are failing to teach our kids the skills and knowledge they need to succeed in today's world. So how will we prepare them for jobs that haven't even been invented yet? The real work of a 21st century education is to spark the passion for lifelong learning that our kids will need to navigate their way to a promising tomorrow.*⁷⁵

One of the direct consequences of the rapid development of the digital labor market in the Fourth Industrial Revolution is that lifelong education is no longer a luxury activity anymore that only people in rich countries can afford; it has become an indispensable component of any education system. Thus, all tertiary education institutions in Sub-Saharan Africa should consider offering up-to-date programs designed to provide working adults with relevant training, recycling, retraining, and career change opportunities. This is especially true for programs in digital skills, where change is fast and constant.

To date, however, most universities and institutes are barely able to accommodate the rapidly growing numbers of young students; they are unable to give much priority or devote limited resources to continuing education and lifelong learning. All institutions that are involved in the provision of digital education and training programs should nevertheless embrace lifelong learning as a priority area with great potential, not only as a source of additional income, but more importantly as a mechanism for serving the world of work and for making sure that their programs are aligned with the training needs of firms. It is therefore suggested that higher priority be given to the development of continuing education for adult employees in all walks of life, as well as executive development programs for leaders or managers in government, regional and municipal management bodies, and private companies.

⁷⁵ <http://www.instituteofplay.org/about/>

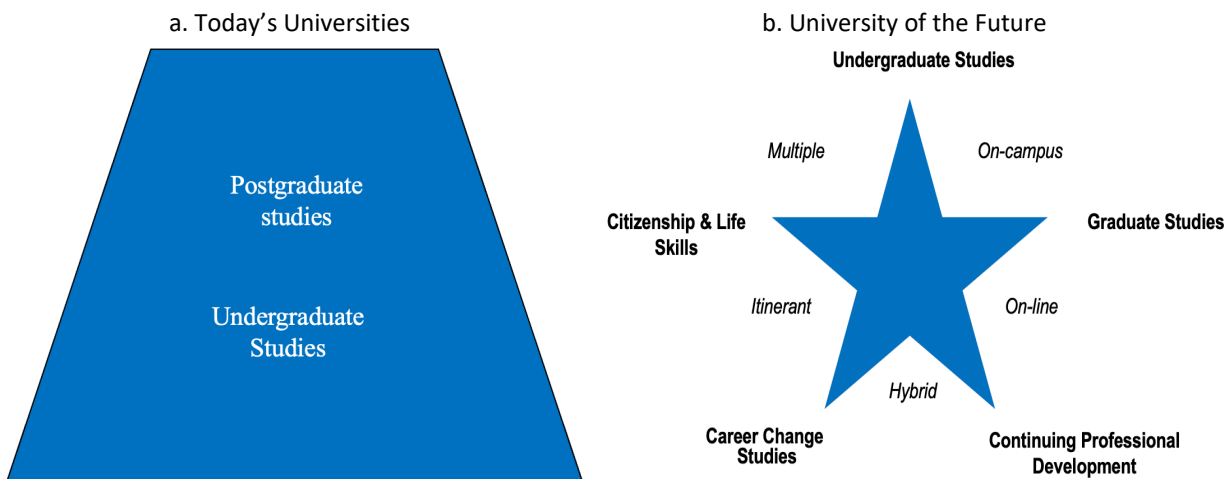
The emergence of microcredentials and digital certification has been a logical response to this need. In the United States, for example, Madison Technical College has led the way with Open Badges. Wichita State University runs a for-credit program of stackable microcredentials. Brigham Young University has convened a coalition of seven universities to organize professional development for teachers, based on microcredentials. The University of Maryland system has introduced digital microcredentials for career-readiness skills across its 14 campuses. In Australia, the Royal Melbourne Institute of Technology (RMIT) offers microcredentials to its 80,000 students across the entire curriculum (Radionoff et al. 2018). In the United States alone, it was estimated in 2022 that academic institutions offered 58,342 certificate programs that year, compared to the 607,000 digital badges and online course certificates from non-academic providers.⁷⁶ Within Sub-Saharan Africa, the African Virtual University, the University of Witwatersrand, and the University of Rwanda are among the leaders in having developed the capacity to offer online certificate programs.⁷⁷

The leading science and technology universities in Sub-Saharan Africa could become pioneers in their respective countries by offering short professional courses organized either as stand-alone certificates or as stackable microcredentials leading to degree qualifications. The leadership teams of these institutions should think through the long-term implications of these trends and be prepared to plan for a gradual transition away from the present pyramid shape of university study, where most students are undergraduate students coming directly from secondary education making up the broad base of the student population, with a smaller share of postgraduate students at the top. In the future, universities should evolve towards a star-shaped configuration that is more responsive to multiple groups of students with diverse needs. Undergraduate students would represent a small part of the picture, as would graduate students. A growing proportion of programs would be designed to address the continuing education and career change needs of adult workers, as illustrated by Figure 5.4. A large share of the programs would be delivered online or in a hybrid or hybrid/flexible mode.

⁷⁶ <https://wenr.wes.org/2023/06/navigating-a-jungle-of-certificates-how-should-credential-evaluators-approach-the-mainstreaming-of-micro-credentials>

⁷⁷ <https://www.wathi.org/sub-saharan-africa-tertiary-education-the-docs-world-bank-december-2020/>

Figure 5.4 - Shape of African Universities of the Future



Source: Authors' own elaboration.

Deep Partnerships with Foreign Institutions

An effective way to strengthen science and technology universities is to forge a few strategic partnerships with foreign institutions that are leaders in digital skills education, with the purpose of improving program quality and building overall institutional capacity. These partnerships are commonly designed as deep relationships with a small number of carefully chosen institutions that are not necessarily at the same level of development but do share a common vision and similar values. The principal objective would be to undertake together mutually beneficial projects across the entire range of academic and administrative activities, including the development of joint academic programs and/or double degrees, collaborative applied research projects, joint services to the community, and possibly joint benchmarking exercises that could help Sub-Saharan Africa's universities of science and technology to identify gaps and define stretch goals.

Promotion of Gender Equity in Advanced Digital Education Programs

To speed up the progress toward gender balance in advanced digital education programs, universities in Sub-Saharan Africa could consider a comprehensive set of measures that would promote access and success for female students: (i) outreach and bridge programs, (ii) affirmative action, (iii) retention, (iv) prevention of sexual harassment, (v) specific measures in support of female PhD students and academics, (vi) role modeling, and (vii) mentoring programs.

Outreach and bridge programs. Programs that link universities to secondary schools can be effective in reducing the academic, aspirational, informational, and personal barriers that obstruct female students' access to higher education. It is particularly important to showcase role models who demonstrate that women can excel in science and engineering programs. Sub-Saharan African universities could put in

place a comprehensive program of visits to high schools to reach out to female students and provide information about career options at the postsecondary level, following the example of the University of Dar Es Salam in Tanzania. They could also introduce pre-entry remedial programs to help female high school graduates reduce possible academic gaps in science subjects. Another possibility would be to organize summer camps for high school students to make them aware of all the opportunities that STEAM careers can offer, with a special focus on attracting female students.

Affirmative action. Sub-Saharan African universities could emulate the experience of the University of Dar Es Salam, which has been a pioneer in establishing a positive discrimination program to attract more female students. In 1974, the university started granting female high school graduates automatic admission. In 1997–98, a new affirmative action policy was put in place. The University lowered the entry cut-off point by 1.5 points for female students and provided remedial classes to boost their performance in science and math subjects. Full scholarships were also available for the beneficiaries of the program. Evaluations of the program have found that female students admitted through this program had results equal to or better than results for their male peers (Kilango et al. 2017).

Retention. Improved access for female students is not the only driver of progress. Student success and degree completion are equally important. These require support programs and regular measurement of outcomes such as graduation rates for female students. To promote student persistence, universities in Sub-Saharan Africa should put in place dedicated support mechanisms—financial, academic, psychological—that can help to increase completion rates. Adequate financial aid in the form of scholarships that cover all expenditures for female students is a key component of retention policies, especially in STEAM programs.

Prevention of sexual harassment and violence. It is important to define and enforce strict policies against all forms of sexual harassment and corruption involving sexual favors. In Rwanda, for example, a 2022 survey found that 42 percent of women working in higher education institutions had experienced sexual harassment at their workplace.⁷⁸ “According to the report, some female students are asked for sexual favors in exchange for marks and they are often subjected to gender-based corruption when writing their dissertations. Some supervisors, according to the report, delay students’ work in order to be able to personally meet with female students and, when they meet, lecturers request sex, and only a few female students refuse” (d’Amour Mbonyinshuti 2022).

Many universities in Sub-Saharan Africa have official policies against any form of sexual harassment and exploitation, but it is important to assess whether existing policies and guidelines are effectively implemented. This requires monitoring and evaluating, through regular surveys, whether female students, academics and administrators are satisfied with the helpfulness of these guidelines and the universities’ punitive and corrective actions when cases are reported. In addition, it may be useful to put in place special counseling programs, sensitization workshops, and victim care centers. All members of

⁷⁸ <https://rwandatoday.africa/rwanda/news/sexual-harassment-and-violence-against-women-plague-job-market-3992422#:~:text=A%20new%20report%20by%20anti,while%20looking%20for%20an%20employment>

the academic community must be fully aware of existing regulations, and university leadership must make it clear that victims will be protected and that perpetrators will be punished severely.

Gender balance among PhD students and senior academics. To improve the promotion of female senior academics, universities could define and implement clear employment and promotion policies that, while respecting meritocratic principles, would effectively promote the advancement of qualified female academics. These policies and measures could include special provisions to support female academics pursuing a PhD, such as financial incentives and scheduling adapted to the family life of academics with young children. McKinsey research has shown that building a critical mass of female professionals within any organization is likely to reduce the feelings of isolation that many women feel as they fill positions typically occupied by men.⁷⁹ Box 5.8 relates the experience of the Consultative Group on International Agricultural Research to improve gender balance among its researchers.

Box 5.8 - Improving Gender Balance at the CGIAR

The Consultative Group on International Agricultural Research (CGIAR) established its Gender and Diversity program in 1999 with a mandate to promote the recruitment, advancement, and retention of women scientists and other professionals. A Gender Monitoring Framework was designed for the CGIAR in 2013 to monitor progress in addressing what CGIAR has done in its own workplace(s) to raise the share of women in senior positions and those seeking out CGIAR as an employer of choice; and to monitor progress in gender mainstreaming achieved throughout the CGIAR system, using such indicators as the number of male and female staff in key leadership positions, the integration of gender considerations the setting of research priorities, implementation, and evaluation and, lastly, the extent to which research budgets and expenditure are allocated with respect to gender.

In 2014, women made up 31 percent of the CGIAR leadership. The CGIAR Consortium has since hired a Senior Advisor on Gender and Research to advise centers on related issues in the workplace. Reports are also submitted to the CGIAR Fund Council every six months to monitor the performance of the Gender and Diversity program.

Source: CGIAR (2015).

Role modeling. Positive role models may encourage women to enter STEM programs (Riise et al. 2019). A recent study has shown, for example, that female students are more likely to pursue a STEM field if their introductory class in that discipline was taught by a female academic. In a historical perspective, Marie Curie's life represents the ultimate role model story. After being denied the opportunity to study at Jagiellonian University, her native Poland's oldest and most prestigious university, because she was a woman, she moved to Paris to study at the Sorbonne. Not only was she the first female scientist to win a Nobel Prize in 1903, but she is still also the only female scientist to win the Nobel Prize twice, once in physics and once in chemistry. Marie Curie is the ultimate role model, inspiring her daughter to become a scientist who also won the Nobel Prize, in chemistry.

⁷⁹ <https://www.mckinsey.com/featured-insights/gender-equality/one-is-the-loneliest-number>

Mentoring. In challenging career paths where females are in the minority, women can benefit greatly from a friendly and effective support system (African Academy of Sciences 2020). Studies have found that mentoring young female professors increases their probability of having top-tier publications and research grants. Mentoring, through individual counseling and workshops, can help women build the skills needed for careers in science, such as preparing successful grant applications, developing leadership and ethics, improving research quality, and project management. Generally, the evaluation of mentorship programs has shown that they help women establish networks and grow professionally. Such networks and mentoring systems can provide a sense of professional community to females in male-dominated fields. A good example is the Peer Counseling program put in place by Kirimanjaro Christian Medical University College in Tanzania, an innovative experience that other universities in Sub-Saharan Africa could emulate. Cameroon's success with supporting early-career women scientists also has lessons (Box 5.9).

Box 5.9 - Supporting Early-Career Women Scientists in Cameroon

Early-career women scientists in Cameroon face numerous challenges in establishing their careers, including a lack of mentors and role models, a lack of research and proposal development skills, inadequate capacity for fundraising, and a lack of networking opportunities.

To address these challenges, women health researchers came together in 2015 to form the Higher Institute for Growth in Health Research for Women (HIGHER Women). The Cameroon-based consortium was designed to provide the country's early-career women scientists with the mentoring, skills development, and career planning they need to establish an enduring presence in the field of health research.

HIGHER Women provided professional support, mentoring, and networking opportunities to a cadre of young women scientists to enable them to undertake health research and contribute to addressing infectious diseases in Cameroon. A mentor-protégé program partnered 17 mentors, representing 18 research institutions and universities across Cameroon, with 52 protégés who had less than 5 years of experience. Pairs were tailored to the protégés' needs and professional interests. A five-day workshop provided training in grant writing, proposal development, and research fundamentals, including study design, research ethics and intellectual property. In addition, the workshop served as an important venue to facilitate and promote networking among the early-career and established women scientists.

Initially comprising just a few individuals, the consortium received a great deal of attention in the media, prompting other established women scientists working in academia, research institutes, and government institutions to join their ranks. The original 50 protégés are expected to transition to researcher within 5 years, and to "pay it forward" by becoming mentors to future early career women scientists. HIGHER Women has established a website to facilitate networking, information sharing, and advocacy for women researchers.

With support from several ministries, including the Ministry of Higher Education, the Ministry of Women's Empowerment and the Family, and the Ministry of Scientific Research and Innovation, HIGHER Women is being formalized and launched as a national network with countrywide membership, and a platform to bring women scientists together.

Source: <https://www.who.int/tdr/capacity/gender/higher-women-cameroon/en/>.

5.3 Leveraging the African Diaspora

5.3.1 Size and Present Contribution of the African Diaspora

For decades, Africa's development has lagged in comparison with other continents. The lag is partly attributed to the continent's low human development, exacerbated by the exodus of its skilled professionals. The African Union estimates that approximately 70,000 skilled professionals emigrate from Africa every year.⁸⁰ This means that African countries are losing their skilled academics, engineers, scientists, medical doctors, nurses, and accountants, among other professions, to industrial countries that can offer much better wages. The loss of these critical skillsets adversely affects the continent's socioeconomic development and growth aspirations. There are currently more African PhD holders outside the continent than inside it, a unique situation that no other region in the world has experienced.⁸¹ Table 5.6 provides a few illustrations of the scope and seriousness of the issue.

Table 5.6 - Impact of the Brain Drain on Sub-Saharan Africa

Research and Education	Health	Engineering
African PhD holders outside Africa outnumber those inside it. Shortage of teachers and instructors African researchers are pressured with time in ways that have clear impact on their research productivity. 80% of African researchers indicated that they have considered leaving Africa Since 1990. At least 20,000 qualified researchers left Africa every year.	Disparities in the ratio of health professionals: - in Nigeria, the ratio was 1 to 41,000 - in Liberia, one pharmacist for 85,000 people - Ethiopia had 900 practicing doctors in a country of 90 million. 3,000 Ethiopian doctors work overseas; more Ethiopian-trained doctors practice in Chicago than in Ethiopia	Significant shortage of engineering skills all over the continent (engineers, technologists, and technicians). In Namibia, Zimbabwe, and Tanzania, there is on average one qualified engineer for each 6,000 people, compared to one engineer per 200 people in China.

Source: Sheikheldin and Mohamed 2021.

Studies indicate that Africa loses approximately US\$2 billion every year to brain drain, while the economic contributions of African professionals in Australia, Canada, the United Kingdom, and the United States are estimated to reach close to US\$4 billion (Sheikheldin and Mohamed 2021). At the

⁸⁰ https://www.afdb.org/sites/default/files/2022/11/21/development_without_boarders- g-cop-01_dec_2022 - afdb- auc-kcu-17-10-22-v2-eg.pdf

⁸¹ <https://suraadiq.com/wp-content/uploads/2021/07/Skills-for-science-systems-in-Africa.pdf>

same time, the remittances sent by the African diaspora represent a substantial source of external funding for the continent. The World Bank calculates that these amount to close to US\$100 billion annually, a huge jump from the US\$37 billion recorded in 2010.⁸² Nigeria is the largest recipient in the region, receiving about US\$24 billion annually, compared to Ghana with US\$3.5 billion annually, Kenya with US\$3.1 billion annually, and Senegal, which gets about US\$2.5 billion annually.

In recent decades, African governments and development partners have implemented several policies and initiatives to limit the brain drain. Several nations have even appealed to Western countries to stop targeted recruitment campaigns, especially those recruiting medical professionals. All these efforts have had little results.

5.3.2 Policies to Leverage the Diaspora More Effectively

Rather than fighting the uphill battle of trying to prevent or reduce the brain drain, countries in Sub-Saharan Africa may find it more effective to engage with African professionals living and working in industrial countries to encourage knowledge transfers and facilitate the global integration of African economies. Leveraging the potential of the Diaspora could indeed be crucial for accelerating the construction of an inclusive and resilient digital ecosystem on the continent. The African Union recognizes the African Diaspora as the continent's sixth region and has tasked the African Union Development Agency (AUDA-NEPAD) with finding ways to encourage diaspora members to contribute to scaling up innovative digital technology programs.

Successful diaspora networks are characterized by the following three elements: (a) members of are talented and show strong intrinsic motivation; (b) they are involved in development projects in their home country as connectors, catalysts, or drivers; (c) their efficiency, continuity, and development over time are based on concrete activities with measurable outcomes (Salmi 2017).

In most cases, diasporas and expatriate networks emerge spontaneously. However, government interventions can also help structure, strengthen, and scale up such initiatives. The home country must recognize that expatriate talents represent a great opportunity to facilitate the digital transition toward a knowledge-based economy. Organizations like the African Diaspora Network and the African Technology Foundation have been instrumental in connecting diaspora members with opportunities to contribute to Africa's tech ecosystem. The African Diaspora can play a pivotal role in accelerating the digital transition through various avenues: direct investment, skills transfer, entrepreneurship, advocacy, and partnerships. Table 5.7 suggests some of the multifaceted potential contributions that African professionals living overseas can make.

⁸² <https://www.worldbank.org/en/results/2024/01/18/digital-transformation-drives-development-in-afe-afw-africa>

Table 5.7 - Contributions of the African Diaspora to the Digital Transition

Areas of Intervention	Activities
Investment in Digital Infrastructure	Funding tech hubs and start-ups, providing much-needed capital to develop new technologies and scale up operations. Participation as angel investors or venture capitalists focused on digital enterprises in Africa.
Transfer of expertise and experience for capacity building	Mentorship programs to guide budding tech entrepreneurs, academic leaders, faculty members, and students. Support of new digital educational programs, coding boot camps, and online courses to build digital skills among the youth. Taking academic leadership positions
Entrepreneurship and Innovation	Setting up tech companies or branches of existing businesses in Africa, fostering innovation and job creation. Organization of innovation challenges to stimulate local talent and find novel solutions to local problems.
Advocacy and Policy Influence	Lobbying for policies that foster a conducive environment for the growth of the digital economy, such as improved internet access, reduced taxes on tech products, and supportive regulatory frameworks for attracting tech investment. Promoting E-government initiatives for the adoption of digital public services to improve efficiency and transparency. Working with African governments and regional bodies to help shape digital development strategies and initiatives.
Partnerships and Collaboration	Creation of networks linking African tech ecosystems with global technology hubs, facilitating knowledge exchange and collaboration. Establishment of partnerships with governments, private sector players, and international organizations to fund and implement digital projects.
Philanthropy and Social Impact	Supporting Non-Profits: Diaspora members can fund or collaborate with non-profit organizations focused on digital literacy and technology access in underserved communities.
Research Development, Innovation, Knowledge, and Technology Sharing	Collaborative research with African institutions to develop new technologies and digital solutions tailored to local needs. Guidance on use of data analytics for development planning and decision making. Leveraging cultural identity and trust for knowledge and technology sharing for capacity development
Bridging Global Connections for Digital Trade	Creating and supporting e-commerce platforms to reach regional and global markets, boosting trade and economic growth. Supporting the adoption of blockchain and fintech solutions to enhance financial inclusion and streamline cross-border transactions. Facilitating access to international markets, capital, and partnerships for African tech companies and start-ups
Driving Digital Inclusion	Spearheading of initiatives to bridge the digital divide, facilitate access to digital tools and training, and promote STEM education especially for women, rural populations, and other marginalized groups.

Sources: African Union 2020; World Bank 2023; Salmi 2017.

One of the first examples of an efficient Diaspora network was GlobalScot, a network of high-powered Scots from all over the world who have used their expertise and influence to generate projects in Scotland. Launched in 2001 by Scottish Enterprise, this network has proven extremely attractive and efficient, with more than 1,000 influential businesspeople participating and contributing to Scotland's economic development (Kuznetsov and Sabel 2006). ChileGlobal, Mexico's Network of Talent Abroad, and the Global South Africans project have taken inspiration from the GlobalScot model and adapted it to their respective specificities.

Nigeria, which has the largest African Diaspora, boasts several relevant initiatives. The Medics2You network and mobile application, developed by a coalition of scientists, innovators, and medical doctors, is a digital platform that has been designed to improve and complement the existing Nigerian medical ecosystem. It connects patients in Nigeria to approximately 18,000 Nigerian medical doctors based in the United Kingdom for face-to-face video consultations. Furthermore, through international guidelines and agreements, the diaspora medical doctors can prescribe medication and have it delivered at the patient's door and workplace, in collaboration with local medical partners.⁸³ In 2017, Malawi launched a national diaspora engagement policy that "seeks to establish a mutually beneficial relationship between Malawi and its diaspora, with the underlying goal of mainstreaming and empowering Malawians abroad to make significant and effective contribution to the development of the country".⁸⁴ Malawi's first diaspora portal was launched in 2019. This interactive platform aims to facilitate continuous engagement with highly skilled Malawians abroad and connect them with stakeholders at home.

At the continental level, one example of short-term diaspora engagement project is the Carnegie African Diaspora Fellowship Program, which supports educational projects at African higher education institutions. It is coordinated by the Institute of International Education in collaboration with the United States International University-Africa and funded by a grant from Carnegie Corporation of New York. In the pilot phase of the program (2013–15), the Carnegie African Diaspora Fellowship Program supported 110 short-term fellowships for African-born academics.

Another initiative is the collaboration between the African Academies Diaspora Fellows Program in Senegal and the Inter-Academy Partnership Carnegie Project. The Inter-Academy Partnership created a diaspora database to develop strong cooperation links between the scientists in the Senegalese diaspora and their home country. It also helped to develop a national strategy for skilled Senegalese residing abroad, so that they can contribute to Senegal's economic, social, and cultural development efforts in training, research, expertise, consultancy, and specific initiatives that enhance research results.⁸⁵

Diaspora scientists, healthcare workers, and engineers have joined forces to offer module courses to their colleagues in Africa through e-learning on digital platforms. These collaborative e-learning possibilities can be provided through African institutions and provide new prospects for African

⁸³ <https://www.nepad.org/blog/tackling-africas-brain-drain-challenge-through-smart-digital-technologies>

⁸⁴ <https://www.malawiembassy.de/National-Diaspora-Engagement-Policy-Final.pdf>

⁸⁵ <https://www.iie.org/programs/carnegie-african-diaspora-fellowship-program/>

countries in advanced healthcare, research and development and enhance particularly south-south collaboration. The University of the Mountains in Cameroon has benefitted from such collaborative e-learning programs with European universities in France and Italy.⁸⁶

An example of success at the individual level is the Nigerian-born entrepreneur Iyinoluwa Aboyeji, who launched Andela, Africa's largest engineering organization, employing over 1,000 software engineers. Andela has received investment from Meta and Google Ventures, among others. Mr. Aboyeji went on to co-found and lead Flutterwave, a US fintech company that provides a payment infrastructure for global merchants and payment service providers across several continents.

Diasporas as search networks can be compared with alumni networks and can learn from them. There is a great opportunity for tertiary institutions to participate in the diaspora network process. Universities can follow outstanding alumni, identify leaders abroad, and gradually build a search network. This is how successful diasporas begin.

Among the lessons that can be taken from these experiences is the importance of bridge or home organizations, search networks being interdisciplinary and inter-organizational in nature. When such organizations do not exist, ingenuity should intervene to sidestep the multiple obstacles of bureaucracies. Concrete activities with measurable outcomes are also essential to maintain diaspora members' motivation over time. Because transforming discussions into projects is extremely important, a realistic approach begins with small projects that ask for small commitments and result in relatively quick outcomes. These small early successes encourage diaspora members to undertake further and larger commitments and projects. Similarly, tertiary institutions can play a leveraging role by bringing native scholars who teach abroad for lectures, conferences, or even to support student project. These relatively small but concrete commitments can lead to further collaboration and even to larger research or business projects (Kuznetsov and Sabel 2006).

5.4 The Contribution of Donors

The success of initiatives to develop and strengthen advanced digital education programs in Sub-Saharan Africa depends, in the first place, on the willingness and capacity of all local stakeholders to mobilize sufficient public and private resources; nevertheless, the international donor community can also join in supporting the development of science and technology universities. First, they can offer technical and financial assistance to help with the vision development and strategic planning phases that precede the design and implementation of national programs for the digital transition and the supply of advanced digital skills.

The second important type of collaborative activity that the donors could usefully support would be to prepare analytical reports to provide an objective diagnosis of the challenges faced by the tertiary

⁸⁶ <https://www.nepad.org/blog/tackling-africas-brain-drain-challenge-through-smart-digital-technologies>

education system and institutions in a given country, especially science and technology institutions and programs, and to propose reform and development options based on relevant international experience. This could include putting in place effective monitoring and benchmarking systems to measure progress in the delivery of digital skills training and applied research in support of the digital and green transitions.

Third, the donors could help partner countries ensure the sustainability of advanced digital education programs through co-financing of investments to accompany the establishment of new universities or centers of excellence, focusing donor funding on crucial elements of the program. For example, rather than offering scholarships for doctoral studies in OECD countries which risks aggravating the brain drain, support for PhD programs in the strongest local or regional universities can go a long way toward building the advanced training and applied research capacity of Sub-Saharan African countries. Similarly, instead of financing only advanced equipment for scientific laboratories, the donors could enter into an agreement whereby they would finance maintenance and equipment renewal expenses using a sliding-down schedule, while the national institution would cover a progressively larger share of expenses over the duration of the project, thus guaranteeing the availability of national funds once the external funding stops.

Donor coordination is important to avoid a possible dispersion of efforts when the programs and projects supported by the various bilateral or multilateral agencies are not fully consistent with government priorities or compatible among themselves. To mitigate these risks, the national authorities in charge of higher education need to play a proactive role in orchestrating donor coordination and thus ensuring that the various donor programs and projects are fully aligned with the governments' strategic plans for the digital transition. The positive experience of collaboration between the World Bank and the French Development Agency (Agence Française pour le Développement) in support of the African Centers of Excellence shows that donor coordination can work effectively at the scale of multiple countries and can promote the development of South-South networks.

Considering the more advanced state of development of the leading universities in South Africa, there could be merit in enhancing their participation in South-South collaborative initiatives in Sub-Saharan Africa. Inter-university collaboration between South Africa and the rest of Sub-Saharan Africa has been relatively limited since the 1994 democratic transition. When South African universities have partnerships with foreign universities, these are more likely to be with higher education institutions in Europe or North America than with universities in other Sub-Saharan African nations. This seems to be a missed opportunity for both South African and other Sub-Saharan African higher education institutions; all would certainly benefit mutually from closer linkages and collaborations. The Intra-Africa Academic Mobility Programming, which was launched in 2016 by the European Commission in partnership with the African Union Commission, has helped generate more collaborative activities to enhance capacity of higher education institutions throughout Sub-Saharan Africa to cooperate internationally. Donor agencies could work together to fund similar programs in support of the digital and green transitions.

6. Conclusion

Human development and scientific inquiry are increasingly at the heart of national and regional strategies for promoting innovation and raise productivity. In this context, digital technologies and innovation have emerged as major drivers of social and economic transformation. A recent report prepared by the World Economic Forum (2024) lists 10 emerging technologies most likely to become game changers and to have a deeply disruptive impact on economic systems and people's lives.⁸⁷ From the use of artificial intelligence in scientific discoveries to genomics for transplants, these novel technologies will accelerate the digital transition that both advanced economies and developing nations have experienced in the past decade. In July 2024, Australia's Deakin University was the first foreign university to open a campus in India under the New Education Policy. It will offer two masters' degrees, one in cybersecurity, and the other one in business analytics, responding to the eagerness of Indian students to acquire advanced digital skills.⁸⁸

More than any other region in the world, Sub-Saharan Africa must harness the opportunities of the digital transition to overcome the big challenges it faces, including persistent poverty, slow economic growth, political instability and conflict, vulnerability to climate change, high rates of infectious diseases, and defective social infrastructures. These complex challenges, for which there are no easy solutions, are compounding each other, thereby creating a situation of polycrisis.

In many ways, the COVID-19 pandemic has fast-tracked the digital transition in Sub-Saharan Africa, especially in finance, health, and education. At the same time, it has starkly revealed the dangers of the digital gap experienced by countries and groups in the region and the need for better and more equal access to digital technologies and digital skills. While many parts of the world are advancing rapidly in digital technology, Sub-Saharan Africa risks being left behind without significant investment in digital infrastructure and skills. Bridging this digital divide is crucial for ensuring that the region can fully participate in the global digital economy and secure its benefits.

The ability of Sub-Saharan African countries to build a thriving digital economy will depend on the skills, technical capacities, and adaptive mindset of their people. Their tertiary education systems and institutions have, therefore, a crucial role to play in support of the digital transition.

The production of digital skills has increased steadily in recent years. Sub-Saharan Africa is emerging as a promising hub for specialized digital skills, a trend driven by a young, tech-savvy population and specialized digital education programs. The region has experienced a rapid growth in the number of

⁸⁷ The 10 emerging technologies are (i) AI in scientific discoveries, (ii) privacy-enhancing technologies, (iii) reconfigurable intelligent surfaces, (iv) high-altitude platform stations, (v) integrated sensing and communication, (vi) immersive technology for the built world, (vii) elastocalorics, (viii) carbon-capturing microbes, (ix) alternative livestock feeds, and (x) genomics for transplants (WEF 2024).

⁸⁸ <https://www.afr.com/politics/federal/caps-on-overseas-students-are-unworkable-ridiculous-20240707-p5jros>

graduates with advanced/specialized digital skills. There is strong demand for African graduates with these skills, not only locally but also internationally through remote work and online platforms.

However, the quality, relevance, and range of computer science and engineering programs and related areas in Sub-Saharan Africa's universities are largely unsatisfactory and leave much room for improvement. National governments and higher education leaders must step up their efforts to train young people and adults with advanced digital competencies within innovative and resilient higher education systems. These should be characterized by good digital infrastructure, modern governance, robust quality assurance, and sustainable financing.

A new mindset is needed to engage faculty members in the transformation effort. Training young academics and bringing more experienced faculty members with high academic qualifications on board is a necessary but not sufficient condition for creating a culture of excellence at all higher education institutions involved in the delivery of advanced digital education programs. Equally important is a shared conviction that change is urgently needed, as is an open attitude toward innovative curricular, pedagogical, and assessment practices.

The report explores policy options for achieving these goals at the national and institutional levels, and it tries to identify the decisions and measures that can have the most positive impact. It also proposes ways of harnessing the Diaspora and leveraging donor support in a more effective way. The African Diaspora's massive scale, resources, skills, and global connections make it a powerful force that can help accelerate the digital transformation across Africa.

Finally, the success of national and institutional strategies in producing competent graduates with advanced digital skills will depend on genuine cooperation and collaboration that bring together government authorities, tertiary education institutions, industry partners, and the global donor community. Building these synergies is the only way of successfully realizing the African Union Vision for 2030 of "a strong, inclusive, green and digital recovery and transformation for the continent."

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ABSTRACT

This study explores the link between digital skills, innovation, and economic transformation in the context of Africa, focusing on the role and potential contribution of higher education institutions in the development of advanced skills for the digital transition. It documents relevant global case studies from Asia, Australia, Europe, and North America that showcase good examples of investment in skills development through higher education and their impact on innovation and economic growth. The study investigates the evolving global demand for digital skills and explores how advanced digital skills can create new economic development opportunities for Africa and help solve the big challenges faced by the subcontinent, such as food security, health threats, learning poverty, and climate change. It takes stock of existing capacities for digital skills training in Sub-Saharan Africa and proposes a bold vision for improving and expanding digital skills education programs.

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