ARTIFICIAL INTELLIGENCE CAPACITY IN SUB-SAHARAN AFRICA - COMPENDIUM REPORT

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IDRC Grant/ Subvention du CRDI: 108914-001-Building a network of excellence in artificial intelligence in Sub-Saharan Africa

ARTIFICIAL INTELLIGENCE CAPACITY IN SUB-SAHARAN AFRICA

Compendium Report

January 2021

ARTIFICIAL INTELLIGENCE FOR DEVELOPMENT AFRICA

Date of Publication: March 29, 2021
Published by: AI4D Africa

The research presented in this publication was carried out with the financial assistance of Canada's International Development Research Centre. The views expressed herein do not necessarily represent those of IDRC or its Board of Governors.

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List of Abbreviations

4IR	Fourth Industrial Revolution
AIMS	African Institute for Mathematical Sciences
ACE-DS	African Centre of Excellence in Data Science
ADB	African Development Bank
ADC	Africa Development Centre
AI	Artificial Intelligence
AI4D	Artificial Intelligence for Development
CAIR	Centre for AI Research
CIRG	Computational Intelligence Research Group
CPD	Continuing Professional Development
CSTD	UN Commission on Science and Technology for Development
DSA	Data Science Africa
EBtI	Ethiopian Biotechnology Institute
FAIR	Forum for Artificial Intelligence Research
GDP	Gross Domestic Product
GIBS	Gordon Institute of Business Science
GPU	Graphics Processing Units
Hons	Honours
HPC	High Performance Computing
IDRC	International Development Research Centre
IIS	Institute for Intelligent Information Systems
IP	Intellectual Property
ISG	Intelligent Systems Group
IT	Information Technology
IoT	Internet of Things
ITU	International Telecommunications Union
JKUAT	Jomo Kenyatta University of Agriculture and Technology
K4A	Knowledge for All Foundation
MIIA	Machine Intelligence Institute Africa
ML	Machine Learning
MUST	Malawi University of Science and Technology
NICOG	Nature Inspired Computing Optimization Group
NUL	National University of Lesotho
NWU	North-West University
OECD	Organisation for Economic Co-operation and Development
PRASA	Pattern Recognition Association of South Africa
R&D	Research and Development
RAIL Lab	Robotics, Autonomous Intelligence and Learning Laboratory
RL	Reinforcement Learning
ROI	Return on Investment
SDG	Sustainable Development Goals
SSA	Sub-Saharan Africa
STEM	Science, Technology, Engineering and Mathematics
SU	Stellenbosch University
TPU	Tensor Processing Unit
TU	Telecommunications Union
UAE	United Arab Emirates
UCT	University of Cape Town
UDS	University of Dar es Salaam
UKZN	University of KwaZulu-Natal
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organization
UniSwa	University of Swaziland
UP	University of Pretoria
UJ	University of Johannesburg
UWC	University of the Western Cape
VC	Venture Capital
WEF	World Economic Forum
WIDS	Wits Institute of Data Science
Wits	University of the Witwatersrand
WiMLDS	Women in Machine Learning and Data Science

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Executive Summary

Introduction

The term 'Artificial Intelligence' (AI) was coined by scientist John McCarthy at Dartmouth College in 1956. The term generally refers to 'machines that respond to stimulation consistent with traditional responses from humans, given the human capacity for contemplation, judgment, and intention.'[1] Today, AI has come to the fore due to the exponential growth in computing capacity, the development of more sophisticated algorithms, and burgeoning data in an 'information society'.[2] This is what makes AI such a powerful technology – the fact that it is rapidly accelerating and forging new paths in almost all major industries, impacting all aspects of our lives. AI therefore provides the promise of developing human-like capabilities in software more effectively, efficiently and at a lower cost.[3]

At present, no sub-Saharan African (SSA) country is listed in the top ten countries expected to benefit most from AI and other emerging technologies that are predicted to usher in the Fourth Industrial Revolution (4IR).[4] Despite this, AI's unprecedented advancements are set to impact all countries, regardless of geography. Its impact in Africa will, perhaps, be most interesting, as several SSA countries are still coming to terms with issues surrounding the first three industrial revolutions. This includes problems around universal access to electricity, the mechanisation of production, and automation of industries.

This raises many questions about how prepared Africa is to benefit from the 4IR, and where governments and other actors (funders, intergovernmental organisations, etc.) should focus their attention to build that preparedness. While the existence of some indexes that compare the relative readiness of different governments, or countries[5] are compelling, they provide only a cursory overview of what is happening across the continent.

To guide future investments in capacity building that will build responsible AI development and deployment, it is important to know answers to questions such as: what does the AI landscape in SSA look like? What measures are stakeholders in the region taking to ensure that they are AI-ready? Where does capacity already exist or not?

To answer these questions, Artificial Intelligence for Development (AI4D) Africa supported research on three key stakeholders involved in AI capacity building in SSA, namely, Centres of Higher Education and Training, Governments, and the broader AI community in the region. A comprehensive desktop literature review was also conducted.

This report presents the integrated results of the research with these stakeholders. The research draws from four data sources, listed below:

- A detailed desktop review of available literature on AI in the region, with a specific focus on the three stakeholder groups;
- Two surveys distributed to 89 representatives of Centres of Higher Education and Training (Response rate = 43) and 57 representatives within the industry (Response rate = 32);

[1] West, D.M. (2018). "What is Artificial Intelligence?" Brookings Institute.

[2] Abardazzou, N. (2017). "The rise of artificial intelligence in Africa." How we made it in Africa.

[3] Singularity University. (nd). "An Exponential Primer." Singularity University.

[4] Hoosen, Z. (2018). "Op-Ed: How Africa can embrace an artificial intelligence enabled future." CNBC Africa.

[5] Oxford Insights. (2020). "Government AI Readiness Index." Oxford Insights.

- In-depth interviews with 24 representatives of Centres of Higher Education who were involved in AI-related activities; and
- Findings from a UNESCO survey on AI capacity building needs that was distributed to UNESCO's national commissions in Africa (response rate = 32 UNESCO Member States).

Key Findings

Taking available data into account together with the desktop review of literature and the findings from the UNESCO report, below is a summary of the key takeaways from this research.

AI-related Academic Activities

- Formal education, on-the-job experience and teaching oneself are regarded as the most beneficial ways to develop AI expertise. Respondents evidently derived value from teaching themselves about AI and related concepts, implying that the role of upskilling people with technical skills should not be limited to formal education, although formal education also has a key role to play.
- Comprehensive formal education that equips students with knowledge and skills across their school careers will better position them to enter AI-related fields. This includes education that focuses on building competencies in the hard sciences such as Science, Technology, Engineering and Mathematics (STEM), as well as building soft and critical thinking skills in the Humanities and Social Sciences.
- Skills related to training Machine Learning (ML) algorithms and associated competencies are one of the most important skills sets required to develop AI activities. This is followed by programming skills and probability and statistics.
- There was considerable enrolment across the region in AI-related courses and qualifications at both undergraduate and postgraduate levels, with males in the majority. Being mindful of the small number of courses for which enrolment data was provided, the graduate output and enrolment data suggests that a number of students are participating in AI-related qualifications and courses and that in many cases, demand exceeds supply.
- The difference in enrolment figures between undergraduate and postgraduate students shows that large numbers of students do not go on to pursue postgraduate training in AI-related fields. There are likely to be various reasons for this, including that there are generally fewer postgraduate than undergraduate enrolments in any field, but the specific reasons were not clear in the data available so further research is needed to explain this trend.
- Several institutions that participated in the study did not provide detailed enrolment data. This lack of enrolment data from a broad sample of institutions indicates a need for comprehensive data collection and sharing practices on enrolment, graduation and attrition rates for AI-related degrees and qualifications, together with national level higher education data collection and reporting. This data will be critical to ensuring the success of AI-related academic offerings at universities, as well as measuring how they relate to broader institutional and national goals of promoting AI-related activities.
- The majority of institutions who participated in the research are planning on offering new AI-related courses or qualifications in the next three to five years, as well as adding AI-related aspects to existing degrees or courses instead of creating standalone degrees. This includes offering courses on image processing, machine learning (ML), Robotics and Natural Language Processing. It was clear that new offerings were dependent on both student demand for AI qualifications and institutional capacity.

- It is crucial to consider demand and supply of AI-related courses and qualifications at these institutions – building capacity for AI at Centres of Higher Education and Training depends significantly on raising awareness amongst students about the option of studying these types of programmes, as well as upskilling them with the foundational skills to be eligible to enrol.

- There is a need for greater capacity – both in terms of the number of Centres of Higher Education and Training working on AI and in terms of potential employers – to ensure employment opportunities for their graduates. This should take a holistic view of the AI ecosystem in SSA. Just as it is important to ensure that Centres of Higher Education and Training prepare students to work in AI-related fields and sectors, so too is it important to build capacities within the organisations that employ them, particularly because countries all over the world are expected to experience significant job displacement across all industries as a result of AI.

- Other capacity issues included a need for AI experts and lecturers, time constraints in undertaking teaching and research duties, and needing more capacity to take in and supervise larger numbers of postgraduate students. Some of these constraints might be addressed by developing joint academic programmes in partnership with other Centres of Higher Education and Training, supported by industry or government partners.

- There was an interest in and attendance of AI-related short courses, training opportunities and workshops, although events were still mostly attended by males. Respondents also noted considerable involvement in AI communities of practice, including Data Science Africa and the Deep Learning Indaba. These provide a basis for further development of AI work and demonstrate that there is a growing African AI community of practice. Integrating communities of practice into Centres of Higher Education and Training would be a useful way of consolidating and growing AI activities.

- At the national level, governments require greater support for AI education, research and training. This includes ensuring that education systems are responsive to AI skills and competency requirements, improving research capacity, and providing AI-related trainings for workers.

Research and Development

- Respondents provided numerous examples of research in various AI-related fields, including Robotics and Autonomous Intelligence, Health and Biology Agriculture and Disaster management, Development, Language and Physics.

- Although most interview respondents indicated that AI research and development is a priority for their institutions, some noted that their department or school was prioritizing AI as opposed to their institution more broadly.

- There is considerable engagement between academia and organisations working with AI and related technologies. This included R&D, lecturing, providing content for course materials, supervising theses, hosting events, providing internships and bursaries, as well as developing programmes, streams, and modules in Data Science, AI, and ML. However, there was a lack of engagement between government and the broader AI community.

- Creating a robust AI ecosystem in SSA will require institutional commitment to AI-related activities – it will be necessary to implement solutions in higher education with a view to changes we want to inspire and capacities that we want to develop in broader society. This will require institution-wide support for AI-related research and development, particularly given the emphasis of respondents on the multi-disciplinary nature of AI work.

- At Centres of Higher Education and Training, most respondents indicated that their institutions did not have mechanisms solely available to fund AI research and

development. Many noted, however, that there were general funding mechanisms available that could be used for AI research and development. Partnerships with government and industry could raise additional funding for AI-related research and development.

- There is a need to increase output of AI-related educational resources, to increase fundamental and applied AI research, and provide access to resources for research, including AI research networks.

Policy Environment

- The research identified very few policies aimed directly at AI-related activities at Centres of Higher Education and Training, with respondents indicating that many of them were general policies that governed their institutions and not AI teaching and research in particular. Despite this, respondents did seem to derive some value from existing policies.

- While it might hold true that an over-regulated environment can sometimes stifle innovation and that this is particularly applicable to AI, encouraging Centres of Higher Education and Training to adopt a few critical policies can go a long way to ensuring fair practices.

- At the national level, countries in SSA need to create legal and regulatory frameworks for AI governance, as well as improving and implementing policy initiatives for AI governance. This might include implementing legal measures for new applications of AI and related technologies; launching AI strategies and policies; implementing legislation; and developing ethical guidelines for AI.

Challenges and Capacity Building Needs

- Respondents noted a diverse set of challenges that they thought were hindering the development of AI in their countries. One of the most prominent of these was a lack of quality education in AI and related fields. Other requirements include a need for capacities in AI governance; and human capacity for addressing the ethical implications of AI.

- Respondents also highlighted funding issues regarding AI-related activities – early-stage start-ups struggle to raise capital, universities have difficulty in securing funding for their equipment and research, and governments are operating in resource constrained and often corrupt environments.

- They also noted a lack of technical expertise and issues with funding and infrastructure – including a lack of reliable internet.

- In considering which sectors would see the most growth in demand for AI applications over the next five years, healthcare applications were most popular. Respondents also noted commercial enterprises, financial services, and education.

- Although SSA countries' AI priorities are diverse, they provide an opportunity for collaboration on key priority areas such as personal data and data governance; leveraging AI for economic growth; and supporting start-ups and digital innovation.

Diversity in AI-related Activities

- Many respondents saw diversity as being an issue in AI in their country, institution or organisation, the most prominent of these being a lack of gender diversity.

- In the Higher Education and Training sector, there were more males involved in AI-related activities than females. This is perhaps unsurprising given global gender imbalances in the sector as well as a general lack of diversity. Most respondents indicated that their institutions did not offer incentives for women, people with disabilities, or people from other groups considered as minorities to participate in AI-related courses or qualifications. There were,

however, broader merit-based programmes or opportunities. It became clear over the course of the research that some efforts were being made to try to encourage women, people with disabilities and minorities to pursue AI-related paths. These efforts are being made at all levels, from undergraduate to postgraduate, as well as within communities of practice and the broader AI community. They appear to mostly be aimed at gender imbalances.

- The findings indicate a significant opportunity for the AI market in SSA, where AI and related technologies can be used as an opportunity to create and reinforce diversity. Key to this will be to facilitate and promote skills development of diverse people and make concerted efforts at levelling the playing field for women and other minorities in the industry. There is a clear role for Centres of Higher Education and Training in these efforts. These institutions can introduce funding schemes to improve the uptake of diverse groups, remove biases from staff recruitment procedures and ensure that women and other minorities are supported and incentivized to study further than the undergraduate level.

Recommendations

Drawing on the key findings, the report offers a set of detailed recommendations for each stakeholder group. The full set of recommendations is available at the end of the report, while a summary is provided below.

Centres of Higher Education and Training

The recommendations address the need to increase capacity for AI-related activities by, for example, creating data and ethics committees and developing new frameworks to allow individuals to cultivate the skills that they need to thrive in a rapidly changing environment. This includes increasing human capital capacity and encouraging the formation of communities of practice.

In terms of R&D, recommendations include providing institutional support for AI-related R&D, bolstering institutional funding sources, providing support for African researchers to attend conferences, and undertaking multi-disciplinary research on socio-economic and political effects of AI. Other research areas might include how to create a sustainable AI ecosystem that responds to the needs of communities in SSA and what types of infrastructure, technology, access, support, systems and personnel institutions require to contribute meaningfully to the AI ecosystem.

For the institutional policy environment, the report recommends reviewing existing policies from other institutions to gain insight on best practice. In addition, Centres of Higher Education and Training could lobby government to develop national policies, participate in policy formulation processes on AI-related activities, and begin adopting a few critical policies with a view to developing a robust institutional policy environment, including:

- Ethics, data management and privacy policies;
- Intellectual property policies as they relate to AI; and
- Policies setting out institutional AI priority areas, how resources will be allocated and encouraging collaboration across faculties and departments.

To promote diversity in the sector, institutions could provide incentives for women, people with disabilities, or people from other groups considered as minorities to participate in AI-related courses or qualifications; use AI and related technologies as an opportunity to create and reinforce diversity; and develop open access datasets that reflect diverse populations.

Members of the AI Community

The research has shown that the AI community in SSA is diverse and contains several stakeholders including – but not limited to – developers, data scientists, entrepreneurs, SMEs, venture capitalists, researchers, manufacturers, service providers and big business. These recommendations, aimed at the AI community as a whole, take the AI community's diversity into

account. As such, certain recommendations are applicable to specific stakeholders within the AI community.

First, the AI community could promote holistic and life-long education by collaborating with educational institutions, including Centres of Higher Education, and organisations working with AI and related technologies; providing educational opportunities for staff and students at institutions or organisations where they study and work; and encouraging staff to undertake self-learning activities.

In engaging with other sectors, the AI community could collaborate with government on AI-related R&D and form public-private partnerships that aid this. Stakeholders in the AI community can lobby government for regulatory and policy development that supports AI-related activities and creates a fair playing field that protects citizens. In addition, members of the AI community could provide guidance on technical issues to steer the national strategic direction and encourage the formation of professional bodies in AI and related fields, which will promote regulations, codes of conduct and ethical standards.

To build AI capacity, the AI community could support infrastructure development by providing technical expertise, human capital and other resources. They could also donate time, skills and resources such as equipment where possible to organisations and institutions who seek to promote AI-related activities.

Lastly, to promote diversity, the AI community could support NGOs and organisations that promote diversity in AI by providing funding and time; ensure that recruitment processes are fair and support a diversified workforce; and include the diversity dimension in organisational policies.

Government

Governments could build national AI capacity by prioritising infrastructure development in key areas and leveraging the social benefit of AI on behalf of citizens by supporting initiatives that improve peoples' lives. Governments could also collaborate with Centres of Higher Education and the AI Community in aid of responsive policy formulation, giving intensive focus to AI ethics, privacy and data protection and human rights protection measures. The report also recommends that governments conduct regular monitoring and evaluation on government activities and funding allocations with respect to AI. To build internal government capacity, governments can undertake activities such as engaging with academic institutions and the private sector to provide training for public servants; employing AI specialists in government; and providing AI-related funding schemes and employment opportunities for students in AI-related fields.

With regard to policy development and creating a fair AI ecosystem, governments might consider including a diversity dimension in national policies and strategies, focus on curbing corruption, and promote responsible use of AI by keeping the public informed on what AI is, how it is used, and what their rights are. In addition, governments might undertake comprehensive data collection on AI activities and capacity building needs.

Lastly, governments could facilitate regional integration by participating in the development of a regional vision for AI and technological innovation and prioritising regional integration and cooperation to increase SSA's standing in the global community.

Setting an agenda for AI capacity building in SSA

The results of this research demonstrate that there are notable AI-related activities in all three stakeholder groups. One of the main limitations of this research was a lack of accessible data on involvement in AI-related academic offerings, R&D and AI community activities. Despite this, the available data points to a burgeoning ecosystem that uses AI in innovative ways. But there is a long way to go to ensure that SSA becomes competitive on the world stage. To fully harness the opportunities that AI offers, SSA will, amongst other things, need to change governance structures to support innovation, institute consumer protection laws and revamp education

systems to cater more directly to AI-related fields, while supporting the AI community with resources. If the region will not or cannot move beyond existing infrastructure and capacity challenges, SSA countries risk falling behind in AI adoption. This will, in turn, accentuate the digital divide and decrease their ability to compete globally.

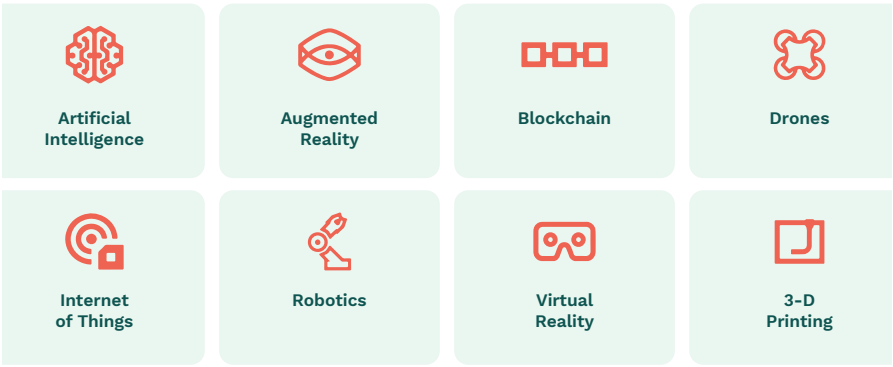
In line with the recommendations presented in this report, the key to creating a vibrant AI ecosystem is committed stakeholder engagement that pushes individual countries and the SSA region as a whole forward by building capacity in key areas. Building this ecosystem will require institution-wide changes, funding, cross-institutional and cross-sector collaboration, as well as a commitment to prioritizing AI activities. This process also provides an opportunity for the burgeoning AI market in SSA to employ AI and related technologies to facilitate and reinforce equality through skills development and concerted efforts to level the playing field for marginalised groups in the sector. Critically, this creates an imperative to develop an AI ecosystem where diversity is an entrenched norm.

Introduction

The term 'Artificial Intelligence' (AI) was coined by scientist John McCarthy at Dartmouth College in 1956. The term generally refers to 'machines that respond to stimulation consistent with traditional responses from humans, given the human capacity for contemplation, judgment, and intention.'[6] In other words, an AI system can make decisions, learn and adapt while doing so, and exhibit intelligent behaviours (such as problem-solving and pattern recognition).[7] These decisions are based on context rather than direct input.[8] AI systems are therefore able to behave in ways that are commensurate with human expertise.[9] Today, AI has come to the fore due to the exponential growth in computing capacity, the development of more sophisticated algorithms, and burgeoning data in an 'information society'.[10] This is what makes AI such a powerful technology – the fact that it is rapidly accelerating and forging new paths in almost all major industries, impacting all aspects of our lives. AI therefore provides the promise of developing human-like capabilities in software more effectively, efficiently and at a lower cost.[11]

AI comprises part of a set of eight emerging technologies. These technologies are referred to as 'disruptive' because of the potential they hold to redefine processes and approaches in industries where they are applied. As the number of applications increase for each of these technologies, they are also accelerating the rate of innovation. What makes these technologies even more powerful is that they can be combined in new ways. The eight emerging technologies are shown below:

Figure 1 The Eight Emerging Technologies [12]



Source: PwC Global, The Essential Eight

[6] West, D.M. (2018). "What is Artificial Intelligence?" Brookings Institute.

[7] West, D. M. & Allen, J.R. (2018). "How artificial intelligence is transforming the world." Brookings Institution.

[8] CompTIA. (nd). "Understanding Emerging Technology: Artificial Intelligence."

[9] West, D.M. (2018). "What is Artificial Intelligence?" Brookings Institute.

[10] Abardazzou, N. (2017). "The rise of artificial intelligence in Africa." How we made it in Africa.

[11] Singularity University. (nd). "An Exponential Primer." Singularity University.

[12] PwC. (nd). "The Essential Eight." PwC.

AI can be classified into two categories: general and narrow. Narrow AI is built for a highly specified set of tasks. It exhibits one or two types of intelligence (such as image and sound recognition). Examples of narrow AI include digital smartphone assistants or self-driving cars.[13] Conversely, General AI can call on multiple types of intelligence. It has human-like characteristics such as the ability to plan, understand language, recognise objects and sounds, learn, and solve problems.[14] For an AI to exhibit general intelligence, it must be able to 'transfer learnings from one environment to another, use common sense, work collaboratively with other machine and human stakeholders, and attain consciousness.'[15] There are currently several applications of narrow AI around the world, while general AI is thought to be decades away.

AI applications can execute a wide variety of intelligent behaviours, including optimisation (for example, supply chains); pattern recognition and detection (such as facial or speech recognition); prediction and hypothesis testing (such as predicting disease outbreaks); natural language processing; and machine translation (such as Google Translate). As such, AI is being used as a tool to reduce the cost and increase the efficiency of products and services in several sectors, while pioneering new offerings that were previously possible only by human intervention, as well as offerings that humans have not been able to do on their own.[16]

Machine Learning (ML)[17] is a subset of AI. The term refers to the ability of computers to process information about their environment and take actions to maximise their chances of achieving their goals without being explicitly programmed to do so.[18] In other words, ML manipulates algorithms by feeding massive amounts of data into the algorithm and allowing the algorithm to adjust its behaviours accordingly.[19] ML allows researchers to analyse data in new and significant ways. Today, computers can process enormous amounts of data very rapidly and recognise intricate patterns, when given the correct classification sets.[20] ML algorithms are able to recognise patterns in data that allow it to make increasingly accurate predictions and better decisions. AI, ML and data analytics often work simultaneously, and the resulting combination enables intelligent decision-making.[21] For example, GE Power uses big data and ML to build an 'internet of energy.' This enables predictive maintenance and power, operations and business optimisation to help GE Power create an early version of a 'digital power plant.'[22]

According to the Atlantic Council, global investment in AI was approximately $30 billion in 2016, 90% of which was spent on research and development (R&D) and deployment, while 10% was spent on AI acquisitions. Although digital giants such as Google and Baidu are responsible for most of this investment, private investors are gaining traction, having put up an estimated $4-$5 billion of venture capital and $1-$3 billion in private equity in 2016.[23]

While the opportunities that AI creates are countless and exciting, its fast-increasing capacity to overtake human abilities is sobering. The World Economic Forum (WEF) predicts that in the period leading up to 2022, 75 million jobs may be displaced through shifts in the division of labour between humans and machines.[24] As a result of AI, skills and jobs displacement is likely to affect every industry and geographical region over time. But the news is not all bad; job losses

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[13] Anirudh, V. K. (2019). "What Are the Types of Artificial Intelligence: Narrow, General, and Super AI Explained." Toolbox.

[14] McClelland, C. (2017). "The Difference Between Artificial Intelligence, Machine Learning, and Deep Learning." Medium.

[15] Davidson, L. (2019). "Narrow vs. General AI: What's Next for Artificial Intelligence?" Springboard Blog.

[16] Smith, M.L., Neupane, S., Leonard, G. and Mendonca, C. (2018). "Artificial Intelligence and Human Development: Towards a research agenda." IDRC.

[17] Deep Learning Indaba. (nd). "Deep Learning Indaba Fact Sheet." University of the Witwatersrand.

[18] Ballim, F. and Breckenridge, K. (2018). "Divinatory Computation : Artificial Intelligence and the Future of the African continent." Wits Institute for Social and Economic Research (WISER).

[19] McClelland, C. (2017). "The Difference Between Artificial Intelligence, Machine Learning, and Deep Learning." Medium.

[20] Cohen, J.L. & Kharas, H. (2018). "Using big data and artificial intelligence to accelerate global development." The Brookings Institution.

[21] West, D.M. (2018). "What is Artificial Intelligence?" Brookings Institute.

[22] Marr, B. (2018). "27 Incredible Examples Of AI And Machine Learning In Practice." Forbes.

[23] Gadzala, A. (2018). "Coming to Life: Artificial Intelligence in Africa. Atlantic Council – Africa Centre." ISSUU.

[24] Centre for the New Economy and Society, World Economic Forum. (2018). "The Future of Jobs Report." World Economic Forum.

can be offset by job creation in key areas. The same WEF report indicates that an estimated 133 million new roles may emerge that respond more directly to the way that the new labour market is structured.[25] Similarly, a global study conducted by Accenture found that AI adoption will create several new job categories that will require new skills. Accenture identifies at least three of these new categories, including 'trainers' to teach AI systems how to behave, 'explainers' to close the gap between technologists and business leaders, and 'sustainers', who will ensure that AI systems are operating as intended.[26]

With the wide-ranging effects of AI – both current and anticipated – it is critical to both develop local networks and facilitate South-South cooperation. This will ensure that the interests and values of diverse communities living in the Global South are considered with the advancement in AI and related technologies. It will also allow countries in the Global South to use these technologies in ways that uplift their societies. A recent report by the Worldwide Web Foundation explains that although technology discourse is becoming universal, different socio-economic contexts should be considered. AI has the potential to transform societies, but whether this technology is applied equally across different contexts remains the responsibility of humans.[27]

AI and related technologies are attracting interest in Africa and other regions of the Global South for their potential to address socio-economic challenges. This is seen most notably in the increase of 'AI4Good' projects that seek to use AI in applications that benefit communities around the world. Projects include applications in education with personalised learning, protecting ocean life, health and food safety.[28] Central to the conversation around employing AI and related technologies effectively is ensuring that countries prepare themselves for the Fourth Industrial Revolution (4IR). With this in mind, the next section will look at 4IR and its relevance to Sub-Saharan Africa (SSA).

Sub-Saharan Africa and the Fourth Industrial Revolution

At present, no SSA country is listed in the top ten countries expected to benefit most from AI and other emerging technologies.[29] Despite this, AI's unprecedented advancements are set to impact all countries, regardless of geography. Its impact in Africa will, perhaps, be most interesting, as several SSA countries are still coming to terms with issues surrounding the first three industrial revolutions. This includes problems around universal access to electricity, the mechanisation of production, and automation of industries. This raises many questions about how prepared Africa is for 4IR.

Also known as Industry 4.0, The World Economic Forum defines 4IR as follows:

> *The Fourth Industrial Revolution represents a fundamental change in the way we live, work and relate to one another. It is a new chapter in human development, enabled by extraordinary technology advances commensurate with those of the first, second and third industrial revolutions. These advances are merging the physical, digital and biological worlds in ways that create both huge promise and potential peril. The speed, breadth and depth of this revolution is forcing us to rethink how countries develop, how organisations create value and even what it means to be human.*[30]

[25] Centre for the New Economy and Society, World Economic Forum. (2018). "The Future of Jobs Report." World Economic Forum.

[26] Accenture. (2018). "Creating South Africa's Future Workforce." Accenture.

[27] 4IRSA. (nd). "The Future of Artificial Intelligence in Africa."

[28] AI for Good Foundation. (2020). "About us."

[29] Hoosen, Z. (2018). "Op-Ed: How Africa can embrace an artificial intelligence enabled future." CNBC Africa.

[30] World Economic Forum. (2010). "Fourth Industrial Revolution." World Economic Forum.

4IR is characterised by integration between the digital, biological, and physical worlds. A core component of this integration is the increased use of emerging technologies such as AI, cloud computing, robotics, 3D printing and the Internet of Things (IoT).[31]

4IR technologies are increasingly acting as transformational forces. Those who argue that 4IR is a positive development explain that advancements in digitisation, computerisation and the internet have the potential to trigger unprecedented social and economic change. Klaus Schwab, the founder and executive chairperson of the World Economic Forum (WEF), believes that technology is a crucial driver of social progress and that 'unless individuals, governments and companies adapt to these technologies, they will fall behind and become irrelevant.'[32] Similarly, Alison Gillwald notes the following:

> *There is little doubt that the inevitable rise of the advanced technologies of artificial intelligence, blockchain and drones will disrupt economies and societies. But when this happens, the degree to which it will happen will be highly uneven. Like other industrial revolutions, this one will be characterised by evolution as much as by disruption. Unless something dramatically different is done, one of the continuities will be the perpetuation of inequality. And the primary determinant of inclusion is education and digital skilling.*[33]

Failing to capitalise on the opportunities that 4IR brings will pose significant challenges for African stakeholders. The continent will need to change governance structures to support innovation, institute consumer protection laws and effectively implement regulations that inspire competition. If they will not or cannot move beyond existing structures for innovation, entrepreneurship and digital growth, African countries risk falling behind. This will, in turn, accentuate the digital divide and decrease their ability to compete globally.[34]

If SSA can capitalise on 4IR, its society will be able to harness the transformational potential by:

- encouraging economic growth and structural transformation;
- reducing poverty and inequality;
- changing how labour, skills and production are organised;
- improving financial services and increasing investment;
- reforming agriculture and agri-industries; and
- improving healthcare systems and human capital.[35]

But as it stands, does SSA have the capacity to catch up with exponential technological development? Significant obstacles remain to realizing 4IR in Africa. In 2020, internet penetration averaged 39.3% of Africa's population compared to 62.9% in the rest of the world. There was, however, marked variation between African countries, ranging from 87.2% in Kenya to 9.7% of the population in Burundi.[36]

Aside from uneven internet penetration, other significant challenges present themselves. First, Africa has the lowest average level of statistical capacity globally, while lacking or flawed data severely limits the efficacy of AI systems. Second, there is a missing knowledge base for AI adoption due to insufficient education and training. According to a report published by the Atlantic Council's Africa Centre:

> *Despite the fact that Ethiopian government spending on education nearly doubled between 2000 and 2013, improvements in youth literacy and student enrolment*

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[31] Ndung'u, N. and Signé, L. (2020). "The Fourth Industrial Revolution and digitization will transform Africa into a global powerhouse." Brookings Institute.

[32] Duncan, J. (2019). "What can the Fourth Industrial Revolution learn from the Third Industrial Revolution?" Daily Maverick.

[33] Gillwald, A. (2019). "SA must be wary of big promises made about 4IR." Tech Central.

[34] Africa Growth Initiative, The Brookings Institution. (2020). "Foresight Africa: Top Priorities for the Continent 2020-2030." The Brookings Institution.

[35] Africa Growth Initiative, The Brookings Institution. (2020). "Foresight Africa: Top Priorities for the Continent 2020-2030." The Brookings Institution.

[36] Internet World Stats. (2020). "Internet Penetration in Africa 2020 – Q1 – March."

rates have been disappointing. Only one-fifth out of every 1,000 children who starts school advances beyond the eighth grade, and those who do progress learn on average only 40 percent of the material they are expected to master. Nigeria also ranks in the bottom twenty countries of the WEF index, at 114th out of 130 countries. With an estimated 10.5 million children out of school, Nigeria's unenrolled rate is the highest in the world, and its primary and secondary school systems are largely failing.[37]

Despite these challenges, the current industrial revolution presents an opportunity for Africa to make its way to the forefront of the world economy. With a large, young labour force – 60% of Africa's 1.25 billion population are under the age of 25[38] – and with an abundance of natural resources, SSA will need to merge its advantages with the requirements for 4IR, which include substantial investment capital, R&D, as well as highly skilled individuals.[39]

Progress in this regard is becoming increasingly visible. There has been significant growth in the technology sector – the African Development Bank identified an estimated 6,500 technology start-ups on the continent in 2019, about 10% of which developed 4IR applications. These ventures had received a total of $210 million in investment. Growth in Africa's ICT sector has mostly been driven by expanding mobile digital financial services, with nearly half of global mobile money accounts in 2018. These technologies are acting as transformational forces for change in African countries – mobile technologies and services have created 1.7 million direct jobs in the formal and informal sectors. They have also contributed $144 billion of economic value (8.5% of SSA's GDP), and provided $15.6 billion to the public sector through taxation.[40] Another positive sign is that Africa's population, which is anticipated to double to 2.4 billion by the year 2050, creates a rich source of data to fortify 4IR innovations and develop a market for these technologies.[41]

Despite the substantial infrastructure challenges that SSA faces, 4IR in general and AI in particular, provide the opportunity to leapfrog legacy systems and roll out entirely new technological systems. But creating an efficient AI ecosystem that supports innovation requires collaboration, successful governance, investment, infrastructure and skills. There are several key stakeholders whose support will be critical in advancing AI in SSA. The following section explores these stakeholders in detail.

Who are Africa's AI stakeholders?

As one might imagine, the efforts of several stakeholders are required to create and sustain a well-functioning AI ecosystem. From developing inclusive policy objectives and creating regulatory frameworks to sharing best practices, or from generating data to designing and commercialising AI applications, realising an inclusive, thriving AI ecosystem in SSA depends on all of these stakeholders' collaboration. The infographic below provides a breakdown of key stakeholders in the AI arena, together with some of their required contributions.

[37] Gadzala, A. (2018). "Coming to Life: Artificial Intelligence in Africa. Atlantic Council – Africa Centre." ISSUU.

[38] Smith, C. (2019). "Revolutionary technologies will drive African prosperity - this is why." World Economic Forum.

[39] Abardazzou, N. (2017). "The rise of artificial intelligence in Africa." How we made it in Africa.

[40] Africa Growth Initiative, The Brookings Institution. (2020). "Foresight Africa: Top Priorities for the Continent 2020-2030." The Brookings Institute.

[41] Technopolis & Research ICT Africa & Tambourine Innovation Ventures. (2019). "Potential of the fourth industrial revolution in Africa: Study report. African Development Bank." African Development Bank.

Figure 2 Stakeholders in the AI ecosystem

Source: Access Partnership, Microsoft and University of Pretoria (2018)

An overview of the challenges and opportunities for promoting AI in SSA raises many questions about how prepared Africa is to benefit from the 4IR, and where governments and other stakeholders (funders, intergovernmental organisations, etc.) should focus their attention to build that preparedness. While the existence of some indexes that compare the relative readiness of different governments, or countries[42] are compelling, they provide only a cursory overview of what is happening across the continent.

To guide future investments in capacity building that will build responsible AI development and deployment, it is important to know answers to questions such as: what does the AI landscape in SSA look like? What measures are stakeholders in the region taking to ensure that they are AI-ready? Where does capacity already exist or not?

To answer these questions, Artificial Intelligence for Development (AI4D) Africa supported research on three key stakeholders involved in AI capacity building in SSA, namely, Centres of Higher Education and Training, Governments, and the broader AI community in the region. The research process also included a comprehensive desktop literature review. This report presents the integrated results of the research with these stakeholders.

The research draws from four data sources, listed below:

- A detailed desktop review of available literature on AI in the region, with a specific focus on the three stakeholder groups;
- Two surveys distributed to 89 representatives of Centres of Higher Education and Training (Response rate = 43) and 57 representatives within the industry (Response rate = 32);
- In-depth interviews with 24 representatives of Centres of Higher Education who were involved in AI-related activities; and
- Findings from a UNESCO survey on AI capacity building needs that was distributed to UNESCO's national commissions in Africa (response rate = 32 UNESCO Member States).

The results presented in this report consider findings from all four data sources, synthesising them into findings, key takeaways and recommendations for each of the stakeholder groups. A detailed outline of the methodology is provided in Appendix 1.

The following sections present the findings for each of the three stakeholder groups that are the focus of this report. The research delves into how AI can contribute to these sectors, stakeholders' current activities related to AI, as well as their intended plans. In addition, it highlights areas for development of AI capacity.

[42] Oxford Insights. (2020). "Government AI Readiness Index." Oxford Insights.

AI in Centres of Higher Education and Training

There is consensus that AI is changing our world, is here to stay, and offers abundant opportunities for every sector.[43] The literature suggests that Centres of Higher Education and Training will need to start grappling with the idea of AI in two main ways. First, institutions will need to prepare students for a world in which AI is a rapidly developing reality that permeates most spheres of society. What skills, competencies, and awareness will the future workforce require and what are the most effective and efficient ways of developing educational programmes that equip them sufficiently? Second, these institutions will need to consider how AI might be used to assist administration, teaching and learning, as well as management. Within this, they will need to think about the potential risks of introducing AI into current institutional processes. This section tackles these questions by examining academic offerings, R&D, Policy and capacity building needs at Centres of Higher Education and Training.

AI-Related Academic Activities

AI necessitates the development of new human skillsets and capabilities. To meet the growing demand for these new skills, education systems need to adapt fast and new frameworks need to be developed to allow individuals to cultivate the skills to thrive in a rapidly changing environment.[44] AI requires people specialised in digital skills and data science to meet growing demand. But this will involve more than upskilling in disciplines such as Science, Technology, Engineering, and Mathematics (STEM). As AI systems increasingly develop the ability to behave like human beings, people with skills in the Social Sciences and Humanities will be ever more important – disciplines such as Art, History, Economics, Ethics, Languages, Philosophy and Psychology will come to the fore as being able to teach critical, philosophical, and ethical skills which will be vital for research, development, and management solutions for AI.[45]

An effective education system that supports AI-related activities will lay the foundation for a robust AI ecosystem. As an article in South Africa's Daily Maverick notes:

> *SSA is going to need good policies which start with education that prepares learners for a different work environment. Although it's not possible to forecast with certainty what the workplace will look like in future, we will most certainly transform into a different world. A wider array of educational and training programmes that can successfully train mostly poorly educated workers in the skills they need to perform the jobs of the future must be established...*[46]

The article adds that although the popularity of digital learning is on the rise, adoption is still concentrated in historically advantaged universities. It argues that digital learning enables cost effective teaching and learning, which provides a useful tool to bridge the educational gap.[47] But issues of access to higher education still pervade SSA. The World Bank estimates that tertiary education enrolment in SSA averages about 9%, which is well below the global average of 32%. There is also significant variation between African countries. For example, South Africa's tertiary enrolment sits at 24%, in Nigeria it is 10%, and in Tanzania it is only 4%.[48] Coupled with this, research by the International Telecommunications Union reveals that two of the key barriers to

[43] PwC. Sizing the Prize – PwC's Global Artificial Intelligence Study: Exploiting the AI Revolution. PwC.

[44] Access Partnership, Microsoft and University of Pretoria. (2018). "Artificial Intelligence for Africa: An Opportunity for Growth, Development, and Democratisation." University of Pretoria.

[45] Hoosen, Z. (2018). "Op-Ed: How Africa can embrace an artificial intelligence enabled future." CNBC Africa.

[46] Old Mutual Investment Group. (2020). "Enabling Lifelong Learning Through Artificial Intelligence." Daily Maverick.

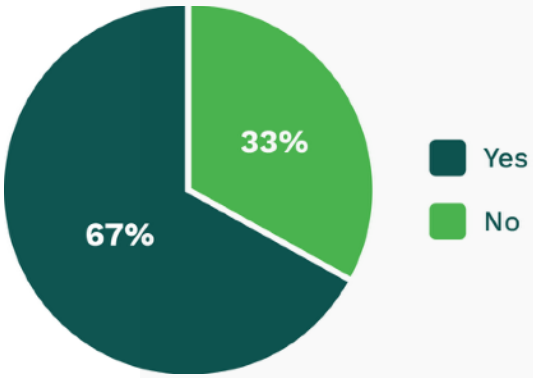
[47] Old Mutual Investment Group. (2020). "Enabling Lifelong Learning Through Artificial Intelligence." Daily Maverick.

[48] World Bank. (2020). "School enrollment, tertiary (% gross) - Sub-Saharan Africa." World Bank.

internet adoption in developing countries is the lack of education and skills.[49] This demonstrates systemic challenges regarding higher education access in SSA. In addition, research shows that the percentage of individuals with ICT skills is the highest in European countries, while the lowest percentage is in the Middle East and Africa. Because ICT skills are increasingly necessary at every stage of employment, lifelong learning is central for the adjustment to changing work environments.[50] Significant efforts are therefore required to support access and quality of education in SSA at all levels through an individual's life. Because SSA's population is so young – and is expected to double to over 830 million by 2050 – key will be to support youth by equipping them with the right education at tertiary level, skills when they enter the workforce, and social capital to draw from when they look for a job.[51] In addition, promoting lifelong learning and on-the-job training – what the WEF refers to as an 'upskilling imperative' – that aligns workforce skills demand and supply.[52]

Despite the challenges highlighted above, AI is gaining traction as a specialisation in academic and research institutions across Africa, particularly with a view to solving the continent's most significant challenges. The AI4D research supports this – as shown in Figure 3, 67% of respondents from Centres of Higher Education and Training indicated that there are currently AI researchers or experts at their institutions.

Figure 3 Institutions with AI researchers/experts



AI-related Academic Offerings

When looking at AI-related degrees, qualifications, and courses, 54% of respondents indicated that their institutions had AI-related academic offerings. This included the following universities:

- University of the Witwatersrand;
- University of the Western Cape;
- University of Cape Town;
- University of Ghana;
- University of Kwa-Zulu Natal;
- University of Ibadan;
- Makerere University;
- University of the Witwatersrand;

Box 1: Undergraduate courses with AI-related elements

Respondents and the desktop research highlighted the following degrees as having AI-related components:

- BSc in Applied Mathematics;
- BSc in Computational and Applied Mathematics;
- BSc in Computer Science;
- BSc in Computer Science and Informatics;
- BSc in Data Science;
- BSc in Information Technology;
- BSc in Business Computing;
- BSc in Communication Technology and Computer Science;
- BSc in Statistics/ Statistical Models and Methods;
- BSc in Computer Technology;
- BSc Computer Systems and Security;

BCom Mathematical Sciences;
Interdisciplinary BSc; and
BSc in Informatics and Computer Science.

[49] Nwaodike, C. (2020). "The AI Digital Divide – An African Perspective." Internews.

[50] UNESCO. (2019). "International Conference on Artificial Intelligence and Education: Final report – Planning education in the AI Era". UNESCO.

[51] Kapoor, K., Mansaray, H., Sennett, L., Pitti Rivera, O., Ocana Marin, A. and the African Centre for Economic Transformation. (2018). "The Future of Work: Regional Perspectives." African Development Bank.

[52] Microsoft News Centre. (2020). "Continuous learning is the key to success." Microsoft.

- University of the Western Cape;
- University of Cape Town;
- University of Ghana;
- University of Kwa-Zulu Natal;
- University of Ibadan;
- Makerere University;
- University of Pretoria;
- Université Nouveaux Horizons;
- University of Rwanda;
- Jomo Kenyatta University of Agriculture and Technology;
- Kabarak University;
- Stellenbosch University;
- Strathmore University;
- University of Nairobi;
- University of Johannesburg; and
- North-West University.

Sixteen institutions provided additional information about AI-related qualifications and courses. At the undergraduate level, the data indicated that there were no AI-specific degrees, but rather that general degrees had AI-related course offerings or modules (see Box 1). Most undergraduate degrees with AI-related courses had been introduced in the last eight years, so there were relatively new course offerings.

When looking at institutions' postgraduate offerings, there were several AI-focussed degrees on offer (see Table 1 in Appendix 2), many of them containing a research component that provided students the option of researching an AI-related topic. Several AI-related degrees were new according to the interview data, with the year that they were first offered ranging from 2000 to 2019, the most frequent year of initial offering being 2017. Respondents and the desktop research indicate that the following institutions offer postgraduate degrees that are either focused on AI or contain AI components:

- University of the Witwatersrand;
- University of the Western Cape;
- University of Cape Town;
- University of Ghana;
- University of Kwa-Zulu Natal;
- University of Ibadan;
- Makerere University;
- University of Pretoria;
- Université Nouveaux Horizons;
- University of Rwanda;
- Jomo Kenyatta University of Agriculture and Technology;
- Kabarak University;
- Stellenbosch University;
- Strathmore University;
- University of Nairobi;
- University of Johannesburg; and
- North-West University.

Box 2: Courses with AI-related components

Respondents mentioned course offerings that concentrated on several topics, including:

- C++ and Machine Learning;
- Data Science;
- Bioinformatics;
- AI;
- Embedded Systems;
- Robotics; and
- Data Mining.

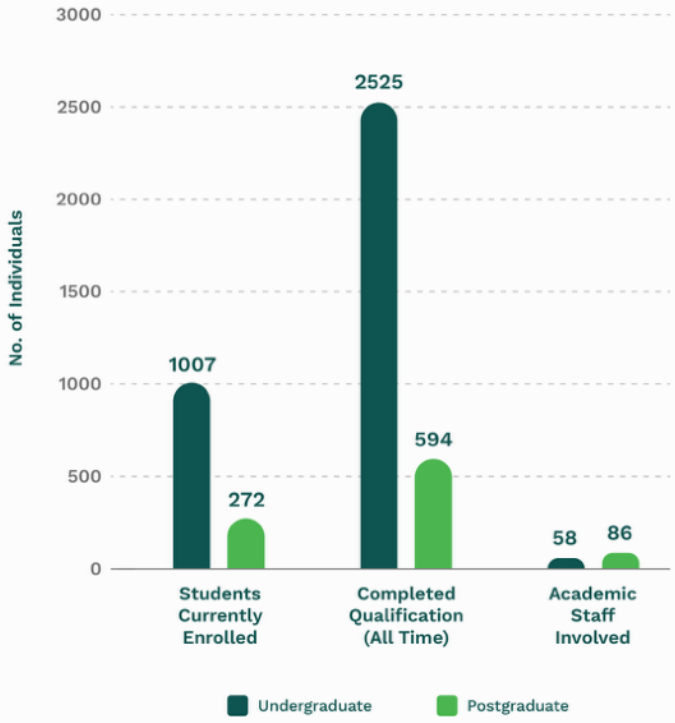
The table in Appendix 2 provides a breakdown of postgraduate offerings with AI-related components. Drawing from the data collection and desktop research, these offerings have been collated across institutions and provide an indication of the range of postgraduate academic offerings already available in SSA. The table demonstrates that there are various academic offerings that seek to train students in AI, Data Science, ML and related fields. Note that this is not an exhaustive list but is intended to demonstrate the range of offerings. The table also reveals that the vast majority of AI-related qualifications are in the hard sciences, with little or no focus on the Humanities or Social Sciences. As noted, it will be important to develop skills related to

the Humanities and Social Sciences to aid research, development, and management of solutions for AI.[53]

Although enrolment data was not provided by all institutions for these programmes, the enrolment data that the team received from eight institutions (Figure 4) showed that at least 2,525 undergraduate and 594 postgraduate students had completed AI-related courses and qualifications since those courses were introduced. There was a total of 1,007 undergraduate students and 272 postgraduate students currently enrolled in AI-related courses and qualifications across the institutions.

Being mindful of the small number of courses for which enrolment data was provided, the graduate output and enrolment data suggests that a number of students are participating in AI-related qualifications and courses. However, the difference between undergraduate and postgraduate enrolment suggests that large numbers of students did not go on to pursue postgraduate education.

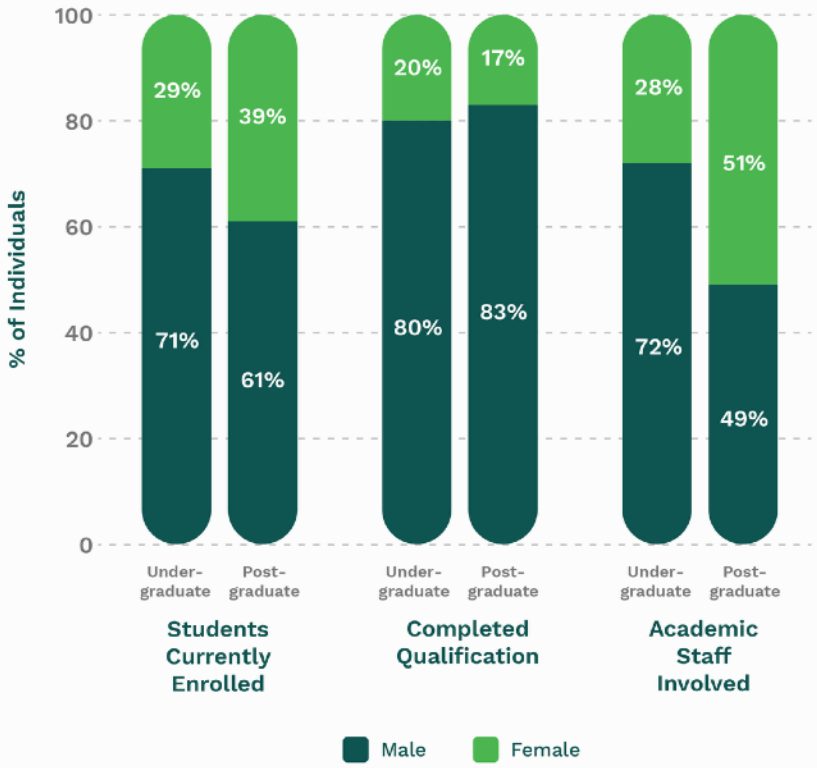
Figure 4 Enrolment in AI-related Qualifications



Looking at the same dataset, but focussing on gender representation (Figure 5), the results showed that students who had graduated from AI-related courses and qualifications were predominantly male, at both the undergraduate (80%) and postgraduate (83%) levels. The trend continued when looking at undergraduate students (71% male) and postgraduate students (61% male) who were currently enrolled in AI-related qualifications. Results, however, indicated an even split between male staff (49%) and female staff (51%) who were involved in teaching postgraduate courses. However, the disparity was much more pronounced at the undergraduate level with male staff at 72% and female staff at 28%. Note that where institutions provided combined figures for both genders, they were removed from the dataset for these calculations.

[53] Hoosen, Z. (2018). "Op-Ed: How Africa can embrace an artificial intelligence enabled future." CNBC Africa.

Figure 5 Gender Representation in AI-related Courses and Qualifications



Respondents noted the following disciplinary fields where AI teaching is currently in demand:

- Computing, including Computer Science, IT Statistics, Mathematics;
- Commerce;
- Machine Learning;
- Engineering (Electronic and Computational);
- Physics and Natural Science;
- Energy;
- Health including Biotechnology;
- AI as a method of data analysis (Finding new patterns in data that traditional methods have overlooked);
- Social Sciences including linguistics; and
- Geography.

A sampling of respondents' comments is included below:

> *We are experiencing demand from students and demand from industry for graduates who can come work for them. Students are requesting computational, mathematical, and statistical fields. We also know about students from other disciplines like biology or physical science or other faculties like humanities and education who are realising that AI and Data Science is important. We haven't experienced a massive demand from those fields but I think it is growing.*

> *Machine learning is the core. Looking at the industrial perspective, there is a need to have image processing as well. There is always enough data in the space of images and cameras are mounted all around to capture civilians- but there is a need for us to understand all these images first. Without the data, there is nothing we can do.*

Other respondents focused on the multidisciplinary and interdisciplinary nature of AI teaching and research. Comments included:

> *The Information Science is the demand-side of tech, whereas the other disciplines are the supply side. What we see happening now is that organizations are now seeing the benefits of Information Science – being applied to logistics, accounting, education… The impact of tech is in each and every department. We are seeing more multidisciplinary [work].*

> *More in engineering (electronic and computer) and also at the College for Information and Computer Science. Although, the applications that we hear about are more related to health and things like that. We see a lot more interdisciplinary research going on, for example, in Agriculture and Health Science.*

However, the comments above on demand for AI courses should be interpreted in a context where not all institutions are experiencing similar volumes of students who are interested in AI-related offerings or where students are impatient to wait for courses to be offered. As one respondent noted:

> *We have not been running [the course] because we have not been able to roll it out- there are only a few applicants when we advertise so we are forced to send them to other programmes. It's not effective to run a course when there are one or two students to do it. When we ask students to wait until they get to quorum, some are impatient and join other courses.*

These comments highlight that demand and supply are interrelated; an institution's ability to offer AI-related courses and qualifications is dependent on student demand, which in turn is determined by student interest and foundational skills.

Employability of Students After Having Studied AI-related qualifications

Several respondents indicated that they knew of students who had used their qualifications for different areas of application, including in banks, retail, and at insurance companies, as the following comments illustrate:

> *Graduates who have experience with AI (either as an Honours, Masters or PhD) or have done an AI related project are generally more employable by local and international companies who are looking to develop machine learning applications for Big Data – e.g. Allan Gray and Amazon – All my AI graduates have found jobs because of their experience with AI.*

> *The moment Machine Learning came on my CV, I get so many job offers – as do my students. IBM is trying to get us on board. Banks and all sorts of networks are desperate for people who can deal with data and who can programme.*

Respondents explained that their graduates had gone on to further studies or to being employed in international and local universities or research institutes in South Africa, Canada, the USA, Ghana and the UK. These included the following:

> *I have a student who did his thesis with me and has applied to do his postgraduate studies in Canada, where he was one of the strongest contenders. I have about 70 students who have gone on to be employed.*

> *One of my star students who was a Masters student with me completed his Ph.D. [in the UK]… A few have gone on to get academic positions overseas.*

Some respondents noted that their students found jobs in data science, working for software companies, or had started their own businesses:

One of our former graduates studied pure Computer Science but is now involved in data science applications. He formed a company...

In terms of my own students, we've had them placed in AI startups

One of our PhD students started his own company... and it's a Machine Learning company that is doing very well, employing 30-40 people I think.

Importantly, some respondents highlighted a need for greater capacity, both within institutions and at potential employers, to ensure employment opportunities for their graduates. This included the following:

What has been happening is that we are trying to teach them, but if you look at the Zimbabwean context, very few companies are using AI.

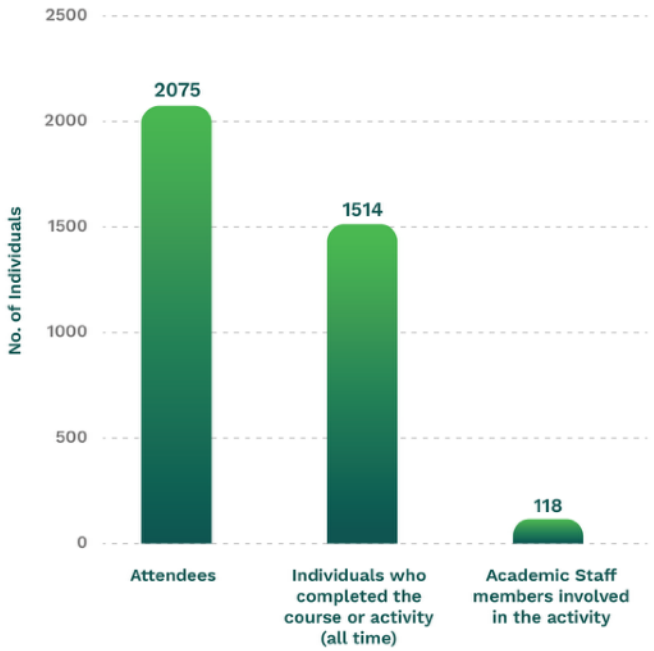
If the university did more to showcase what we are doing in this space, to make the capacity evident, perhaps we would have more interest.

At the moment, it's a question of whether other organisations are ready. Because I have past students who are all over the country at different organisations and normally the challenge they are dealing with is the organisation understanding what they are trying to do. They work in banking, retail, consultancies...

AI-related short courses, workshops, training opportunities

Fourteen institutions provided information about their non-degree related offerings, including short courses, workshops, and training opportunities (hereinafter referred to as 'learning activities'). Note that only six institutions provided data on the number of individuals involved.

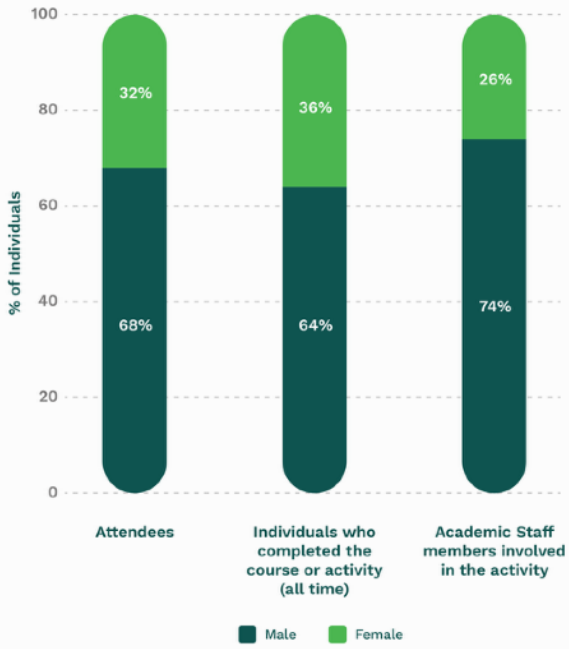
Figure 6 Involvement in AI-related short courses, workshops, training opportunities



Based on this sample, a total of 2,075 people attended AI-related learning activities (see Figure 6). A total of 1,514 people had completed learning activities to date. The data therefore shows considerable attendance of AI-related learning activities. Note that the number of attendees exceeded the number of individuals who completed the learning activity over all time because

data for the latter was not provided for all activities. When looking at staff representation, there were 118 staff involved in learning activities.

Figure 7 Gender Breakdown of involvement in AI-related Short Courses, Workshops and Training Opportunities



Examining the same dataset in terms of percentage of gender representation (Figure 7), the data indicated that males were in the majority in all three categories. For the number of attendees of these activities, there were 68% males compared to 32% females. The individuals who had completed the course or activity to date were 64% male and 36% female. Male staff also held a majority of 74% compared to 26% of their female counterparts. Note that where institutions provided combined figures for both genders, they were removed from the dataset for these calculations.

The results indicate diverse involvement of Centres of Higher Education and Training in learning activities and communities of practice such as the Deep Learning Indaba and satellite events like IndabaX, as well as Data Science Africa. Other activities included:

- Summer School on Machine Learning and Data Science;
- Conferences (Computing and Information Systems);
- Involvement in short courses, some in collaboration with other universities and industry partners such as IBM;
- Seminar programmes, workshops and talks from academics and industry experts – some aimed at people without a background in AI, Data Science or Machine Learning, while others are aimed at those who have specialised in these areas;
- Hackathons;
- Hosting visiting Professors;
- Outreach programmes; and
- Career mentorship programmes.

Survey respondents also demonstrated significant interest in joining or contributing to a nascent AI network to strengthen and develop scientific and technological excellence in a range of AI-related issue areas for sub-Saharan Africa, with 79% of respondents indicating that their institutions would be interested. This involvement in learning activities and communities of practice provides a basis for further development of AI work and demonstrates that there is a growing African AI community of practice.

AI-related Research and Development

A report by Access Partnership, Microsoft, and the University of Pretoria notes that universities and research institutions create the conditions for AI ecosystems to flourish, as they are locations where scientists and engineers who are at the forefront of innovation should be able to experiment with new ideas.[54] However, potential growth of AI in SSA educational institutions requires more than resources and increased capacity. There is a worrying trend of accomplished African researchers, looking to attend global conferences to network and share their findings, being denied entry to countries where these conferences were held. This played out most recently at the Neural Information Processing Systems conference (NeurIPS) in Canada where, for the second year in a row, over a dozen researchers from African countries were denied visas. In 2016, no papers from African countries were accepted by the conference.[55] As Will Knight explains: 'This means an event that shapes the course of a technology with huge economic and social importance will have little input from a major portion of the world.'[56] If this kind of exclusion – whether intentional or inadvertent – becomes a pattern, there is a risk that African researchers will be excluded from contributing to what should undoubtedly be a global effort to innovate around AI and to discuss its uses, challenges, and its ethical implications.[57]

At the institutional level, there are several efforts by Centres of Higher Education and Training in SSA to undertake R&D activities and grow communities of practice. Some examples are discussed below.

The University of Pretoria (UP) in South Africa formed the Intelligent Systems Group (ISG),[58] which specializes in the theory and application of systems that perceive, reason, learn, and act intelligently. The group aims to create real-world intelligent systems applicable in the South African context. Its research areas include digital image processing and computer vision; music and AI; radio systems planning; and remote sensing. ISG members work with centres, organisations and institutes around the world such as Cambridge University Engineering Department, the United States Office of Naval Research, and the United States Space and Naval Warfare Center. In addition, UP established the Institute of Big Data and Data Science in September 2017. UP's Computer Science Department research groups, namely, the Nature Inspired Computing Optimisation Group and the Computational Intelligence Research Group focus on different areas and applications of AI technologies.[59]

In, 2018, IBM partnered with Malawi University of Science and Technology for the IBM Digital-Nation Africa (D-NA) Project, which trains students on emerging technologies including AI, cloud computing, data science and analytics, blockchain and security, and IoT.[60]

In Ethiopia, at least two universities have prioritised activities in the field of AI. The Addis Ababa Science and Technology University established the Artificial Intelligence and Robotics Centre of Excellence, which has been promoted by the Ministry of Science and Technology. The Centre seeks to create a close collaboration between academia and industry in the fields of AI and robotics.[61] In 2019, Addis Ababa University organised the first annual AI conference in Ethiopia aimed at organizing Ethiopian researchers and advancing the field of AI for developing countries.[62]

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[54] Access Partnership, Microsoft and University of Pretoria. (2018). "Artificial Intelligence for Africa: An Opportunity for Growth, Development, and Democratisation." University of Pretoria.

[55] Gershgorn, D. (2019). "Africa Is Building an A.I. Industry That Doesn't Look Like Silicon Valley." OneZero.

[56] Knight, W. (2019). "African AI Experts Get Excluded From a Conference—Again." Wired.

[57] AI Expo Africa. (2020). "About us."

[58] See https://www.up.ac.za/en/intelligent-systems/article/1950533/research-focus

[59] Access Partnership, Microsoft and University of Pretoria. (2018). "Artificial Intelligence for Africa: An Opportunity for Growth, Development, and Democratisation." University of Pretoria.

[60] Global Information Society Watch. (2019). "Artificial intelligence: Human rights, social justice and development." GISWatch.

[61] Global Information Society Watch. (2019). "Artificial intelligence: Human rights, social justice and development." GISWatch.

[62] Addis Ababa University. (2019). "About us."

Strathmore University in Nairobi created the @iLabAfrica Research Centre, which advances innovative research on emerging technologies including Big Data, AI, Blockchain Technology, Cyber Security, IoT and Cloud Services to achieve development goals that align with Kenya's Vision 2030. @iLabAfrica aims to consolidate activities and organise academic researchers and technology experts in Kenya, enabling them to collectively innovate and develop applications in several areas, including healthcare, education, energy, banking, and transport. The research centre also champions development of the local technology ecosystem. @iLabAfrica has established a research group devoted to ML and intelligent systems, which explores high-impact areas of bioinformatics, natural language processing, and e-learning.[63]

Data Science Nigeria recently launched Nigeria's first Data Science Community Centre and Artificial Intelligence Hub at the University of Lagos. The Hub focuses on cross-industry and academic research and concentrates on deep learning and encouraging young talent discovery within the innovation and data analytics space.[64] Mentors and lecturers from the academic and technology community will be invited to support students. The AI Hub will be heavily focused on tools to collect data, which is essential for the development of the technology.[65]

Established in 2011, the Centre for AI Research (CAIR) in South Africa is a research network that aims to build South Africa's AI research capacity. CAIR conducts foundational, directed and applied research on several areas related to AI through its nine research groups: Adaptive and Cognitive Systems, AI and Cybersecurity, AI for Development, Applications of Machine Learning, Computational Logic, Ethics of AI, Foundations of Machine Learning, Knowledge Representation and Reasoning, and Probabilistic Modelling.[66] It has nodes at five South African universities: The University of Cape Town, University of KwaZulu-Natal, North-West University, University of Pretoria and Stellenbosch University.[67] CAIR hosted an inaugural South African Forum for Artificial Intelligence Research (FAIR) in Cape Town in December 2019. The conference brought together researchers, scholars and industry participants to exchange their experiences and latest research results in all aspects of AI.[68]

The University of Rwanda launched the African Centre of Excellence in Data Science (ACE-DS). ACE-DS is one of 24 Eastern and Southern Africa Higher Education Centres of Excellence in the World Bank's ACE II Project. The ACE Il Project aims to strengthen selected Eastern and Southern African higher education institutions to deliver high quality post-graduate education and build collaborative research capacity in the regional priority areas.[69] Based at the University of Rwanda in the School of Business and Economics, ACE-DS aims to train post-graduate students with expertise in statistics, economics, business, computer science, and engineering to use big data and data analytics to solve development challenges.[70]

The Robotics, Autonomous Intelligence and Learning (RAIL) Lab at the University of the Witwatersrand (Wits) is a research hub that focuses on AI, ML, and Robotics. Its research focus is Reinforcement Learning (RL). Other research focus areas include computer vision and theory of deep networks. Application areas include healthcare and education.[71] In mid-2019, IBM announced that it would collaborate with Wits on the expansion of its quantum computing efforts to Africa. Wits is the first African partner on the IBM Q Network, which seeks to accelerate

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[63] For more information on @iLabAfrica research group, see Strathmore University website.

[64] The Guardian. (2018). "Data Science Nigeria opens 1st AI Hub in Unilag." The Guardian.

[65] Access Partnership, Microsoft and University of Pretoria. (2018). "Artificial Intelligence for Africa: An Opportunity for Growth, Development, and Democratisation." University of Pretoria.

[66] Centre for Artificial Intelligence Research. (2020). "About."

[67] Access Partnership, Microsoft and University of Pretoria. (2018). "Artificial Intelligence for Africa: An Opportunity for Growth, Development, and Democratisation." University of Pretoria.

[68] South African Forum for Artificial Intelligence Research. (2019). "Homepage."

[69] World Bank. (nd). "Eastern and Southern Africa Higher Education Centres of Excellence." World Bank.

[70] African Centre of Excellence in Data Science. (nd). "About." University of Rwanda.

[71] University of the Witwatersrand. (nd). "Robotics, Autonomous Intelligence and Learning (RAIL) Research Groups." University of the Witwatersrand.

and scale quantum computing, a field that shows great promise in surpassing the capabilities of traditional computers.[72]

Makerere University in Uganda formed the AI & Data Science Research Group, which examines various areas related to AI and data science such as ML methods, computer vision and predictive analytics. The group has conducted research on automated diagnosis of crop and human diseases, auction design for mobile commodity markets, analysis of traffic patterns in African cities, and the use of telecoms and remote sensing data for anticipating the spread of infectious disease, to name a few.[73]

The University of Johannesburg (UJ) established the Institute for Intelligent Information Systems (IIS) in 2016. It aims to fulfil its vision of driving the university's industry 4IR initiatives. IIS operates in three key areas; academic development, strategic research, and enterprise development. In its academic branch, the Institute tackles the development of multidisciplinary taught and online programmes for a postgraduate qualification and continuing professional development (CPD), for the purpose of capacity building in the areas of ML, AI, data science, and IoT.[74] IIS has formed partnerships with industry, government and communities to 'dismantle big data problems to the economic benefit of South Africa.'[75]

The African Institute for Mathematical Sciences (AIMS) is a Pan-African network of Centres of Excellence for post-graduate training, research and public engagement in mathematical sciences. It represents 22 African countries. All students reside in Africa, 35% of which are female. The AIMS network has five Centres of Excellence that teach a Masters in Mathematical Sciences. This includes a work-integrated learning option with links to industry in three Centres. The network has 1,682 alumni from 43 African countries and includes research centres and programmes. In Cameroon and Rwanda, AIMS hosts a gender-responsive teacher training programme.[76]

Senegal has one of the first programming schools in West Africa at the Dakar Institute of Technology, which was established in 2019. However, one of the key barriers to innovation in the country is that research institutions are fragmented as they are supervised by different ministries. Funding sources are also splintered and often lack visibility. Senegal has approximately 555 researchers per million inhabitants, which is lower than many OECD countries. The balance of R&D activity is undertaken by the state, with little private sector involvement.[77]

Respondents were asked to highlight AI-related R&D at their institutions. Data on these activities was provided by eight institutions. The results in the graph below (Figure 8) indicate that there was a total of 75 staff involved in AI-related R&D, while there were 279 students involved in AI-related R&D.

[72] BizCommunity. (2019). "IBM expands quantum computing program to Africa." BizCommunity.

[73] AI Research and Data Science Group. (nd). "About." Makerere University.

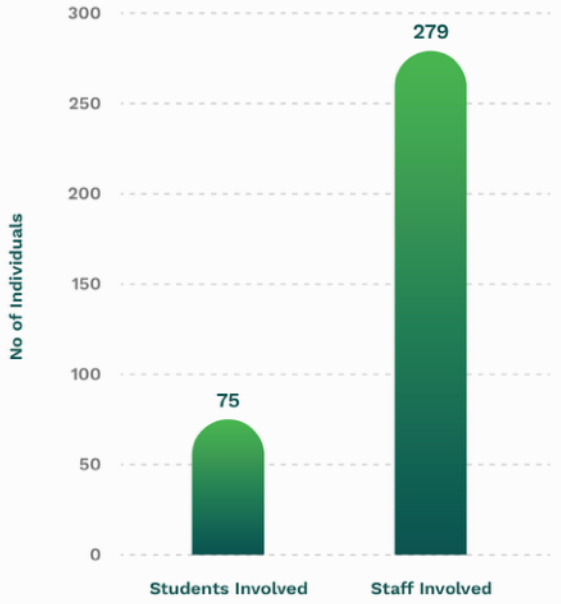
[74] Institute for Intelligent Systems. (nd). "About us." University of Johannesburg.

[75] University of Johannesburg. (nd) "Leading Africa into the Fourth Industrial Revolution to Solve Future Challenges." University of Johannesburg.

[76] The African Institute for Mathematical Sciences (AIMS). (nd). "About."

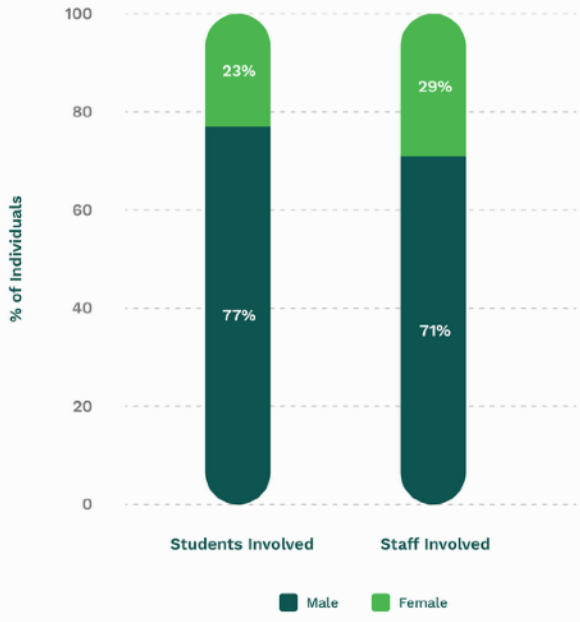
[77] Oxford Insights. (2020). "Government AI Readiness Index." Oxford Insights.

Figure 8 Number of Staff and Students Involved in AI-Related R&D



When looking at the same data in terms of gender representation (Figure 9) the data indicates that most students (71%) and staff (77%) who participated in these activities were male. This data suggests a gender imbalance in AI-related R&D.

Figure 9 Gender representation of staff and students Involved in AI-related R&D



Development

- Machine Learning for Sustainable Development (NUL);
- Data Science for Social Impact (UP);
- Monitoring air quality using AI (Makerere); and
- Robust traffic flow monitoring (Makerere).

Physics

- SKA Telescope.

Language

- Data generation and language technology for low-resourced African languages (Makerere).

Respondents also noted that postgraduate students were conducting research in several areas of interest, including:

- ML in SPAM detection;
- ML in intrusion detection systems;
- Energy research; and
- Health (including blood pressure management).

Most (83%) interview respondents indicated that AI R&D was a priority for their institution (Figure 10). However, some noted that their department or school was prioritizing it rather than their institution more broadly:

> *The university is driving the whole agenda of AI because they understand that AI will become the frontier of development. They want it to become the foundation of the institution.*

> *It's a priority for our school- we went out of our way to develop a MSc in AI and are encouraging people to carry out AI research because we think it is the future of computing.*

When considering disciplinary fields where AI research is currently in greatest demand, several respondents noted that there was significant demand in the field of Computer Science. This included reference to applications such as facial recognition and image processing, speech, banking and retail. Others said that there was notable demand in engineering, including electronic, electrical, process, mechanical. Respondents also mentioned the following fields:

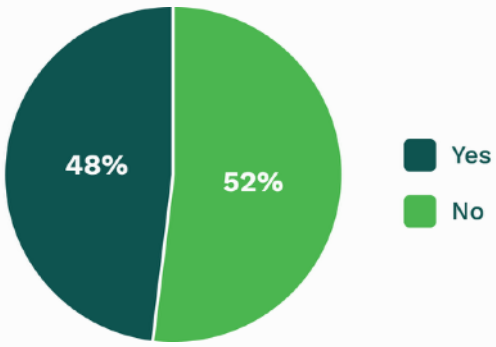
- Mathematical sciences (including statistics);
- Humanities (Language, Philosophy);
- Data science (including Bioinformatics);
- Health;
- Disaster preparedness;
- Agriculture;
- Energy (Weather forecasting, energy consumption);
- Computer vision, image recognition;
- Quantum ML;
- Remote Geographic Information System Mapping;
- Biotechnology and physics; and
- Astronomy.

One respondent indicated that there are not enough people researching natural language processing in South Africa and that language was still underexplored, while another noted that there was a lot of cross-disciplinary work at his institution, particularly with ML and other fields.

The research suggests that there is significant AI-related R&D occurring in Sub-Saharan Africa, with 83% of respondents indicating that such research was happening at their institutions. Examples of institution-specific research groups and activities are outlined in Box 3. Note that this list is not exhaustive, but it intended to demonstrate the range of R&D activities in SSA.

About half (48%) of survey respondents indicated that their institutions engaged with industry on AI-related R&D (see Figure 11). Industry engagement included university collaborations with banks, telecommunication companies, software companies and mining companies.

Figure 11 Industry Engagement on AI-related R&D



A significant proportion of industry engagement occurred through conferences, workshops and hackathons such as the Deep Learning Indaba and its satellite Indaba X events as well as IBM-supported workshops. Others noted bringing experts in to speak to students:

Sometimes we bring in people from industry to teach classes and run workshops. We do collaborative teaching and sometimes people from the industry who are working show a practical implementation of these concepts.

We have many engagements with industry. We sometimes get guest speakers or we visit industries and work on ways to engage each other in a way that is beneficial.

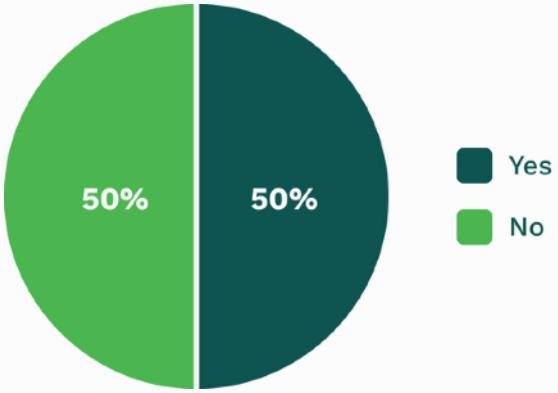
Respondents also mentioned research collaborations with industry, noting that their relationship with industry enables both parties to benefit by gaining access to research expertise and specialized datasets:

> *We have a few projects running in collaboration with industry. In applied mathematics, we're always looking for problems to solve. A lot of industry partners have access to specialised data.*
>
> *We've worked with industry, for example, on healthcare related projects. Industry engages with us on research-related problems.*

The last type of engagement that respondents noted was industry funding for AI-related activities, with one institution explaining that there were incentives for engagement with external partners from industry. This included bursaries and sponsorship for students who were involved in AI-related qualifications or research and AI-related programmes.

Half of respondents indicated that their institutions engaged with government on AI-related R&D (Figure 12). The nature of these engagements varied. In some cases, institutions were involved in research for national government departments. This included activities such as data collection and prototype validation. Other types of engagement included advising inter-governmental and government AI task forces and seeking authorisation to introduce new AI-

Figure 12 Engagement with governments for AI-related R&D



related offerings at their institutions. One respondent highlighted engagement with the Hong Kong government, but did not specify any details.

Box 3: Institution-specific research groups and activities

Robotics and Autonomous Intelligence

- The Robotics, Autonomous Intelligence and Learning (RAIL) Laboratory (Wits);
- Wits Institute of Data Science (WIDS) (Wits);
- Computational Intelligence Research Group (UP);
- Automating Robot Design for General Applications (University of Cape Town) (UCT);
- Guided Self-Organisation in Artificial Complex Systems (UCT); and
- Spatiotemporal models for Biosurveillance (Makerere).

Health and Biology

- Machine Learning for Cancer Detection (NUL);
- Nature Inspired Computing Optimisation Group (NICOG) (UP);
- Prediction of Co-infection of TB and HIV using Computational Intelligence Methodologies (UniSwa);
- An Expert System for Malaria Diagnosis Using Fuzzy Cognitive Map Engine (Best Paper Award) IEEE-IST Africa Botswana (UniSwa);
- Multi-Target Regression Prediction on Cervical Cancer for evaluation of Performance Measures (UniSwa);
- A Framework for Early differential diagnosis of tropical confusable diseases using the fuzzy cognitive map engine (UniSwa); and
- Machine learning-based detector for cervical cancer (Makerere).

Agriculture and Disaster management

- Early Warning System for Disaster Preparedness (MUST);
- Forecasting crops using drones (UWC);
- WineTech (UWC);
- Disease surveillance – mobile monitoring of crop disease (Makerere);
- Automated Malaria diagnosis (Makerere);
- Computational prediction of famine (Makerere);
- Auction design for agricultural commodity trading (Makerere); and
- A portable deep-learning-based diagnostic platform for passion fruit diseases (Makerere).

In addition to industry and government engagement, the research showed that there was also significant involvement in communities of practice outside of the higher education sector, with 64% of survey respondents indicating that they were aware of or involved in AI initiatives in their country. This included participation in key AI-related conferences and events:

- Data Science Africa;
- Deep Learning Indaba and Indaba X events;
- International conferences on AI;
- Computational Intelligence Research group;
- Open Data Durban;
- Machine Learning Community;
- South African Innovation Summit; and
- Community-level symposia.

Funding for AI-related R&D

Most interview respondents indicated that their institutions did not have special-purpose mechanisms to fund AI R&D. Many noted, however, that there were general funding mechanisms available that were not solely intended for AI-related R&D but could be used for such purposes. These included mechanisms such as research hubs, government grants, and university funds or research directorates.

Some respondents indicated that they were in the process of trying to get funding for AI-related research, with many having submitted applications to the institution where they were based or to their government. Some noted challenges that they had experienced in obtaining funding for their projects:

> *We are trying to set up a Directorate of Research, trying to get the grant writing processes, policies etc up and running. Policies to allow the establishment of research centres [have been] lacking. In a short while, we should have a framework for establishing policies in multi-disciplinary work. At the moment, everything relies on the Directorate to support any type of research.*

> *There is a centre of research that I am trying to get off the ground. But funding mechanisms are non-existent. We write proposals for funding from the university but we don't know a lot that can help with this kind of funding.*

> *...Because of the economic difficulties in the country, research is not well funded. If you are looking for funding, you need to look for private funding, so that's a huge impediment to doing research at the institution.*

Policy Environment Relevant to AI

Respondents explained that IP policies were the most significant policy influencing AI-related teaching and research at their institutions, although several indicated that their institutions' IP policies were not aimed specifically at AI. Respondents also mentioned research and ethics policies, with some explaining that these policies were in the process of being revised:

> *[The institution] is busy revamping its data research policy. It's fuzzy now. The people rewriting the policy do not understand the implications of data research so have taken a suboptimal approach to the challenges of AI research.*

> *Given the 4IR conversation, the university has been trying to consolidate their understanding of what teaching and research is going on inside the university... So the university has also caught up to that and said we need to understand what is it*

that we are actually doing in this space and how can it be used to enhance what we are doing.

Other policies or documents that respondents noted as having an influence on AI-related teaching and research included:

- Data protection and copyright policies;
- ICT policies; and
- Institutional strategic plans.

Respondents stressed that these were general policies that governed their institutions and not specific to AI teaching and research.

In considering which policies most enabled them to carry out good quality AI-related teaching and research, many respondents said that they did not know of any or were unsure. However, they did note that they did not experience any obstacles in the policy environment regarding this kind of work:

> *Currently we don't have any... Our research policies are outdated so it's a work in process. Nothing stops anyone from undertaking research of their choice, but the policies don't actively promote and support AI research and teaching.*
>
> *Not that I can think of... except we are allowed to have time for any research (e.g. sabbatical leave).*
>
> *They are fairly flexible with us starting new courses and pushing initiatives around AI. I think they are generally supportive of our research activities. I think it's generally a very supportive environment.*

One respondent mentioned a policy to enter university consortia that allows the institution to deploy cloud computing facilities and run AI work on the cloud. Another respondent noted:

> *Freedom to research and publish on any AI related topic and to attend international AI conferences to engage and discuss topics with international peers and colleagues.*

These responses suggest that, although there were no AI-specific policies at these institutions, respondents derived value from existing general policies at their institutions.

In considering policies that least benefitted their ability to carry out good quality AI-related teaching and research, most respondents indicated that there were none or they could not think of any. A few responses pointed to a dearth of policies related to data management. One respondent noted that the institution's research data management policy was not clear about restrictions for data, including institutional data. Another explained, with regard to IP policies:

I found that some students do have a bit of an issue with the IP policies. It's also a delicate issue if we're working with industry and it's sensitive data. Then there's usually a negotiation process between the university and the company who gets the IP.

Respondents also mentioned the following policy-related issues at their institutions as having an impact on their ability to carry out AI-related teaching and research:

- A lack of dedicated funding (and associated policies);
- Workload and having to deal with a high volume of students; and
- Having too many part-time students as opposed to full-time students, which affects research output.

Five institutions indicated that some focus or mention of AI was explicitly included in their institutional strategic plan or strategic direction. This included UCT, which has formed a 4IR 'think-tank' to do strategic planning, in which AI is included as an important focal point for

future teaching and research.[78] Another example is UKZN, which has introduced four flagship programmes as part of its strategic direction, one of which is a Big Data and Informatics programme.[79]

Overall, respondents' responses suggested that there was a lack of policies informing AI-related teaching and research. Several respondents appeared to be unfamiliar with the policy environment as it related to AI teaching and research, pointing to a lack of awareness of key policies.

Growth of AI in SSA and Capacity Building Needs

HolonIQ identifies four global drivers of education in a report that explores education in 2030. These are: Globalisation and Economic Growth; Population Growth; Future of Work and Skills; and Advancements in Technology. The report sets out five scenarios for the future of learning and talent. The fifth and most advanced of these scenarios is called 'Robo Revolution', where AI drives a role reversal in who leads learning. In this scenario, virtual tutors and mentors structure learning paths, provide assessment tasks and feedback, and adjust according to individual progress. The report predicts that by 2030, Africa will deliver an estimated 90 million more primary-educated and 190 million more secondary-educated people. Moreover, the report notes that six national economies constitute 80% of the world's demand for education, one of these being Nigeria.[80]

Many have argued that AI has the potential to contribute significantly to education systems as we know them, particularly in contexts where education scalability depends on being able to reach rural areas and overcome resource deficits. As a report by Smith, Neupane, Leonard and Mendonca notes:

> *The promise of AI in education is substantial, as it can help move offerings beyond an industrial, one-size-fits-all delivery model that hasn't substantially changed in a century. In effect, AI techniques can be used to support (and perhaps at times substitute) the roles of teachers, tutors, and administrators to improve the teaching and learning process and make it student-centred and individualized – a core advancement required for transforming education (Winthrop and McGivney 2017). In particular, AI techniques can provide quality personalized learning opportunities at scale and can facilitate the creation of quality content.*[81]

AI can influence education in multiple ways, including making admissions processes smoother, increasing student retention and supporting students more effectively. It can be harnessed to improve student outcomes, and in so doing, provide these institutions with the ability to anticipate enrolment trends, optimise recruitment efforts, and elevate academic performance.[82] There are various potential applications of AI within the higher education landscape. Zeide (2019) outlines three key areas:

- **Institutional**: Including marketing and recruiting; admissions and enrolment; and curriculum and resource planning;
- **Student Support**: Including guidance; financial aid; and early warning and
- **Instructional**: Including self-paced progress; individualised learning; and pedagogical improvement.[83]

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[78] See Phakeng, M. (2018). "Futures Think Tank to be established." University of Cape Town Campus Communication.

[79] See University of KwaZulu-Natal. (2017). "Strategic Plan 2017-2021." University of KwaZulu-Natal.

[80] HolonIQ. (2019). "Education in 2030." HolonIQ.

[81] Smith, M.L., Neupane, S., Leonard, G. and Mendonca, C. (2018). "Artificial Intelligence and Human Development: Towards a research agenda." IDRC.

[82] Wiley Education Services. (nd). "5 Ways Artificial Intelligence May Influence Higher Education Admissions & Retention." Wiley Education Services.

[83] Zeide, E. (2019). "Artificial Intelligence in Higher Education: Applications, Promise and Perils, and Ethical Questions." EDUcause Review.

AI thus holds the potential to significantly improve educational processes at Centres of Higher Education and Training in SSA. It could be used to automate simple activities like grading, which would free up time for teachers to perform more important tasks such as interacting with students, preparing for class, or working on professional development. Similarly, AI is increasingly able to support students through learning analytics – the measurement, collection, analysis and reporting of data about learners, their contexts, how learners engage with learning materials and other support resources – which can optimise learning and the environments in which it occurs.[84] Through learning analytics, institutions can monitor student progress, drop-out rates (which are high across the African continent, as in many other regions), and provide feedback to teachers on how effective courses are. This could allow educational institutions to develop student talent in SSA more efficiently.[85] AI also offers the capacity for further student support through intelligent tutoring systems and can enable individualised learning plans based on each students' strengths and weaknesses.[86] AI algorithms could also allow educational institutions to derive maximum utility from educational resources. With assistance from student data and educator feedback, institutions could predict a career paths for students, as well as their likelihood of success in individual subjects.[87]

However, the current reality is that AI only offers this *potential* in SSA – not actual systems that are able to perform all of these functions. And even if these systems did exist, budget constraints, current capacity in Centres of Higher Education and Training, and a shortage of required skills sets across primary, secondary and tertiary institutions in many parts of SSA would limit access to these systems and prevent many teachers and students from benefitting from them.[88] The survey and interview results speak to these prevailing issues, whilst highlighting current and future efforts for building AI institutional capacities.

Most interview respondents indicated that their institutions had specific plans to expand their focus on AI. Respondents noted current plans to offer more AI-related courses and programmes at both the undergraduate and postgraduate levels. In terms of new degree offerings, respondents noted plans to roll out degrees that included:

- BSc in Ed Informatics;
- BSc in Data Science, one focusing on Engineering and the other on Computer Science and Statistics;
- MSc Computer Science;
- MSc in Artificial Intelligence;
- MSc in Robotics;
- MSc in Machine Learning; and
- Postgraduate Data Science Programme.

Some indicated that it was their department and not the institution at large that was pursuing these activities:

> *Not the institution but rather the computer science department – Undergraduate and honours level course offerings in AI will be expanded from 2020.*
>
> *We have plans to expand in the future, but that's a departmental plan. We are hoping to float undergraduate programmes in the near future and I think AI will be one of them. We hope to have an AI degree.*

Other plans that respondents highlighted included the following:

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[84] Siemens, G. (2010). "First International Conference on Learning Analytics and Knowledge." Athabasca University.

[85] Access Partnership, Microsoft and University of Pretoria. (2018). "Artificial Intelligence for Africa: An Opportunity for Growth, Development, and Democratisation." University of Pretoria.

[86] Mathieson, S.A. (nd). "Reinventing higher education: 'Can we use AI to give the lecturer superpowers?'." The Guardian.

[87] Ndemo, B. (2019). "Can Artificial Intelligence disrupt education?" Business Daily.

[88] Access Partnership, Microsoft and University of Pretoria. (2018). "Artificial Intelligence for Africa: An Opportunity for Growth, Development, and Democratisation." University of Pretoria.

We are starting a Health Data Analytics in 2021 – an online programme focussing on the health sector in terms of the United Nations Sustainable Development Goal 3. We also get funding from the German government.

The [university] Director is in talks with some partners to collaborate with companies like IBM to offer short courses and practical experience in these companies. The benefit is that we are teaching in both English and French, which can reach a wider audience.

Respondents also indicated that their institutions were planning on adding AI-related aspects to existing degrees or courses rather than creating standalone degrees. One respondent reported that AI would be increasingly offered within contexts of existing degrees such as computer science, physics and life sciences because a course on AI is somewhat narrow without a given context. Other comments included the following:

We're actually focusing more on starting modules and units to add to the existing programmes to make them more well-rounded. We have topics on parallel computing, computer vision, reinforcement learning courses. They are ridiculously popular. We just started the course on reinforcement learning. We went from 20 interested students at the beginning and three weeks later we have about 50.

We have been advertising for members in AI and are reviewing some of our courses to ensure they have AI-related subjects. This includes image processing, Machine Learning, Robotics and Natural Language Processing. We have created units for our MSc in AI (the content is written). The content for the MSc in AI was developed some time back.

We are changing curricula in Honours degrees to align with new concepts like Machine Learning.

There have been talks of trying to integrate AI into the curriculum, but not much talk on introducing a standalone qualification. People have been discussing offering specialisations in the Bachelors and Masters. In the Masters, there are currently courses that touch on Machine Learning and AI and one can choose to do research for their thesis in AI. We are looking more into making it a specialisation where someone can do courses that are totally related to ML and AI. We want to do the same thing for the Bachelors.

Respondents suggested several fields that would experience growth in demand for AI teaching over the next five years. The most prominent of these was Engineering (including Robotics) and Health Science, followed by Commerce (including banking) and agriculture. Other disciplines that respondents noted were:

- Education (including Ed Informatics);
- Mathematics;
- Agriculture;
- Natural and Life Science (including Bioinformatics);
- Computer Science;
- Energy;
- Social sciences (Philosophy, linguistics);
- Ethics;
- Applied data science (image recognition, computer vision, mining, insurance, disaster management);
- Theoretical components of AI; and
- Music.

Respondents' comments regarding these areas included the following:

I believe Social Sciences is going to see a lot of growth in ML- especially from an African perspective. These are the people with the right knowledge about the problems and how they can be solved. Also, in Computer Science, there is a need for

the tools and applications that support the use of ML and AI so I foresee a huge growth in Computer Science.

Health and agriculture- this has been informed by the direction our government is taking- with a lot of focus on food security and agriculture. There is some work that our faculty has been doing on maize farming because in Kenya, we rely mostly on food- if someone is able to find an application to help farmers, that will reach a lot of people.

In terms of research there are several activities occurring across the continent. For example, UP has plans to establish a Centre for Data Science and to re-establish its Computational Intelligence Chair. MUST is opening a research laboratory for AI in 2020 while Stellenbosch University is looking to increase its activities in its newly formed School of Data Science. UNH will be conducting activities through a Data Science Research Cluster, while UWC has set up an eResearch Office. JKUAT is in the process of setting up an Innovation Centre for Computing and Technological Solutions.

Respondents identified several fields that would likely experience growth in demand for AI research over the next five years. Health was the most frequently mentioned, followed by Computer Science (and, within this, Natural Language Processing and Computer Vision). Other areas where respondents suggested that AI research might grow were:

- Agriculture;
- Telecommunications;
- Education;
- Banking;
- Machine Learning and Deep Learning;
- Physics;
- Mathematics and Statistics;
- Natural and Life Sciences, including Genetics;
- Engineering, including Robotics; and
- Social Sciences.

Some brought into question the social implications of AI research in the region, explaining that it was important to take into account the ethical considerations of AI R&D in SSA. Others noted that they were struggling to meet the wide-ranging interests of students:

I think for us the question will be on how we apply it... There is a lot that the tech can do, but how are we deploying it in our setting? That is the question for us. AI4D might be the bigger question for us. This also brings up the ethical issues, which we are discussing. One of the events that [my colleague] highlighted also asks what are the implications on ethics and how do we reskill people to do other things (especially amongst the youth, who are driving 4IR)? We have a national taskforce on 4IR.

Pretty much the same. I think we're struggling to take up all the interest we get from students.

Respondents also noted plans to build AI capacity at their institutions:

We have quite a few new degree programmes in the pipeline... As a university, we are also looking to better serve our continent in terms of research, teaching and innovation.

I think the growth might be at the college level- building research and building capacity in the colleges, growing research and teaching at the AI lab.

We have plans but we also have capacity problems. Attracting academics in this area is a challenge. We are collaborating with other universities to fast-track capacity building. [We are] holding workshops.

We are working with the Department of Statistics and Department of Mathematics- I hope in the future, we are looking to work with the Department of Engineering so we can have some implementation. We organize workshops together and teach on the importance of AI technologies.

Areas for AI capacity-building are outlined below, together with explanations that interview respondents provided.

AI Researchers and Experts

Several respondents pointed out that their institutions were lacking researcher capacity and AI experts. Key issues that they highlighted included time constraints in balancing teaching and research duties, needing more capacity to take in larger numbers of postgraduate students, and requiring a greater number of AI experts. A sampling of these comments is included below:

We have some interesting research going on and we need to support our graduate students. We would love to establish an AI-focused research centre.

Not enough capacity to teach, to do research. I'm pretty sure you won't find an AI-related research group in South Africa that has more than ten PhD students sitting in a lab full-time.

We don't have someone who has a higher degree in AI. Most of us have degrees in Computer Science but in the course of our studies, we did some courses in AI. If we can get one or two experts who specialised in AI at Masters level, it will move the department forward.

There is big need for that. We are already struggling to fill positions like that and I think a big problem is we are competing with an industry that is really looking for good people. Difficult for us to convince people to stay in academia instead of going into industry and earning good money.

Academic Teachers

With regard to the need for academic teachers, key issues that respondents noted were to introduce more courses at the undergraduate level (and therefore teaching capacity), supervisors for graduate students during their course and research work, and lecturers who can teach at the cutting edge. Other comments included the following:

My experience is that the current UG curricula are not equipping students to jump into our programme- there's a huge learning curve... It's possible that there is existing capacity, but not enough.

We need them but we don't have them- we have the money to find a person but the people are not there. If the skills are scarce, the price goes up for their salary.

AI is broad and we handle it in pieces often, it would be ideal if we had capacity for all these different fields.

The current academic staff are spread very thinly with the large number of courses offered at the moment.

We had wished to roll out a few courses, but there are always issues of capacity in terms of staffing. It's always an issue, and getting the right people is an issue as well. So we need to think about whether the industry needs it or not [we want to be responsive to the needs of the industry].

Laboratory Staff (technicians)

Many respondents indicated that their institutions had enough laboratory staff, with some noting that there are more centralized IT departments that undertake data-centric tasks which, in the past, may have been assigned to laboratory staff. Others noted that these services could be outsourced to companies such as Amazon Web Services. However, some respondents indicated that they would need technical assistance with computing cluster hardware, as well as operating live laboratories, demo laboratories, and virtual environments.

Physical Infrastructure

Respondents identified a need for the following physical infrastructure at their institutions:

- Robots;
- Laboratories (with equipment for simulation and implementation);
- Physical storage; and
- Small data centres that can run workloads at university level and a multiuser system.

ICT Infrastructure

Respondents noted that in order to build capacity, their institutions required the following ICT infrastructure:

- High Performance Computing (HPC) Clusters;
- Servers;
- Graphics Processing Units (GPUs);
- Tensor Processing Units (TPUs);
- Batteries;
- Stable Internet connection;
- Faster computers, including machines that can do work in ML or image processing;
- Cameras;
- Power backups; and
- Printers.

One respondent emphasized the need for in-house infrastructure to respond to researchers' needs:

> *One can do some work with commercial cloud technology but we also need to develop in-house infrastructure to develop AI tools for research. Workflows can be run on tech provided by Google etc; but there is a need for inhouse infrastructure to be more flexible to respond to needs of researchers more promptly.*

IT Support Staff

Respondents indicated that they need graduate assistants to help with maintaining laboratories, GPUs, and software installations. Other comments included:

> *We are often forced to be self-sufficient – the university does have an IT support unit, but they are always lagging behind. So that is a huge gap... It's why we're looking into alternatives like cloud computing.*

> *Many universities have outsourced to organisations and don't have enough skills in-house. So when you want to use a technology that uses a network, they need the skills...*

Institutional Policy to Support AI

Several respondents indicated that their institutions did not need institutional policies to support AI, indicating that current policies were sufficient. Those who were in favour of

developing such policies noted the need for an institutional policy or policies that contained the following regarding AI teaching and research:

-
- Efficient resource allocation;
- Setting out AI priority areas;
- Clearer guidelines on data use and protection;
- Ethical considerations;
- Engagements across faculties and departments;
- Providing academics the space to experiment without being subject to cost-cutting (incentive systems across disciplines, where you are not penalised for not doing 'pure' work in the field); and
- Importance of AI in Computer Science education (and modern society generally).

Collaborations with Other Organisations

Respondents were open to the idea of increased collaboration with other organisations, including other national and international academic institutions, for teaching and research collaborations, as well as funding partners and industry partners to offer students internships and mentorship opportunities:

> *We seriously need this and we are always open to collaboration. We need to collaborate with industry and many European universities and South African universities.*

> *This is why we have initiated collaborations with industry. We need collaborations with local and international like-minded institutions and research institutions.*

Fundraising

Most respondents indicated that their institutions were in need of funding capacity for AI activities. This included funding for research grants, finances, equipment, and travel. Some of their comments are included below:

> *As far as I'm concerned, the number one thing we would need is funding for students from all over Africa (Deep Learning Indaba showed me that there is a lot of willingness and talent). I think also the way the South African government views bursaries is that it's almost impossible for non-South Africans to get funding.*

> *When we are trying to apply for Data, to get ethical clearance, we need to pay money. When we are brainstorming, we need to have tea and coffee when we have meetings. Sometimes our personal laptops do not have the capacity to do simulations so we may need to get laptops to run the simulations overnight. We don't really have the resources to run huge datasets. When you are doing research, you need to go to conferences to present findings – [there is] not currently much funding for conferences.*

> *The students are not there in terms of the kinds of students that we want to do coding etc. We are going to schools and helping teachers to teach science subjects. We are also looking for funding from other organisations to build more capacity to develop skills at matric.*

Additional Capacity Building Needs

Respondents noted several additional capacity building needs, outlined below:

- Equal incentives to write for both national and international journals;
- Support for interdisciplinary research;
- Short training opportunities for students and staff;
- Technical officers – such as lab technicians/research engineers; and
- More Ph.D. students.

Looking ahead, the higher education sector needs to play a pivotal role in nurturing AI capacity on the continent, but there is still a lot of work to be done for Centres of Higher Education and Training to take up this role. In considering the actions that academia might take to improve AI capacity, a report by Hu, Neupane, Echaiz, Sibal, and Lam highlights the implications for AI and other advanced ICTs on human rights; knowledge; access; governance; and gender. The authors then provide options for action for various stakeholders. For academia, they provide the following options for action:

1. **Human Rights**: Academia could engage in rights-oriented research on the social, economic and political effects of AI content personalisation, including the consequences of online "echo chambers".[89]
2. **Openness in AI**: Academia could support the development of open data standards (while safeguarding privacy) and could ensure interoperability between different data sets while strengthening data commons and the availability of data for machine learning.
3. **Inclusive access for AI Development**: Academia could improve access to AI algorithms for learning through the creation of research repositories and by offering online education for AI.
4. **Multi-stakeholder Approach**: Civil society and Academia could conduct research to support the institutionalisation and sustainability of multi-stakeholder governance experiences.[90]

There are promising signs of AI ecosystem growth in the region. A recent mapping of emerging AI hotspots in African countries found a total of 149 players in SSA, 111 of which were from academia.[91] Strikingly however, the majority of available literature relating to AI in SSA higher education refers to Africa's digital economy and harnessing AI in the future tense, with relatively little documenting work already underway. A limited amount of information is available regarding the current context and much of the in-depth study on AI advancement is Western-centric. So, while the prospect of such widespread improvements to higher education is exciting, it remains a matter of conjecture. Those who attest to the transformational power of AI often work in AI or related fields, increasing the likelihood of biases. The reality is that SSA, with the exception of a few well-funded institutions, currently lags behind in basic infrastructure at Centres of Higher Education and Training. Access to new technologies is limited due to constraints including limited funding, outmoded infrastructure, outdated systems and underqualified personnel.[92] Furthermore, a sector that tends to exclude African voices is likely to further undermine the progress of AI in SSA higher education. Significant support is therefore required to sustain institutional efforts to improve the technological standing of SSA's Centres of Higher Education and Training.

This section has explored how AI could assist institutional practices at Centres of Higher Education and Training. It has also offered insight into how institutions in SSA are preparing students for a world where AI is prevalent. The key message here is that access to new technologies is limited in SSA due to several constraints. Moving forward, this means that the digital divide can either be entrenched or diminished in Centres of Higher Education and Training. To avoid entrenching the digital divide there will need to be a global drive to empower SSA Centres of Higher Education through mechanisms such as partnerships (between global educational institutions, the private sector, and governments); funding support; and sharing of technical expertise. Building on the findings from this section, the following section examines the AI community.

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[89] An environment where individuals are only exposed to information or opinions that reflect and reinforce their own

[90] Hu, X., B. Neupane, L.F. Echaiz, P. Sibal, and M.R. Lam. (2019). "Steering AI and Advanced ICTs for Knowledge Societies." UNESCO.

[91] Knowledge for All Foundation. (2020). "Global South map of emerging areas in Artificial Intelligence." Knowledge for All Foundation.

[92] UNESCO. (2019). "The challenges and opportunities of Artificial Intelligence in education." UNESCO.

The AI Community

The AI Community in SSA consists of multiple players. These include developers, data scientists, entrepreneurs, SMEs, Centres of Higher Education and Training, venture capitalists, researchers, manufacturers, service providers and big business. These stakeholders operate in several sectors, seeing as AI and ML have various market applications and potential uses in a number of different sectors. Some examples are outlined below:

- **Agriculture**: plant breeding to speed varietal selection; automatic plant management; identifying biological anomalies; spatial planning and analysing soil and weather conditions for precision-farming.
- **Industry**: Developing sophisticated ML algorithms to interpret and explore data; fleet management.
- **Modernised services**: credit scoring using non-standard data; driverless cars; recruitment, talent matching, HR management.
- **Health**: Chatbots replacing primary healthcare providers and improving diagnostics; health trend analysis; disease outbreak predictions.
- **Education**: Increasing the efficiency of educational programmes.
- **City Planning**: Optimising transport in cities.[93]

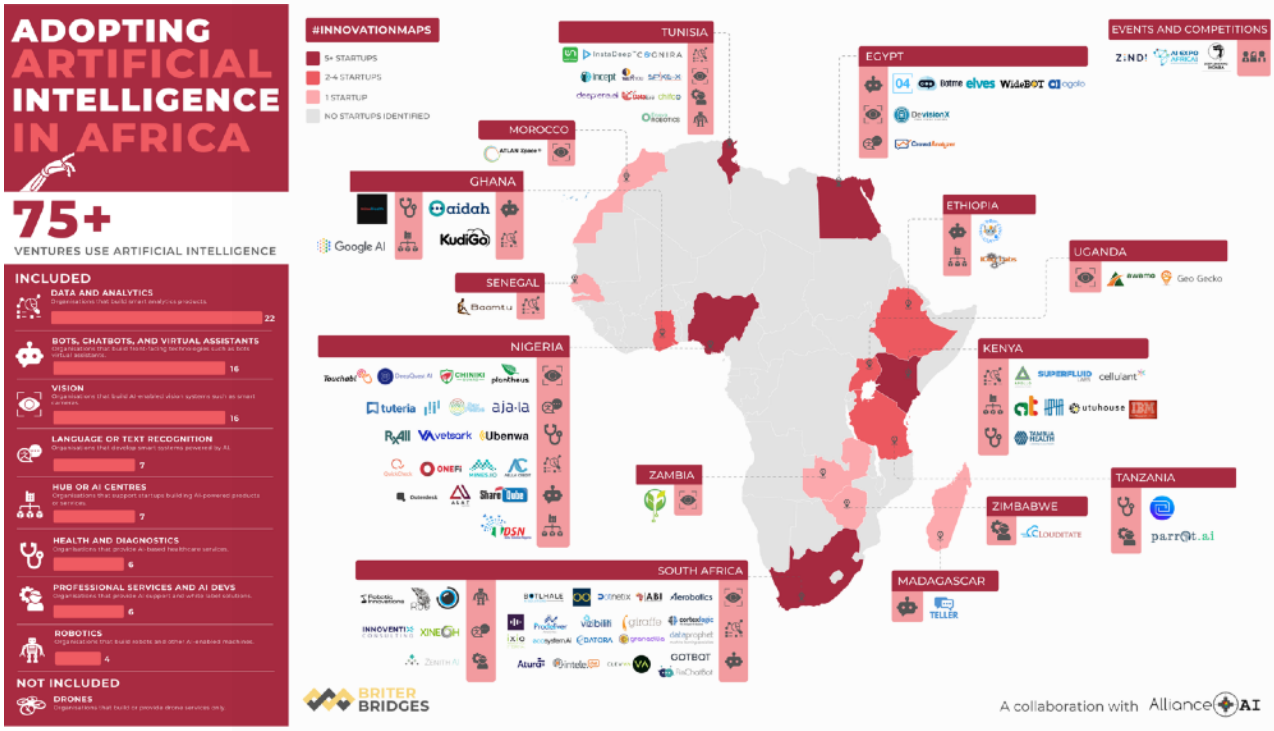
SMEs and individual developers are fast gaining momentum in SSA. AI is already being used to solve local problems from smart farming in Nigeria to sexual and reproductive health monitoring in Kenya. However, it remains to be seen whether AI tools are adopted by these groups and incorporated into, for example, start-up companies, locally developed open-source tools, and educational uses.[94]

The figure below provides an indication of companies using AI, ML and Deep Learning.

[93] Technopolis & Research ICT Africa & Tambourine Innovation Ventures. (2019). "Potential of the fourth industrial revolution in Africa: Study report. African Development Bank." African Development Bank.

[94] Oxford Insights. (2019). "Artificial Intelligence Government Readiness Index." Oxford Insights.

Figure 13 Companies using AI, ML and Deep Learning (Q3 2019)[95]



Source: Briter Bridges

Existing AI Capacity in the AI Community

Industry serves as the main developer of AI-related technologies and as such, nurturing innovation within industry is key to creating a robust AI community. Africa has created the conditions for several very promising AI start-ups, which are assisting governments, universities, and industries through their AI technologies.[96] As UNESCO notes:

> *AI-powered services have already become prevalent in human lives in many places, including the least developed countries. For instance, bots in Kenya now give answers to questions about reproductive health in a safe and confidential way, thus dispensing with a visit to the doctor's office. The bots rely on AI technology to process and reply to questions concerning sexual and reproductive health securely and confidentially. Several AI applications have also emerged in the agriculture sector across several African countries. In Kenya, Vital Signs collects and integrates data on Agriculture, Ecosystems and Human Well-Being. It uses satellite imagery data to estimate rainfall and drought patterns. In Nigeria, Zenvus is a data-driven platform that provides farmers with insights based on data collected from sensors and other means. Their mission is to eliminate poverty in developing countries by improving overall farming productivity.*[97]

In 2019 there were approximately 6,500 technology start-ups in Africa, about 10% of which were focused on 4IR technologies including AI, Big Data and IoT. Africa's AI sector received an estimated $17.5 million in government and private sector investments in the same year.[98] However, investments being made in Africa as of 2019 were skewed towards the financial

[95] BriterBridges. (2019). "Adopting Artificial Intelligence in Africa: Map of Companies using AI, ML and Deep Learning (Q3 2019)."

[96] Access Partnership, Microsoft and University of Pretoria. (2018). "Artificial Intelligence for Africa: An Opportunity for Growth, Development, and Democratisation." University of Pretoria.

[97] Pedró, F., Subosa, M., Rivas, A. and Valverde, P. (2019). "Artificial Intelligence in Education: Challenges and Opportunities for Sustainable Development." UNESCO.

[98] Oxford Insights. (2020). "Government AI Readiness Index." Oxford Insights.

technology sector. Nigeria has now surpassed South Africa and Kenya in start-up investments. In November 2019, Visa paid $200 million for a 20% stake in Nigerian payments processor, Interswitch. China has also shown interest in two promising Nigerian payments companies – OPay and PalmPay – which received a collective $210 million from Chinese investors.[99]

Smaller initiatives have also made valuable inroads into preparing their countries for different implications associated with AI. This includes #iamthecode, which teaches women and girls in Africa how to code through Science, Technology, Engineering, Arts, Mathematics and Design (STEAMD). Their aim is to reach one million females by 2030. In addition, the NGO Their World in partnership with Kano, Codeacademy, and Africa Gathering have set up Code Clubs to teach females between the ages of five and 24 in Kenya, Uganda and Senegal. These initiatives play a critical role in levelling out gender imbalances in AI and related fields, but widespread government investment is also required to break down barriers for marginalised groups and make AI a success at scale in SSA countries.[100]

Below are examples of just a few of the most innovative initiatives in the sector. They stem from a diverse set of countries in SSA and solve varying local problems.

Daptio is a South African solution that uses deep analytics and provides personalised learning to teachers, students and content creators in Africa and other emerging markets through its online software service. Founded in 2013 and based in Cape Town, Daptio uses AI to help students, mentors and teachers to understand the proficiency level of each student and then match the relevant content.

Based in Madagascar, SmartOne is a data annotation service that provides high quality and high scale human-in-the-loop data to feed AI and ML projects.[101]

Diagnostify, an app invented in Ghana, uses AI to provide skincare solutions to patients who suffer from skin diseases. It assists users in diagnosing skin conditions.[102]

Launched in Kenya in 2016, M-Shule is an adaptive mobile learning management platform that is designed to improve academic performance for millions of primary school students in Kenya and other parts of SSA.[103]The platform contains lessons based on national curriculum standards delivered via SMS that vary according to each student's skills and abilities. As students use the platform, M-Shule uses AI to track and analyse student performance, providing insights from this data and recommendations to parents and schools.[104] The platform helps young children learn spelling at their own pace by listening to the child's speech and replaying the correct pronunciation, until the child pronounces it correctly.[105]

Box 4: iMlango, Kenya

The educational technology programme, iMlango is based in Kenya and was established by a partnership between public and private sector organisations. Schools measure daily attendance using sQuid's digital attendance system. This allows schools to easily track and monitor attendance, produce real-time data reporting and receive high reliability and insight into complex student data patterns. The system uses advanced analytics to track and report on class and school attendance. In turn, teachers and a field them use this information to identify low-attending learners. sQuid's interactive learning platform provides learning content in multiple formats for both learners and teachers. Learners can access Maths Whizz, the personalised virtual mathematics tutor that tailors learning experiences depending on a learner's ability, and other content such as Africa-focused stories, the world's first children's encyclopaedia, and curriculum-aligned revision guides.

Source: UNESCO. (2019). Artificial Intelligence in Education: Challenges and Opportunities for Sustainable Development. Retrieved from https://unesdoc.unesco.org/ark:/48223/pf0000366994

[99] Kazeem, Y. (2020). "Startup funding in Africa broke more records in 2019." Quartz Africa.

[100] World Wide Web Foundation. (2017). "Artificial Intelligence: The Road Ahead in Low and Middle Income Countries." World Wide Web Foundation.

[101] SmartOne. (2020). "About."

[102] Diagnostify. (2020). "About us."

[103] M-Shule. (2020). "About us."

[104] Pedró, F., Subosa, M., Rivas, A. and Valverde, P. (2019). "Artificial Intelligence in Education: Challenges and Opportunities for Sustainable Development." UNESCO.

[105] UNESCO. (2019). "Human Learning in the Digital Era." UNESCO.

The Cortex Group is 'a smart technology company using various AI and related technologies in delivering licensed products and bespoke, end-to-end AI-driven solutions that help businesses gain a competitive advantage.'[106] The Group consists of five brands, each focusing on a different part of the AI ecosystem namely; Asset Management, Health, AI Products, AI focused VC Investments and a collaborative lab of AI powered platform businesses that they have partnered with or invested in.

Botter, is a bot creation platform that allows users to create courses, track students' progress, message students and train their chatbots. Based in Ethiopia, the first bot built on this platform was LangBot, which facilitates the creation of AI-powered educational chatbots for schools and teachers.[107]

iCog Labs, based in Addis Ababa Ethiopia, is a research and development company that collaborates with international AI research groups. The Lab specializes in AI, including ML based data analysis, computational linguistics, computer vision, mobile robots and cognitive robotics, cognitive architectures and artificial general intelligence.[108] Other labs are gaining prominence in Ethiopia, creating more opportunities for AI developers to develop, test and incubate ideas for products and services that address community needs. For example, EthioCloud15 allows AI developers to work in Ethiopia's native Amharic language, producing advanced Amharic programming code. Ethiopia also has hubs involved in AI-related activities, including iceaddis16 and blueMoon. However, investment backing is not readily available, as Global Information Society Watch notes:

> *All these developments in the AI sector are met with what has been described as a minimal interest in investing in innovative ideas by the Ethiopian private sector. The young innovators complain that local investors would prefer to build an asset than invest in innovation.*[109]

Twiga Foods is a startup that works with IBM and uses AI, Big Data, and Blockchain to create a credit score for women who apply for unsecured loans for their micro-enterprises. Through AI, Twiga Foods is able to empower women who ordinarily would not have had access to funding for their businesses.[110]

Nigerian startup Aajoh uses AI to diagnose medical conditions. Users send a list of their symptoms to the Aajoh platform via text, audio and photographs.[111]

Enterprises are starting to adopt AI in their day-to-day business operations. For example, Awamo, a Ugandan company, is a digital banking platform and credit bureau that uses AI to reduce fraud when signing up customers and businesses to its platform. The platform helps digitise business procedures, credit information sharing, and many other services using mobile devices.[112]

Large corporates are also employing AI in varied ways. Applications include anything from banking and lending to eCommerce and agriculture. In South Africa, nearly half (46%) of companies indicate that they are already actively piloting AI within their organisations in different ways, including Chatbots, Robotic Process Automation and Advanced Analytics.[113] Discovery Health, a South African insurer, is pioneering a new business model by combining AI with behavioural health interventions to focus on prevention, disease management, and wellness. The company tracks diet and fitness activity and incentivises healthy behaviour with

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[106] Cortex Group. (nd). "Homepage."

[107] Botter. (2020). "Story."

[108] iCog Labs. (2020). "About us."

[109] Global Information Society Watch. (2019). "Artificial intelligence: Human rights, social justice and development." GISWatch.

[110] UNESCO. (2019). "Human Learning in the Digital Era." UNESCO.

[111] Aajoh. (2020). "Homepage."

[112] GSMA. (2019). "The Mobile Economy: Sub-Saharan Africa 2019."

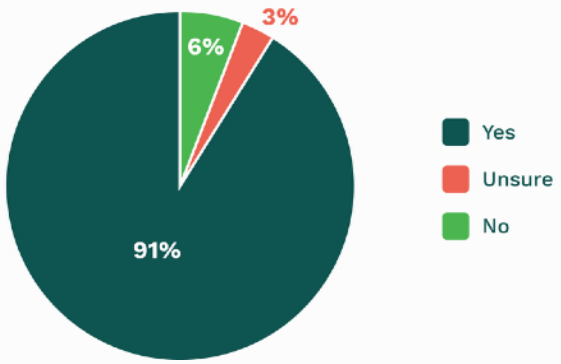
[113] BusinessTech Staff Writer. (2019). "How AI is being used in South Africa." BusinessTech.

the intention of addressing unhealthy behaviours before people become ill as a result of their lifestyle.[114]

The Kenya-based payments company Cellulant partnered with Facebook in 2018 to develop an augmented reality-powered eCommerce feature. Similar to features like Snapchat filters, it allows shoppers to try out items to decide whether or not to buy them.[115]

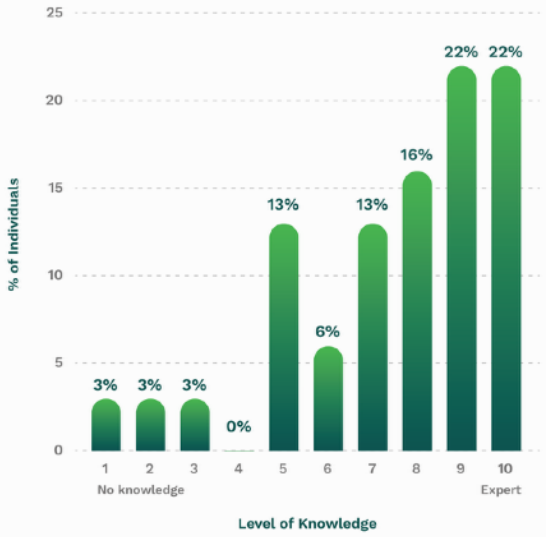
Kudi.ai allows users to improve the process of money transfers through natural languages and AI. Based in Nigeria, the company makes peer-to-peer payments easier using a chatbot that works on popular messaging apps.[116] In addition to money transfer, Kudi.ai offers several other payment products including airtime, TV subscriptions, electricity bills and data subscriptions.[117]

Figure 14 Respondents Working in AI or an AI-related Field



Most respondents (91%) to the AI Community survey were working in AI or an AI-related field at the time of the research (Figure 14). Respondents were asked to provide a rating of their knowledge of AI and related concepts – the scale ranged from 1 (no knowledge) to 10 (expert)

Figure 15 How would you rate your knowledge of AI and related



[114] McKinsey Global Institute. (2017). "Artificial Intelligence: The next digital frontier?" McKinsey and Company.

[115] Idris, A. (2020). "Artificial Intelligence: how are the smartest African companies using it?" Techcabal.

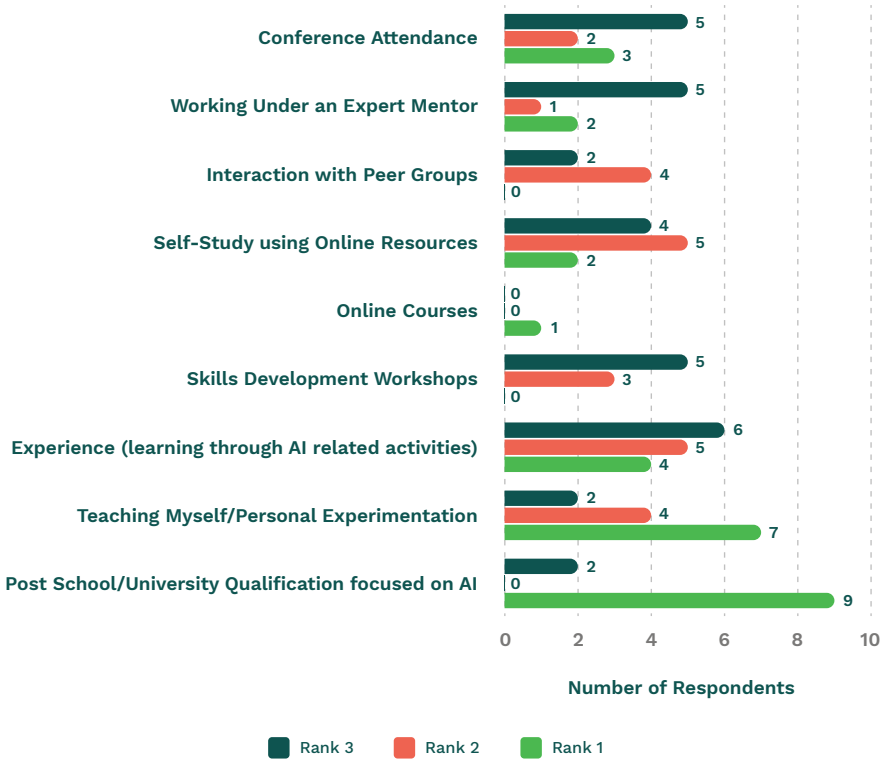
[116] Pedró, F., Subosa, M., Rivas, A. and Valverde, P. (2019). "Artificial Intelligence in Education: Challenges and Opportunities for Sustainable Development." UNESCO.

[117] Kudi.ai. (nd). "Homepage."

(Figure 15). The average rating that respondents provided was 7. The two scores that were provided most often were 9 (22% of respondents) and 10 (22% of respondents). This indicates that most respondents were familiar with AI and related concepts.

Respondents were asked to rank the top three methods and strategies they found most useful in developing their own AI expertise. These rankings are outlined in the graph below (Figure 16).

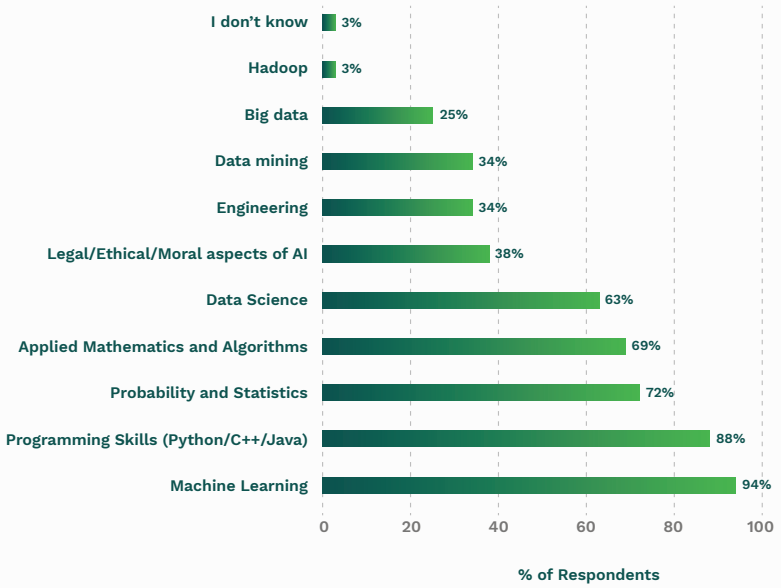
Figure 16 Most useful methods/strategies in developing own AI expertise



Respondents ranked post-school or university qualifications focused on AI as the most useful method or strategy (nine respondents). This was followed closely by self-learning and experimentation (seven) and then learning through experience (four). Overall, respondents found formal education, experience and teaching oneself to be the most beneficial ways of developing their AI expertise.

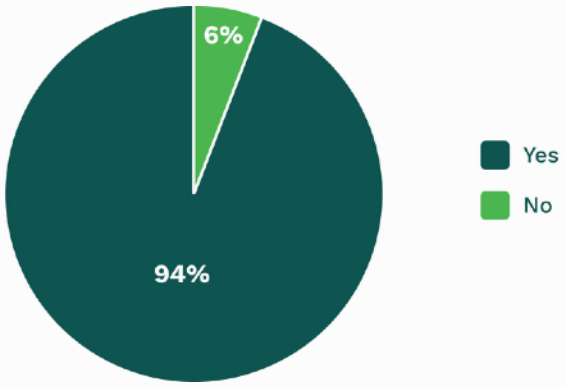
Based on their experience, respondents indicated what skills are needed to develop AI activities in their countries, as illustrated in Figure 17. A total of 94% of respondents noted that ML was one of the most important skills required to develop AI activities. This was followed by programming skills (88%) and probability and statistics (72%). The skills that respondents thought were least required in their countries were Hadoop (3%) and Big data skills (25%).

Figure 17 Respondents' experiences of what skills are needed to develop AI activities in their country



Most respondents (94%) indicated that their organisations were currently involved in AI-related activities. The other 6% were involved in AI in their personal capacity. Many were involved in creating AI-related products and services in various industries including agriculture, automotive, energy, manufacturing, and health (disease prevention). To do this, they were deploying technologies and techniques such as computer vision, natural language processing, supervised deep learning, RL, unsupervised techniques and recommendation systems.

Figure 18 Involvement in AI activities



Some respondents were involved in AI-related research, which included research in ML, robotics, and AI. This involved researching how AI could be applied to e-Agriculture, Education, and Natural Language Processing, amongst others. Some respondents were conducting this research through Centres of Higher Education and Training.[118] One university respondent noted being involved in new and upcoming AI-related academic offerings at a South African university.

[118] There was an overlap between universities represented in this survey and those represented in the survey for Centres of Higher Education and Training. Two AI Community survey respondents represented a university that was accounted for in the Centres of Higher Education and Training report. However, these respondents were not the same as those who answered the Centres of Higher Education and Training survey, so their responses were retained in this dataset. Other universities in this dataset were based in Benin, the UK and the USA (the latter two involving respondents who were familiar with the AI context in SSA).

In addition, 19% of respondents were involved in Communities of Practice and interest groups, many of which focused on capacity building for AI. This included offering training events and other workshops on topics that fall under ML, data science, data analytics and robotics, as well as creating podcasts and funding AI activities on the continent. Respondents were often involved in more than one Community of Practice. The activities included the following initiatives:

- Deep Learning Indaba and Indaba X (2);
- AI Media (1);
- MIIA (1);
- AI Saturdays (1);
- Tensorflow Lagos (1); and
- Data Science Africa (1).

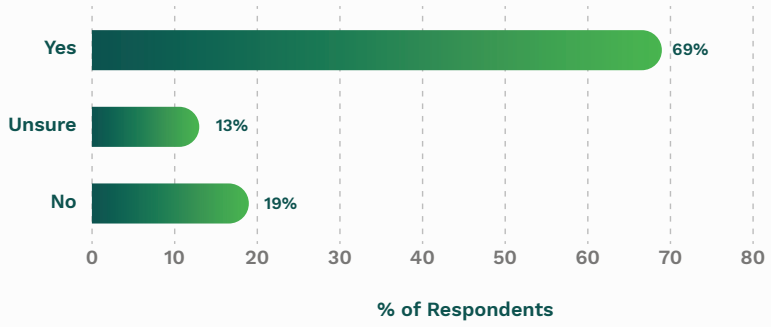
AI Communities of Practice are gaining prominence in SSA. For example, the Deep Learning Indaba is an organisation whose mission is to promote African participation and contribution to the AI and ML, and increase diversity in these fields of science. This mission is currently executed using three principal programmes which aim to build communities, create leadership, and recognise excellence in research and innovation across Africa.[119] Together with the annual Deep Learning Indaba there are IndabaX events – locally-organised Deep Learning Indaba conferences – and the Kambule and Maathai awards.[120]

Data Science Africa (DSA) is an NPO based in Kenya. Their activities have contributed to training over 200 participants on cutting edge ML techniques and data science applications. They have hosted practical sessions at their events, which demonstrate the collection of data using the IoT, together with lectures on practical applications such as spatial data analysis, social media data analysis and application of ML in industry.[121]

AI Media Group, based in South Africa, launched AI Expo Africa in 2018 – the largest business focused AI community event in Africa. The Expo, which is the largest B2B trade focused AI and Data Science Community in Africa, has 4,033 community members, 2,413 registered delegates, 184 speakers & sponsors and 502 companies.[122]

Just over two-thirds of respondents (69%) noted that their organisations engaged with universities on AI-related teaching or research and development. From the academic perspective, this included lecturing, providing content for course materials, supervising theses and developing programmes, streams, and modules in Data Science, AI, and ML.

Figure 19 Engagement with Universities on AI-related teaching or R&D



[119] Deep Learning Indaba. (2019). "Homepage."

[120] Deep Learning IndabaX. (2020). "About."

[121] Data Science Africa. (nd). "About us."

[122] AI Expo Africa. (2020). "About us."

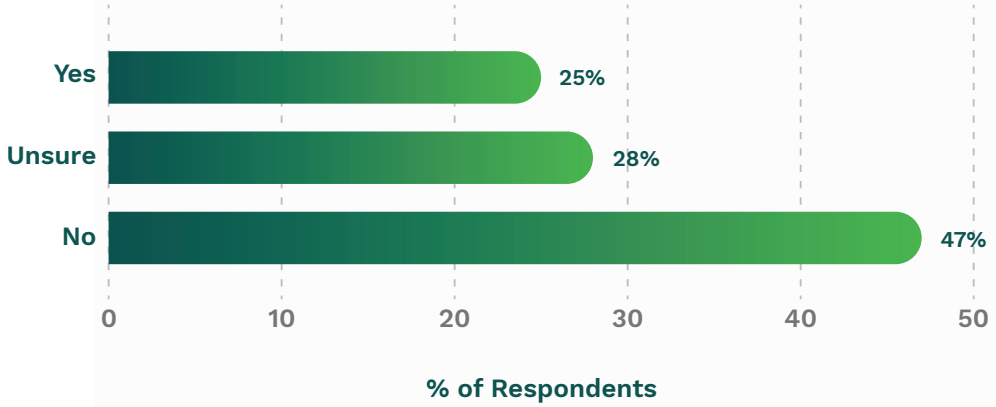
On the research side, respondents noted that their organisations collaborated with universities for AI-related research and development. Other engagement with universities included:

- Seminars, workshops, conferences, and hackathons;
- Providing bursaries or funding to universities/ students; and
- Internships.

Almost half of respondents (47%) noted that their organisations did not engage with government on AI-related policy or research and development, while 28% said that they were unsure. Of those who responded in the affirmative, activities included reviewing policies, providing feedback on draft laws, and providing commentary and advisory services about the implications of government AI-related activities. The data suggests that there is limited engagement between AI experts or organisations and government. One respondent highlighted a need for government to be more active in the sector:

> *Government needs to take a more proactive role in supporting the foundation on which AI is built. Which means funding and policy mainly.*

Figure 20 Engagement with government on AI-related policy or R&D



Respondents indicated that there were various individuals, organisations, and interest groups that are currently driving AI research and development in their countries. The prevalence of South African responses seemingly came through here, where all but one suggestion were South African institutions. Respondents mentioned the following universities and their associated programmes:

- Stellenbosch University - (South Africa);
- University of Cape Town - (South Africa);
- University of the Witwatersrand (RAIL Lab) - (South Africa);
- University of Pretoria - (South Africa);
- University of Johannesburg - (South Africa);
- North-West University - (Multilingual Speech Technologies Group) (South Africa); and
- Moringa School - (Kenya).

In identifying financial service providers, companies and start-ups that were currently driving AI research in their country, respondents noted the following:

- Number boost;
- RetroRabbit;
- Superbalist;
- Takealot;
- Aerobotics;
- DataProphet;
- Praelexis;
- Capitec;
- Zukademy;

- Google;
- Cortex Logic;
- IBM Research Africa;
- UTU Technologies;
- Safaricom; and
- Capitec.

Respondents referenced several interest groups that are driving AI research and development. This included:

- Deep Learning Indaba;
- MIIA;
- Pattern Recognition Association of South Africa (PRASA)/ RobMech;
- IBRO-Simons Neuroscience Imbizo;
- Centre for AI Research (CAIR);
- Women in Machine Learning and Data Science (WiMLDS);
- iCode AI;
- Square Kilometre Array;
- Department of Science and Technology;
- AI for Townships;
- UN Global Pulse; and
- AI Expo Africa.

Box 5: The Machine Intelligence Institute of Africa

The Machine Intelligence Institute of Africa (MIIA) is a non-profit organisation (NPO) founded in 2015 that aims to partner with governments, NGOs, universities, start-up incubators and businesses to support and help mould the future of machine intelligence and data science research and applications on the African continent.

MIIA has conducted application projects on subjects such as financial inclusion, social network analysis, healthcare and renewable energy in Africa. Research projects have focussed on topics such as cognitive computing and deep learning applications and advancing Machine Intelligence.

Source: Machine Intelligence Institute of Africa (MIIA). (nd) About us. Retrieved from http://machineintelligenceafrica.org/about/

Challenges Hindering AI Development

The data above paints a positive picture of the AI community in SSA, particularly in industry. However, AI implementation in the corporate world has been stunted by various factors including a lack of infrastructure and a lack of trust. As a result, AI has not evolved much beyond isolated solutions.[123]Although there are pockets of significant investment in AI and related technologies on the continent, there remain a number of structural challenges that undermine the implementation and widespread adoption of AI in SSA. As Travaly and Muvunyi explain:

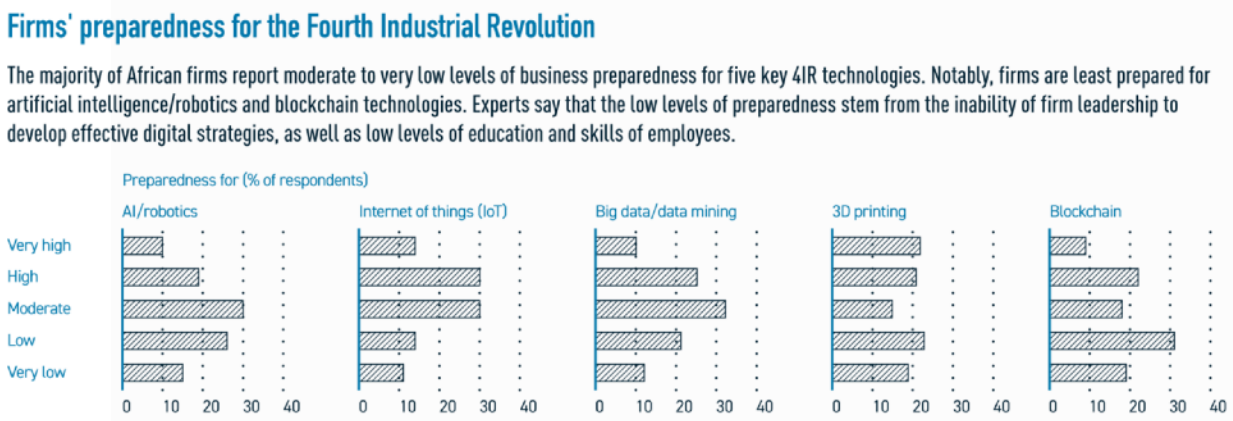
> *Inadequate basic and digital infrastructure seriously erodes efforts to activate AI-powered solutions as it reduces crucial connectivity... A lack of flexible and dynamic regulatory systems also frustrates the growth of a digital ecosystem that favors AI technology, especially as tech leaders want to scale across borders. Furthermore, lack of relevant technical skills, particularly for young people, is a growing threat. This skills gap means that those who would have otherwise been at the forefront of building AI are left out, preventing the continent from harnessing the full potential of transformative technologies and industries.*[124]

A lack of investment might feed into a lack of firms' preparedness for AI, and vice versa. The figure below provides an indication of African firms' preparedness for 4IR.

[123] Microsoft and EY Consulting. (2019). "Artificial Intelligence in Middle East and Africa: Outlook for 2019 and beyond." Microsoft.

[124] Travaly, Y. and Muvunyi, K. (2020). "The future is intelligent: Harnessing the potential of artificial intelligence in Africa." Brookings Institute.

Figure 21 Firms' preparedness for the Fourth Industrial Revolution[125]



Source: Kapoor, K., Mansaray, H., Sennett, L., Rivera, O.P., Marin, A.O. and the African Centre for Economic Transformation. (2019). Fourth Industrial Revolution, Jobs and Skills in Creating Decent Jobs: Strategies, Policies and Instruments. Monga, C., Shimeles, A. and Woldemichael, A. (eds). Abidjan: African Development Bank.

The figure demonstrates how critical an integrated AI system is to promoting the success of 4IR technology like AI. Government support and the role of the Higher Education sector in preparing the workforce with appropriate skills directly feed into firms' preparedness to use and implement these technologies. Focussed capacity building is a key dimension of a comprehensive, self-sustaining AI ecosystem.

Respondents noted a diverse set of challenges that they thought were hindering the development of AI in their countries. One of the most prominent of these was a lack of quality education in AI and related fields, reported by 25% of respondents. This included a failure to build a solid basic public educational system for mathematics, science, and engineering. These issues, respondents argued, filtered into the university environment too, with underqualified trainers, a lack of adoption of AI-related subjects and 'silo thinking in universities that remain isolated or [unaware of the] value of links with Venture Capital (VC) and industrial collaboration.'

> *Training students with AI skills requires students with good quantitative backgrounds, enabling good math and programming skills. A struggling primary and secondary education system is our biggest challenge - the tertiary education system needs school-leavers with much stronger math backgrounds.*

According to respondents, there is also a lack of technical expertise. This ranged from the need for more world class researchers on the continent to software developers who need to be exposed to industries' ML requirements so that they can develop those skills. Other related issues highlighted included:

> *Students in the undergraduate level don't have the support they need to work on advanced technical projects because there are very few project supervisors capable of working through the problems that they may end up choosing. We need to foster continuous industry-academia connections that enable undergraduate students to focus on undergraduate research opportunities, focused on basic mathematical and theoretical research, creating datasets, implementing technical demonstration systems and algorithmic advances.*

> *Placing people to lead AI initiatives that have no experience in AI, entrepreneurship, innovation and VC - we cannot leverage the value / opportunity of AI if these skills are missing from the mix - right now it's too academically focused*

[125] Travaly, Y. and Muvunyi, K. (2020). "The future is intelligent: Harnessing the potential of artificial intelligence in Africa." Brookings Institute.

Funding, respondents explained, is also an issue. For universities, they highlighted a need for equipment, laboratories, scholarships and conference attendance. For governments, respondents indicated issues with spending on enterprise and job development projects that fail to deliver as they are poorly led and Return on Investment (ROI) is not measured. They added that funding was often diverted to pay off legacy debt, and that failed projects and corruption has hampered progress.

Issues around the need for collaboration and effective resource allocation were echoed in respondents' comments regarding industry:

> *Big corporates are slow to collaborate with start-ups and AI consultants and when they do, they tend to not put enough resources into the projects.*
>
> *For ideas built in academia to spill out to industry (e.g. through start-ups), funding is also limited.*

Regarding infrastructure, respondents indicated that reliable internet was lacking and that there are issues with data availability – although respondents did not specify these issues. Additional challenges are listed below, each one highlighted by one respondent:

- Lack of specialized research centres for computational sciences, statistics and mathematical sciences;
- Lack of government engagement and policy implementation;
- Ethical issues of replacing professionals with machines;
- Fragmentation and lack of coordination of initiatives;
- A lack of understanding of the potential use-cases of AI in the corporate world; and
- A need for confidence in competing on the global stage.

Capacity Building Needs

There have been significant capacity-building efforts on the continent that have sought to explore, encourage, innovate with, and educate those within the industry and outside of it. For example, Zindi is a data science competition platform that hosts an ecosystem of scientists, engineers, academics, companies, NGOs, governments and institutions – all focused on solving Africa's most pressing problems. The enterprise works with companies, NPOs, and government institutions to develop, curate, and prepare data-driven challenges.[126] In addition to the competitions that the company hosts, they also host hackathons. One of these is the UmojaHack Africa, the continent's first virtual inter-university AI hackathon. In March 2020, this hackathon had 70 participating universities from 17 African countries, with involvement of an estimated 2500 students.[127]

Data Science Nigeria is a NPO registered as Data Scientists Network Foundation. They aim to 'develop Nigeria's AI ecosystem and position the country as a world-class AI skill, research and outsourcing destination with opportunity to access 2-3% share of the estimated global Artificial Intelligence GDP contribution of up to $15.7 trillion by 2030.'[128] The organisation has a practitioner-led model where experienced data scientists train and mentor young Nigerians through face-to-face, virtual coaching classes, project-based support and holiday boot camps funded by individuals and corporates.[129]

Multinational companies are also providing capacity-building support to SSA. In April 2019, Google opened Africa's first AI Laboratory centre in Accra, Ghana. The company also supports ML programmes at the African Institute for Mathematical Sciences centre in Rwanda. In May 2019, Microsoft launched the Africa Development Centre (ADC) with two initial centres in

[126] Zindi. (nd). "About us."

[127] Ventureburn. (2020). "UmojaHack Africa, continent's first virtual inter-university AI hackathon set for tomorrow." Ventureburn.

[128] Data Science Nigeria. (nd). "About us."

[129] Data Science Nigeria. (nd). "About us."

Nairobi, Kenya and Lagos, Nigeria. Developers at the ADC will focus on transformative technologies, such as AI and ML.[130]

There has also been significant growth in digital innovation hubs on the continent. Research by Briter Bridges and Africa Labs has found that there are approximately 643 technology hubs, 41% of which are incubators, 24% are innovation hubs, 14% are accelerators, while 25% of these only provide co-working spaces.[131] What will be important moving forward is to ensure that the AI community continues to forge its own path, instead of simply adapting Western AI-related products and services:

> *...in a region with multiple social, environmental, economic and political challenges there is a need for more interrogation into how both incumbent and new players in sub-Saharan Africa are shaping the landscape with a view to meeting the UN Sustainable Development Goals. Digital technologies, as some of our case studies show, can play an important role in transforming African economies. However, digital technology solutions must not just be mere adaptations of dominant Western services and products. They must be aimed at meeting the sub-continent's needs.*[132]

Inter-governmental organisations and international companies can play a role in supporting the development of the AI ecosystem in SSA, but should be cognizant of their role as enablers – not necessarily leaders. UNESCO has indicated that Africa is one of its global priorities, as well as being a crucial focus of its AI-related activities. One of the main reasons behind this is that both human resources and technical challenges as well as potential present themselves within the African context. As Hu *et al* note:

> *Speakers of smaller African languages could be left behind in regard to the development of AI-fuelled speech-to-text and translation capabilities. African-generated data can risk being mined without benefit to local stakeholders as well as being traded internationally with insufficient regard for privacy standards. A lack of AI-related policy frameworks in many governments calls out for attention, not least in regard to communication and information issues.*[133]

The data suggests that although there are notable AI-related activities occurring in SSA countries, there is a need for capacity building efforts to create a robust AI Ecosystem in SSA. Bearing this in mind, this sub-section examines capacity building needs for AI-related activities in SSA.

Policies and Regulations that will support AI activities

Respondents provided insights into the kinds of policies and regulations that might be necessary to support AI-related activities in their countries. The results are represented in the graph below.

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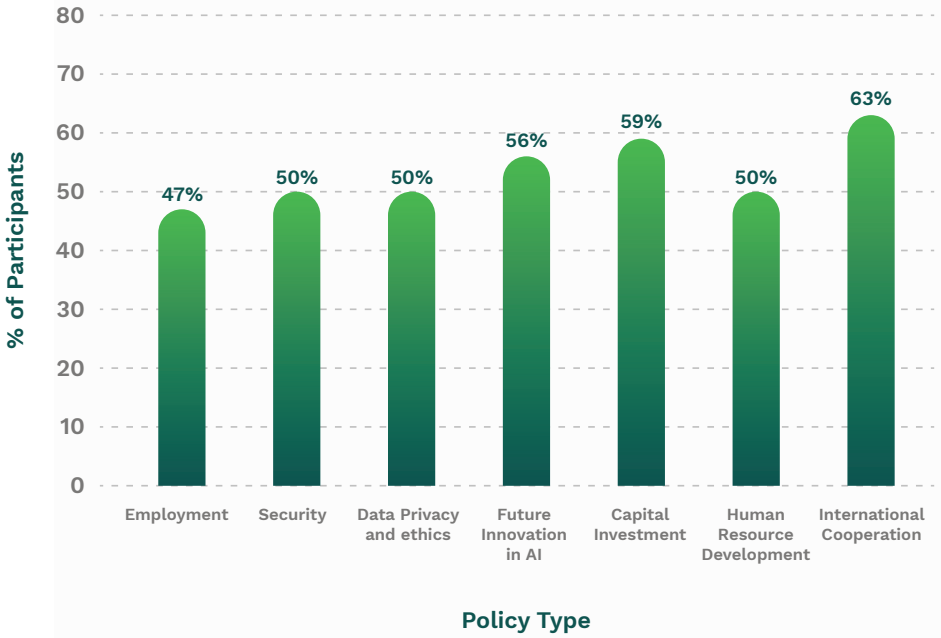
[130] GSMA. (2019). "The Mobile Economy: Sub-Saharan Africa 2019."

[131] Shapshak, T. (2019). "Africa Now Has 643 Tech Hubs Which Play 'Pivotal' Role For Business." Forbes.

[132] Bolat, E. and Taura, N. (2019). "Digital technologies are transforming African businesses, but obstacles remain." The Conversation.

[133] Hu, X., B. Neupane, L.F. Echaiz, P. Sibal, and M.R. Lam. (2019). "Steering AI and Advanced ICTs for Knowledge Societies." UNESCO.

Figure 22 Policies/regulations necessary to support AI-related activities



International cooperation policies (63%), capital investment policies (59%) and future innovation in AI policies (56%) were most often noted. However, the small margin between the different policies, as well as the fact that each policy was selected by at least half of respondents, suggest that all the policies listed in the survey held importance to respondents for supporting AI activities.

According to the survey results, Kenya appears to have one of the more robust policy environments to support AI-related activities. This includes policies on employment, security, capital investment, human resource development, and international cooperation. This is followed by South Africa, which has similar policies as Kenya except for a security policy. Interestingly, only Ghana has a policy regarding the future innovation of AI, suggesting that SSA countries have predominantly not codified their future plans for AI through policies and regulations. Where there was more than one response per country category, respondents sometimes contradicted one another regarding available policies. One respondent commented that they did not know what policies were in place already. This indicates a possible lack of awareness of policies related to AI.

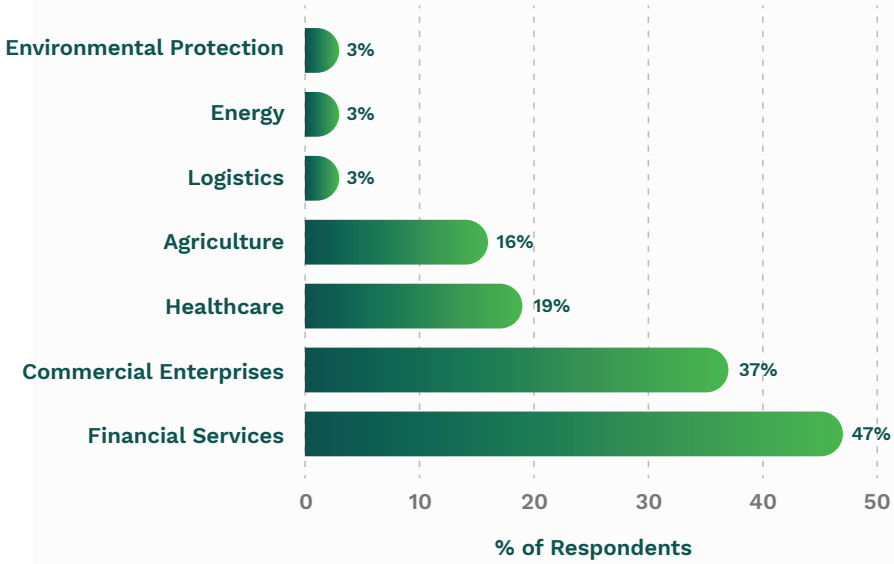
Other suggested policies and strategies to support AI-related activities included the following:

- Equitable distribution of wealth generated by AI activities;
- National level strategy for AI;
- Future innovation in science and technology;
- Skills training; and
- Grants and funded innovation opportunities.

Demand for AI Applications

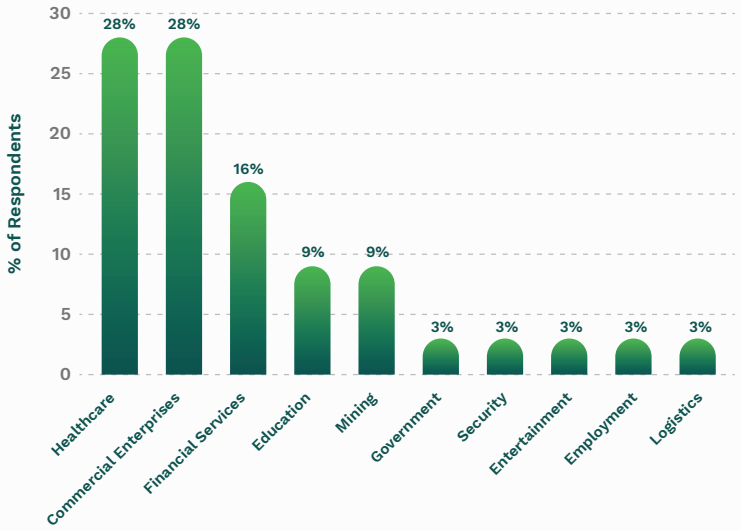
When examining current demand for AI applications (Figure 23), 47% of respondents noted that financial services involving banks and insurance were in demand. In addition, 37% of respondents indicated that commercial enterprises were experiencing significant demand. This included sectors such as manufacturing, telecommunications, mining, technology, retail, and customer services. Other industries included healthcare (19%), agriculture (16%), logistics (3%), energy (3%) and environmental protection (3%).

Figure 23 Current Demand for AI Applications



When considering which sectors would see the most growth in demand for AI applications over the next five years (Figure 24), 28% of respondents suggested that there would be growth in demand for healthcare applications. Respondents also noted several sub-sectors of commercial enterprises (28%). This included automotive, manufacturing, technology, and customer service. Some predicted growth in financial services (16%), education (9%) and Mining (9%).

Figure 24 Growth in Demand for AI Applications



In highlighting the most pressing capacity building needs in the AI sector, upskilling people and providing relevant education was noted as a requirement by 44% of respondents. Respondents called for this at all levels from primary school and university, to upskilling employees. Examples of responses are noted below:

> *Businesses presenting their technical staff with AI challenges and upskilling them to attempt that AI based solution.*
>
> *Strong foundation statistical and computational backgrounds in high school. Stronger emphasis on mathematical, statistical and computational sciences in universities and beyond*
>
> *Growing interest for AI related activities. Knowledge acquisition. Practical experimentation*
>
> *...I don't think many businesses can afford to have entire AI based teams. So we need to develop a propensity for solving things with AI by building in those challenges intermittently for technical staff. The fear aspect can be challenged by greater access to Statistics education, AI tools and AI courses.*

In addition, 25% of respondents indicated that funding was required for AI-related activities. This included funding from industry partnerships, funding for research labs, support for communities of practice and capital availability for small companies.

Others referred to the need for progressive policies that took AI into account. Comments included the following:

> *The development of AI capacity is a sub-project of the development of general scientific and technological capacity. I see the problems hindering its growth as an instance of more general problems affecting the region's ability to push the boundaries. Because of the multi-disciplinary nature of AI, the policies that focus on improving AI capacity should also be equally applicable to other fields.*
>
> *AI moves FAST, and the government simply doesn't give space to innovate. As a knock-on effect, universities have to comply to all these layers of red tape. I've heard it said may times that some Africa universities would be like Stanford, with the same ecosystem. But they never will unless there is more space to innovate.*
>
> *The development of AI capacity is a sub-project of the development of general scientific and technological capacity. I see the problems hindering its growth as an instance of more general problems affecting the region's ability to push the boundaries. Because of the multi-disciplinary nature of AI, the policies that focus on improving AI capacity should also be equally applicable to other fields.*

It is also important, respondents argued, for businesses to understand AI and related concepts, as well as how they could apply them to their own environments and how they could collaborate with partners:

> *Need to learn more about what we can do with AI and ML to start practising and figuring out how to do more of that. I don't think many businesses can afford to have entire AI based teams. So we need to develop a propensity for solving things with AI by building in those challenges intermittently for technical staff. The fear aspect can be challenged by greater access to Statistics education, AI tools and AI courses.*

Other capacity building needs noted by one respondent each were:

- Development of good data curation and maintenance practices (including locally accessible big data archives);
- Employment opportunities;
- Implementation of digital ethics;

- Community building; and
- Capacity development in areas such as engineering, programming, ML and design.

In addition, one respondent highlighted characteristics that SSA has in its favour for building AI capacity:

> *There are many advantages to AI capacity building in Africa: the lack of too many legacy systems, the spirit of innovation that exists in the continent, and the phenomenal growth that we could see. Furthermore, the culture of AI could be shaped from the grounds up, to be socially caring, inclusive, responsible, ethic, environmentally friendly, and with a strong economic mandate to lift people out of poverty.*

There are various measures that industry and those in the technical community can take to ensure that AI and related technologies are implemented fairly, effectively, and with minimal impact on human rights. A report by UNESCO provides the following suggestions;

- Conduct human rights risk and impact assessments of AI applications to minimise their interference with human rights.
- Develop self-regulation norms for ethical practices in deployment of AI to avoid risky or anti-competitive behaviour in pursuit of market advantage.
- Provide greater access to affordable connectivity, hardware and software needed for running AI programmes.
- Be more actively involved in national and international level policymaking concerned with the AI and engage other actors in their internal governance issues such as defining terms of service and operating procedures.[134]

[134] Hu, X., B. Neupane, L.F. Echaiz, P. Sibal, and M.R. Lam. (2019). "Steering AI and Advanced ICTs for Knowledge Societies." UNESCO.

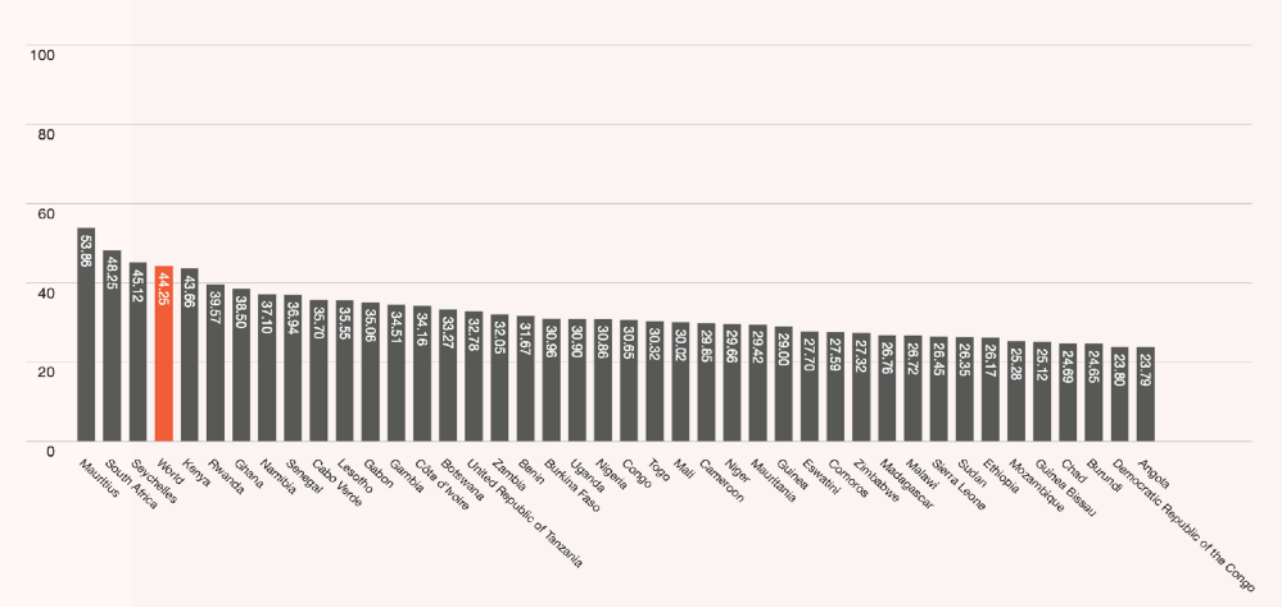
AI and Governments in SSA

Introduction

To successfully manage the transition to an AI-supportive environment, governments in SSA countries will need to have the correct policies and regulations in place. Although SSA countries are displaying increasing interest in smart technologies and 4IR,[135] they seldom have national strategies to support future plans.[136] At present, high levels of corruption in public institutions and weak data infrastructure that is susceptible to data leaks pose a threat to data privacy and successful AI implementation. For example, Nigeria has no data protection laws (although the Nigeria Data Protection regulation was released in 2019)[137] and as a result, has suffered several data breaches such as information being uploaded online without being anonymised.[138]

Oxford Insights' Government AI Readiness Index, now in its third edition, measures how ready governments are to implement AI in the delivery of public services to their citizens. Drawing on 33 indicators across ten dimensions, the Index provides a government AI readiness score. Below is the breakdown of scores for SSA countries. As a comparison, the United States of America achieved the highest score globally, scoring 85.48. China scored 69.08, ranking at 19 out of 172 countries. The global average score is 44.25 and only three SSA countries scored above this – Mauritius, South Africa and the Seychelles.[139]

Figure 25 Government AI Readiness Index 2020



Source: Oxford Insights, 2020

The Government AI Readiness Index indicates that overall, African countries are relatively better prepared in the Data and Infrastructure pillar of the Index, where countries are building telecommunications and other infrastructure to support AI ecosystems as well as improving the

[135] Mzekandaba, S. (2018). "BRICS must collaborate to shape Industry 4.0 tech, says Ramaphosa." ITWeb.

[136] Ludik, J. (2018). "Artificial Intelligence in Africa is on a Roll! Cortex Logic."

[137] ICLG. (2020). "Nigeria: Data Protection Laws and Regulation 2020."

[138] World Wide Web Foundation. (2017). "Artificial Intelligence: The Road Ahead in Low and Middle Income Countries." World Wide Web Foundation.

[139] Oxford Insights. (2020). "Government AI Readiness Index." Oxford Insights.

availability of data to train AI. SSA countries' score is second highest in the Government pillar, while the Technology Sector pillar comes in at third.[140]

National efforts to build AI capacity in SSA

Several African cities have positioned themselves as regional hubs for AI development and innovation on the continent. This includes Cape Town, Addis Ababa, Kigali, and Nairobi.[141] At the national level, a number of African governments have taken decisive steps towards increasing capacity for AI-related activities. In anticipation of AI's increased prominence, the Ghanaian government has invested heavily in fibre infrastructure nationwide with simultaneous private sector investment to provide sufficient capacity in the national fibre infrastructure to allow for the provision of value-added services for citizens.[142] Google also launched a regional AI Hub in Ghana in April 2019, which will collaborate with local universities, research bodies and policymakers on AI applications for Ghana- and Africa-specific challenges.[143]

UNESCO's research with governments found that 19 of the 32 countries surveyed had initiatives for making government data openly available in accessible formats.[144] This suggests that open government data is gaining traction in establishing transparency and innovation through the development of data-driven public services.[145]

One example of awareness around open government data practices is the Government of Ethiopia, which established the Ethiopian Biotechnology Institute (EBtI) as an independent institute to oversee the development of emerging technologies under four categories: Nanotechnology, Material Science, Artificial Intelligence and Reverse Engineering.[146] Within its AI Directorate, EBtI has set up three research teams in Robotics, Computation, and Automation.[147] Although there is increasing potential for the availability of large datasets in commerce, social media, and science, Ethiopia faces some of the lowest average statistical capacity – like most other African countries. To confront this challenge, the Ethiopian government drafted the National Open Data Policy for the Government of Ethiopia in January 2018, although this has not yet been approved by parliament. The Government also invested €87 million in the Ethio ICT Village, a technology park that aims to become a Centre of Excellence for scientific and technological research. In addition, the Government has prioritised ICT and innovation through its transformation agenda by, for example, imposing a quota that requires 70% of university students to study STEM subjects.[148] However, these activities have not been

Box 6: Planning, Prediction, Prompting and Prodding for Change (4P2C), Malawi

The Malawian Government partnered with UNICEF Malawi on a data intelligence initiative, which is also known as Planning, Prediction, Prompting and Prodding for Change (4P2C). The initiative uses geo-spatial and data analytic tools to provide accurate and real-time information for women, children and their families. In 2017, UNICEF Malawi and the Malawian government also launched a Drones lab, which provides universities, the private sector and other expert organisations a platform to investigate how unmanned aerial vehicles (UAVs) can be used to deliver services that will benefit women and children in disadvantaged communities. To ensure that the project is sustainable, UNICEF teaches Malawians to make drones, while also training local pilots. In addition, the Malawi National Registration Bureau (NRB) developed a national registration and identification system that uses biometric data and sensors.

Source: Global Information Society Watch. (2019). "Artificial intelligence: Human rights, social justice and development." GISWatch.

[140] Oxford Insights. (2020). "Government AI Readiness Index." Oxford Insights.

[141] Oxford Insights. (2019). "Artificial Intelligence Government Readiness Index." Oxford Insights.

[142] Hagan, J.E. (2018). "Govt to harness benefits of artificial intelligence – Minister." The Finder.

[143] Oxford Business Group. (2019). "Which sectors stand to benefit from Ghana's AI drive?"

[144] Countries that have reported having initiatives for making government data openly available include: Angola, Benin, Cabo Verde, Cameroon, Côte d'Ivoire, Equatorial Guinea, Gambia, Ghana, Guinea, Malawi, Nigeria, Seychelles, Sierra Leone, Somalia, Sudan, Togo, Uganda, Zambia, Zimbabwe

[145] Sibal, P. and Neupane, B. (2021). "Artificial Intelligence Needs Assessment in Africa." UNESCO.

[146] Xinhua. (2018). "Ethiopian PM calls for efforts in AI after meeting humanoid robot Sophia." New China.

[147] Ethiopian Biotechnology Institute (EBtI). (nd). "Homepage."

[148] Global Information Society Watch. (2019). "Artificial intelligence: Human rights, social justice and development." GISWatch.

without controversy. Ethiopia does not have adequate legal, regulatory and policy frameworks to govern use and distribution of personal data by government entities. For example, the Proclamation on the Registration of Vital Events and National Identity Card permits collection and transfer of personal data to intelligence authorities without consent of the subjects.[149]

Ethiopia is not alone in its need to develop these capacities for AI governance. In the UNESCO AI Needs Assessment, 19 countries highlighted a need to strengthen capacities for handling the legal implications of AI, with countries reporting a lack of legal mechanisms to address the challenges that AI presents, together with a substantial shortage of human resource capacity to address the legal repercussions of these challenges.[150]

The Senegalese government has been collaborating with start-ups and technology innovators to deliver technology-driven public services. For example, TownPay is a digital tax collection platform.[151] It enables municipalities to automate and digitise the collection of local taxes from local shops and merchants to reduce fraud and improve collection rates.[152]

In 2018, Nigeria announced its intentions to set up a new agency for robotics and AI as the country begins work on a strategic policy blueprint to commit more resources to research in science and technology. The new agency is intended to leverage alliances with international research bodies on robotics and AI and will promote research in higher-order technological skills to thousands of youth.[153] Nigeria is expected to collaborate with the United Arab Emirates (UAE) in developing AI technology, although details about this collaboration have not been made explicit.[154]

In December 2019 Egypt presented a proposal to establish an African working group for developing the first unified strategy on AI across the continent. This initiative will allow African countries to present a unified front in terms of private sector and international institution collaborations; ethics of AI; data protection; and human capacity building to name a few.[155] This comes at an opportune time since, according to the UNESCO report, only six countries out of those who responded indicated that they had the capacity to address the ethical implications of AI, while five countries reported having initiatives to bolster knowledge and capacities of government personnel. This speaks to an imperative for human capacity development in addressing the ethical implications of AI. Moreover, it highlights a need for the legislature, executive, and judiciary in each SSA country to develop, implement and uphold policies, laws, as well as financial and human that encourage the development of industry standards for AI.[156]

Governments are fast realising that they are going to need assistance from the commercial sector if they want to achieve their development goals – commercial technology solutions will play a large role in tackling issues that governments have historically been tasked with. Simultaneously, governments are realising that for these solutions to be successful, they will need to overcome critical regulatory and infrastructure bottlenecks. According to the Atlantic Council's Africa Centre:

> *Leaders in Ghana and South Africa have enacted comprehensive data protection legislation—two of only eleven sub-Saharan countries to have done so thus far. Ghana's 2012 Data Protection Act regulates how personal information is acquired, stored, and disclosed. The Protection of Personal Information Act, signed into law in South Africa in 2013, similarly introduces an overarching framework for processing personal information and sets up a supervisory function to ensure legislative*

[149] Global Information Society Watch. (2019). "Artificial intelligence: Human rights, social justice and development." GISWatch.

[150] Sibal, P. and Neupane, B. (2021). "Artificial Intelligence Needs Assessment in Africa." UNESCO.

[151] Oxford Insights. (2020). "Government AI Readiness Index." Oxford Insights.

[152] Ecosystem Accelerator. (2018). "Senegal: A tech ecosystem on the move." GSMA.

[153] Alajemba, N. and James, C. (2018). "Nigeria to set up new agency for Robotics and Artificial Intelligence." ITEdgeNews.

[154] News Agency Nigeria. (2018). "Federal government, UAE to partner on artificial intelligence technology in Nigeria." Today.ng.

[155] Al-Youm, A. (2019). "Egypt proposes unified strategy for Africa on AI technology." Egypt Independent.

[156] Sibal, P. and Neupane, B. (2021). "Artificial Intelligence Needs Assessment in Africa." UNESCO.

> *compliance. Like Kenya, Ghana is one of the few African countries with an open data initiative. In order for technological innovations to be successful in the long term, progress and innovation in government policies is also necessary.*[157]

Other upcoming initiatives include a programme by the African Development Bank, with support of the World Bank. They established the Moonshot for Africa programme, which aims to accelerate internet adoption by funding several ambitious digital connectivity programmes in Africa, ranging from broadband connectivity to ML and AI technologies.[158]

Oxford Insights notes that one of the main challenges in providing a comprehensive overview of AI-related activities in Africa is a relative lack of data, analysis and reporting, meaning that much of the information is anecdotal. It adds, however, that existing evidence points to a trend of greater interest in AI on the continent, explaining: 'Over time, this should lead to better data and higher rankings for African governments in future editions of the Index.'[159] To support the developments outlined above, governments in SSA will need to develop a coherent set of policies on AI and ensure that the regulatory environment strikes a balance between protecting citizens, institutions and national sectors from the threats that AI poses while simultaneously enabling innovation and creativity. The following section explores policy measures in SSA countries in greater depth.

Policy environment

Inconsistent policy and regulatory environments slow SSA countries' progress towards AI readiness. Few countries in the region have official AI strategies or national policies, although AI is gaining increasing prominence on national agendas.[160] Some SSA countries have already taken early steps towards readying their policy environments for the surge of AI information and activities. Cases of key activities are outlined below.

In January 2018, the Kenyan government selected a task force[161] to draft a strategy that would encourage the development and adoption of new technologies like blockchain and AI. The 11-person task force's intention is to develop a set of recommendations on how government might be able to leverage new technologies within the next five years. The recommendations will also provide milestones for 2027 to 2032 and will address areas such as financial inclusion, cybersecurity, election processes, single digital identity, and overall public service delivery.[162] However, because Kenya, like almost all of SSA, does not have any standalone regulatory or policy framework for AI, the use of AI in the country remains underregulated.[163]

Results from the UNESCO survey indicate that 21 of the 32 countries were prioritising the development and use of AI by including it in their national development plans. The report adds:

> *Some of these countries have already undertaken activities to guide the development and use of AI. These activities include launching AI strategies and policies; implementing legislation; establishing of Centres of Excellence on AI; and developing ethical guidelines for AI.*[164]

There are several documented examples of this. Mauritius published an AI strategy in 2018 – the only country in SSA to do so to date. The strategy established an AI council that advises the Government on supporting Mauritius' AI ecosystem.[165] Together with the AI strategy, Mauritius

[157] Gadzala, A. (2018). "Coming to Life: Artificial Intelligence in Africa. Atlantic Council – Africa Centre." ISSUU.

[158] Oxford Insights. (2020). "Government AI Readiness Index." Oxford Insights.

[159] Oxford Insights. (2019). "Artificial Intelligence Government Readiness Index." Oxford Insights.

[160] Oxford Insights. (2020). "Government AI Readiness Index." Oxford Insights.

[161] Kenyan Wallstreet. (2018). "Kenya Govt Sets up Blockchain & Artificial Intelligence Taskforce!" The Kenyan Wall Street.

[162] Dutton, T. (2018). "An Overview of National AI Strategies." Medium.

[163] Mputhia, C. (2018). "Regulation Should not Stifle Innovation." Business Daily Kenya.

[164] Sibal, P. and Neupane, B. (2021). "Artificial Intelligence Needs Assessment in Africa." UNESCO.

[165] Working Group on Artificial Intelligence, Government of Mauritius. (2018). "Mauritius Artificial Intelligence Strategy." Government of Mauritius.

published a Digital Mauritius 2030 Strategic Plan, which focuses on cyber security, digital government, ICT Infrastructure, innovation and talent management.[166] The country also updated its data protection legislation and the Government is highly supportive of digital transformation. As the Government AI Readiness Index notes:

> *Since 2017, the Government has offered tax incentives for innovative companies. The Government also grants regulatory sandbox licences to encourage experimentation, and runs a National SME Incubator Scheme. To encourage collaboration between academia and the private sector in R&D, the Mauritius Research and Innovation Council runs a scheme that offers grants for SMEs to collaborate with local academic and research institutions.*[167]

In late 2018, the South African government set up the Presidential Commission on 4IR, as announced in the State of the Nation Address 2018. The Commission, which includes experts in AI and other emerging technologies, is responsible for coordinating the development of South Africa's national response to AI and related technologies in the form of a comprehensive action plan to address 4IR. The Commission was put in charge of identifying and recommending policies, strategies, and plans that are required to position South Africa as a leader in transitioning to 4IR. In early 2020, the Commission drafted the preliminary report, which included the following eight recommendations:

a. Invest in human capital;
b. Establish an AI institute;
c. Establish a platform for advanced manufacturing and new materials;
d. Secure and avail data to enable innovation;
e. Incentivise future industries, platforms and applications of 4IR technologies;
f. Build 4IR infrastructure;
g. Review and amend or create policy and legislation; and
h. Establish a 4IR strategy implementation co-ordination council in the presidency.[168]

In a 2020 article, President Ramaphosa explained his government's drive to promote 4IR activities:

> *By 2030 we want to be fully integrated into the economy of the future — an economy that uses technological innovation to revolutionize manufacturing and industrial processes and energy provision and distribution. We want to demonstrate how science, technology, and innovation have been used to enhance our food and water security and to build smart human settlements.*[169]

Senegal does not have a coherent policy framework, but introduced its Digital Senegal 2025 Strategy in 2016, which is linked to the Emergent Senegal Plan. The Digital Senegal 2025 channels 2.5 billion Euros into 28 reforms and 69 projects, with the aim of raising the contribution of digital technologies to GDP in the country by 10%, and creating 35 000 direct jobs by 2025.[170]

Countries like Rwanda are already embracing the early-stage use of AI. In 2016, the Rwandan government partnered with Zipline, a drone delivery service that delivers medicine and blood to remote areas. The technology allows Rwandans, wherever they are situated, to have access to life-saving medical supplies within 30 minutes.[171] Rwanda also expects to have a data protection

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[166] Ministry of Technology, Communication and Innovation, Government of Mauritius. (2018). "Digital Mauritius 2030 Strategic Plan." Government of Mauritius.

[167] Oxford Insights. (2020). "Government AI Readiness Index." Oxford Insights.

[168] Marwala, T. (2020). "Building human capital for the fourth industrial revolution." Mail and Guardian.

[169] Ramaphosa, C. (2020). "A national strategy for harnessing the Fourth Industrial Revolution: The case of South Africa." Brookings Institute.

[170] Ministry of Posts and Telecommunications, Government of Senegal. (2016). "Digital Senegal 2025 Strategy. Government of Senegal." Government of Senegal.

[171] Novitske, L. (2018). "The AI Invasion is Coming to Africa (and It's a Good Thing)." Stanford Social Innovation Review.

policy in place by
2020, noting that the policy will indirectly address key AI-related governance issues.[172]

The African Union recently adopted the African Digital Transformation Strategy (2020-2030), which provides a guide for digital development on the continent. The Strategy includes reference to AI in terms of building inclusive digital skills, promoting innovation and encouraging the private and public sectors to embrace emerging technologies.[173] In addition, the African Continental Free Trade Agreement could promote AI infrastructure and human capital growth by facilitating regional collaboration and the free flow of people, investments, goods and services.[174]

There are also efforts by multinational companies to support governments in the region. Microsoft is supporting governments across Africa in developing necessary policy frameworks. They have spearheaded initiatives such as the Microsoft Policy Innovation Centre at Strathmore University in Kenya, which provides a platform to discuss policy issues surrounding digital transformation. Microsoft also partnered with Access Partnership and UP to develop a White Paper on the implications of AI in Africa, which they presented to delegates from the South African government in early 2019.[175]

Despite this progress, Oxford Insights' Government AI Readiness Index 2020[176] does not feature any SSA countries in its top 40 countries that are AI-ready – Mauritius is the highest ranking SSA country at 45th. As the only SSA country to feature in the Automation Readiness Index[177], South Africa ranks 22nd out of the 25 countries in its readiness for the challenges and opportunities of intelligent automation. With an index score of 41.0, South Africa's readiness is categorised as 'emerging'. The country ranks eighth out of the nine upper-middle-income countries included in the index. South Africa's most robust category is its Innovation Environment, where it ranks 18th overall. Within this category, particular strengths are Start-up Support, Technology Adoption, and Knowledge Transfer. This can be attributed to policies that support its broadband infrastructure and internet adoption. Despite this, South Africa and Argentina share a last place ranking for their Labour Market Policies. The former has particularly low scores for government-led research on the impact of automation on employment and programmes to support retraining in the workforce.[178] The UNESCO report also highlights a critical need to increase fundamental and applied AI research and provide access to research resources, including AI research networks, with 22 countries reporting that they had limited research facilities and substantial human resource capacity shortages for AI research.[179]

The potential for Africa to accelerate its AI adoption does exist. The WEF's Human Capital Index found that SSA currently only utilises 55% of its human capital potential, in comparison to a global average of 65%.[180] But before SSA is able to enjoy the benefits of AI, SSA governments, investors and NGOs need to focus on training workers for complex tasks, and reform laws, policies, and education to align with the demands of the future economy. The UNESCO research found that countries need more support for AI education and R&D, including revising education systems so they are responsive to AI skills and competency requirements, improving research capacity, and providing AI-related educational opportunities for workers. Notably, 12 countries

[172] Oxford Insights. (2020). "Government AI Readiness Index." Oxford Insights.

[173] African Union. (2020). "The Digital Transformation Strategy for Africa (2020-2030)." African Union.

[174] Oxford Insights. (2020). "Government AI Readiness Index." Oxford Insights.

[175] Africa Tech Summit Kigali. (2019). "Microsoft: Getting behind AI growth in Africa."

[176] See Oxford Insights. (2020). "Government AI Readiness Index." Oxford Insights.

[177] The Economist Intelligence Unit. (2019). "The Automation Readiness Index: Key Findings from South Africa." The Economist Intelligence Unit.

[178] The Economist Intelligence Unit. (2019). "The Automation Readiness Index: Key Findings from South Africa." The Economist Intelligence Unit.

[179] Sibal, P. and Neupane, B. (2021). "Artificial Intelligence Needs Assessment in Africa." UNESCO.

[180] Samans, R. and Zahidi, S. (2017). "The Future of Jobs and Skills in Africa: Preparing the Region for the Fourth Industrial Revolution." World Economic Forum.

reported that no specific measures for AI skills and education have been executed at any educational level, although there is an interest to do so.[181]

A good starting point is for governments to understand the advantages and implications of AI growth on the African content, and then to respond to the needs that arise constructively and pragmatically. Two key areas to focus on are 'encouraging a transparent and dynamic regulatory environment, and implementing extensive education reform from primary school through university.'[182] Simultaneously, local governments should be cognisant of not blocking or overregulating AI development and use, which might discourage innovation.

Other pertinent challenges for government include how data is used and the threats that AI poses to citizens if not sufficiently regulated. In July 2017, for example, Accenture and the Gordon Institute of Business Science (GIBS) hosted a roundtable discussion on AI in South Africa. The discussion identified several concerns with regard to AI in the country, including data quality, data privacy, workforce readiness and re-skilling, as well as potential job losses.[183] The Government has recently developed several new policies that seek to enhance the role of science and technology in promoting inclusive economic growth while simultaneously highlighting the importance of emerging ICTs for efficient public service. These policy developments include the Draft White Paper on Science, Technology and Innovation;[184] the National Integrated ICT Policy White Paper;[185] and South Africa's National e-Strategy Towards a Thriving and Inclusive Digital Future 2017-2030.[186] However, the shift towards 4IR has not been without controversy, as noted by Global Information Society Watch:

> *The increased use of social media in South Africa means that governments can mine and analyse comments on public channels, then "agilely respond to citizens' complaints" or even influence emerging issues. This raises serious privacy concerns. In South Africa, perhaps the most controversial use of AI technologies by the state has been in predictive policing, such as through "upgrades" to CCTV camera systems in the City of Johannesburg to enable facial recognition and broader research collaborations with the South African defence and police forces to "Build Safer Communities". Meanwhile, the unauthorised use of data to exploit social grant recipients has undermined already limited trust in IT systems.*[187]

In Parkhurst, an upper-middle class suburb of Johannesburg, ML and AI have enabled CCTV cameras to conduct sophisticated video analytics on varied behaviours, objects, and patterns throughout the suburb. As an article in Vice notes, 'Armed with powerful new tech, communities of colour can be watched, flagged, policed, and intimidated into submission.'[188] If unregulated public surveillance becomes a norm, there is increasingly danger that individual rights and privacy will continue to be encroached upon.

The examples of AI 'grey areas' above, together with a relative lack of AI-related policies indicate that extensive reforms of national systems are still required. As a report by the Atlantic Council's Africa Centre notes with regard to the critical factors for effective AI implementation:

> *Unfortunately, except in a handful of countries—namely Kenya, South Africa, Nigeria, Ghana, and Ethiopia—the application of AI is a chimera, not a reality. The critical factors necessary for the technology to take hold are woefully absent across*

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[181] Sibal, P. and Neupane, B. (2021). "Artificial Intelligence Needs Assessment in Africa." UNESCO.

[182] Novitske, L. (2018). "The AI Invasion is Coming to Africa (and It's a Good Thing)." Stanford Social Innovation Review.

[183] Accenture and GIBS. (2017). "Artificial Intelligence: Is South Africa ready?."

[184] Department of Science and Technology. (2018). "Draft White Paper on Science, Technology and Innovation." Government of South Africa.

[185] Department of Telecommunications and Postal Services. (2016). "National Integrated ICT White Paper." Government of South Africa.

[186] Department of Telecommunications and Postal Services. (2017). "Digital Society South Africa: South Africa's National e-Strategy towards a thriving and inclusive digital future 2017-2030." Government of South Africa.

[187] Global Information Society Watch. (2019). "Artificial intelligence: Human rights, social justice and development." GISWatch.

[188] Kwet, M. (2019). "Smart CCTV Networks Are Driving an AI-Powered Apartheid in South Africa." Vice.

> *most of the continent, and many African countries remain incapable of requisite reforms in the areas of data collection and data privacy, infrastructure, education, and governance. Without those reforms, there is little chance that most African nations will be able to exploit AI technologies to advance sustainable development and inclusive growth. The specter of automation threatens to leave these countries behind.*[189]

The UNESCO report shows that countries in SSA need to create and implement legal and regulatory frameworks for AI governance. While 22 countries noted that they had legal frameworks on personal data protection, legal systems will need to remain responsive to new applications of AI as and when they arise – particularly applications that potentially impinge on human rights such as freedom of speech, personal privacy and freedom to information. To add to the complexities of introducing legal frameworks, 26 countries reported significant human resource shortages in tackling the ethical implications of AI,[190] while just six countries[191] reported having sufficient capacity to address the ethical implications of AI.[192]

Looking to the future in SSA, a number of suggestions have been made on how to put the region at the forefront of AI adoption, integration and innovation. As an article by the Stanford Social Innovation Review notes, government should oversee reforms in education to ensure that citizens benefit from progress in AI. The article continues:

> *African state universities should also provide grants within the fields of STEM and information and communications to help bolster domestic research and application, as well as ensure equitable access to advanced technological studies for underprivileged students. The faculties developed in these areas of study are critical for developing the analytical and technical skills young people need to excel in a job market changed by AI.*[193]

UNESCO's report notes that there are diverse AI priorities for countries in Africa, but that these provide an opportunity for collaboration. The report adds that key priority areas include:

- Protection of personal data and data governance;
- Leveraging AI for economic growth;
- Supporting start-ups and digital innovation;
- Updating education, skills and training systems for imparting AI skills and knowledge;
- Facilitating AI research and development; and
- Addressing gender related bias and discrimination in the development and use of AI.[194]

A practical way to approach the need for creative solutions might be for African governments to establish working groups that tackle the application of AI for education, which can support the expansion and execution of AI tools and techniques. This would curb the chances of duplication on the continent and would be an efficient way to use resources.[195]

There are several organisations that will play a key role in assisting African governments in defining domestic AI policies. According to a White Paper by Access Partnership, Microsoft, and the University of Pretoria, this includes:

- The African Development Bank (ADB) has partnered with Microsoft to launch the Coding for Employment Programme, with the goal of preparing African youth for tomorrow's jobs

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[189] Gadzala, A. (2018). "Coming to Life: Artificial Intelligence in Africa. Atlantic Council – Africa Centre." ISSUU.

[190] Benin, Botswana, Cabo Verde, Cameroon, Chad, Comoros, Côte d'Ivoire, Democratic Republic of the Congo, Egypt, Eswatini, Gambia, Ghana, Guinea, Lesotho, Malawi, Namibia, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, Uganda, Zambia, Zimbabwe

[191] Countries include Angola, Congo, Equatorial Guinea, Madagascar, Sudan, Togo

[192] Sibal, P. and Neupane, B. (2021). "Artificial Intelligence Needs Assessment in Africa." UNESCO.

[193] Novitske, L. (2018). "The AI Invasion is Coming to Africa (and It's a Good Thing)." Stanford Social Innovation Review.

[194] Sibal, P. and Neupane, B. (2021). "Artificial Intelligence Needs Assessment in Africa." UNESCO.

[195] Access Partnership, Microsoft and University of Pretoria. (2018). "Artificial Intelligence for Africa: An Opportunity for Growth, Development, and Democratisation." University of Pretoria.

while unleashing the next generation of African digital innovators. The programme will be launching in Côte d'Ivoire, Kenya, Nigeria, Rwanda, and Senegal. In addition, it will establish 130 Centres of Excellence across Africa to help bridge the skills gap.

- The Organisation for Economic Cooperation and Development (OECD) is reviewing the economic and social impacts of AI technologies and applications, as well as the implications for policy. The organisation has launched an Expert Group on AI in Society for multi- stakeholder discussions to scope principles that will foster trust in and adoption of AI, and is actively conducting consultations to take stock of existing principles and best practices. The OECD is planning to launch a policy observatory in 2019 to ensure the beneficial use of AI.

- The United Nations (UN) is leading discussions in many avenues on AI's implications for member states.

    - International Telecommunications Union (ITU) is conducting work to foster inclusive global dialogue on beneficial AI, focused on impactful AI solutions able to yield long-term benefits and help achieve the UN's Sustainable Development Goals (SDGs).

    - International Labour Organisation conducts extensive work to research, raise awareness, and share best practices on the "future of work," especially as it is impacted by automation and artificial intelligence.

    - The UN Interregional Crime and Justice Research Institute has maintained a Centre for AI and Robotics since 2016 in the Hague, which gathers information and knowledge from experts to educate and engage stakeholders, including policy-makers on its implications for security.

    - The UN Commission on Science and Technology for Development (CSTD) and the Conference on Trade and Development, conduct work on the role of AI in achieving inclusive and sustainable economic growth. The latter has partnered with the Brazilian International Chamber of Commerce to explore the potential of AI to help trade negotiators, especially those from developing countries with fewer resources to devote to trade negotiations.

- Pulse Lab Kampala (Pulse Lab) in Uganda is the first innovation lab in Africa, and the third lab of the United Nation's Global Pulse network. It works through partnerships and in alliance with the Ugandan government to support the UN Country Team and the Government of Uganda to achieve the Global Goals for Sustainable Development. Pulse Lab brings together data scientists, data engineers, partnership specialists, academics and technical experts to generate high impact data analysis tools to address development challenges.[196]

With assistance from the organisations above, there are also numerous measures that governments, policymakers and regulators can take to nurture an environment that rewards innovation and AI development while maintaining agency for humans. Box 7 provides a summary of the recommendations from UNESCO's AI Needs Assessment in Africa. Moreover, a paper by Smith, Neupane, and Leonard recommends the following policy and regulatory interventions to create an enabling, inclusive, rights-based AI environment:

- Conduct baseline research on the prevalence of AI applications and policies in countries of the Global South, including research on AI policies, regulations, applications, existing open datasets, and skill levels.

[196] Taken verbatim from Access Partnership, Microsoft and University of Pretoria. (2018). "Artificial Intelligence for Africa: An Opportunity for Growth, Development, and Democratisation." University of Pretoria.

Box 7: UNESCO's AI Needs Assessment in Africa – Summary of Recommendations

Drawing from the results of their research, the UNESCO report on AI requirements in Africa makes two sets of recommendations. The first set of recommendations is for intergovernmental organisations, development organisations, and UNESCO Member States, focussing on processes that can facilitate development of better policies for AI Governance and that can support digital capacity building. They included facilitating digital cooperation between countries for knowledge exchange; adoping digital capacity-building models that consider local contexts; and encouraging multi-stakeholder collaboration for governance.

The second set of recommendations is for intergovernmental organisations, development organisations, and UNESCO Member States to address the implications of AI in the priority areas discussed in the survey, the report provides recommendations in nine key areas, which are discussed briefly below.

Policy Initiatives for AI Governance
Including developing an AI Policy toolkit, implementation guides and launching pilot projects to demonstrate how AI and training data can be used to seize the opportunities in Member States' priority areas. This also includes developing policy guidelines that address issues around gender equality in the AI sector.

Legal and Regulatory Frameworks for AI Governance
Adapting and testing frameworks for human rights risk assessments and due diligence on AI applications. UNESCO also recommends that stakeholders develop or update legal and regulatory frameworks for Personal Data Protection and Data Governance.

Building capacities to address legal implications of AI and uphold fundamental human rights
This includes recommendations to introduce sensitisation programmes for government officials on AI and its human rights and legal implications; developing training modules for judicial actors to tackle the legal aspects of AI; and raising awareness about the legal and policy implications of AI among parliamentarians.

Raising public awareness and understanding of AI
By training journalists to report accurately on AI-related issues including accurate reporting on gender biases in the sector and having stakeholders contribute to multi-stakeholder dialogue at country level.

Capacities to Develop Standards for AI Products and Services
Which includes calls to facilitate multi-stakeholder cooperation for development of industrial standards in cooperation; providing support training for development and implementation of AI technical standards for the development of products and services using AI responsibly; and ensuring equal participation of men and women in the development of standards for products and services through multi-stakeholder processes.

Capacities to address the ethical challenges of AI
Including building on processes that support UNESCO's Recommendation on the Ethics of AI; developing training programmes for inclusion of AI ethics education at different levels of the education system and facilitating knowledge exchange on ethical dimensions of digital technologies among policymakers.

AI educational resources
This includes supporting the development of open educational resources for AI education at all levels of the education system and for AI literacy amongst citizens; support the development of educational curriculum and teaching competencies for AI skills and knowledge education; and facilitating equal participation of males and females in AI education and training programmes and in the development and use of educational content.

Research capacities for AI:
Which recommends that stakeholders strengthen AI research collaborations between universities within Africa and internationally as well as between universities and the private sector; invest in knowledge exchange; launch new postgraduate programmes for R&D in Africa; and address gender divides by facilitating the participation of women in STEM fields.

Data and AI development:
This includes creating open research repositories, open access publishing tools and platforms for open government data; ensuring adequate safeguards for open data; developing standards for interoperability between datasets for ML; supporting new and existing networks of big-data commons and data enthusiasts; and organizing data challenges and hackathons to develop new datasets and enrich existing training datasets.

- Learn about effective regulatory models that have been developed to deal with new AI-driven activities. Determine the potential risks, whether they have been addressed by existing regulations, or if the existing regulation needs to be adapted or a new regulation developed.

- Conduct social and economic policy research to understand the effects of AI on employment, the nature of work, and labour markets.

- Explore approaches to addressing liability, accountability, and redress for AI decision-making.

- Study the impact of AI on human rights.[197]

Furthermore, a report by Technopolis, Research ICT Africa & Tambourine Innovation Ventures provides seven recommendations for African policy makers and regulators:

- Develop a united vision to seize the opportunities of the 4IR.

- Create incentives (financial, fiscal) for technology adoption in national priority sectors (e.g. agriculture and energy) and support small farmers to larger companies.

- Start preparing the next African workforce generation to be 4IR-ready.

- Bolster or redesign existing governance institutions to better prepare for challenges posed by data circulation.

- Develop collaborative and adaptive regulation.

- Seek harmonisation of data protection frameworks at regional level (REC) through compatibility between national legislation, based on a set of a core agreed data protection principles.

- Nurture inclusive institutions favouring and promoting widespread innovation to adopt 4IR technologies in productive and service sectors.[198]

The data demonstrates that countries in SSA are beginning to implement measures to usher in AI. Indeed, AI has the potential to uplift societies and can be used as a tool by governments for service provision, skills development and job creation. Moving forward, it will be critical for governments to strike a balance between creating a conducive environment for AI innovation while simultaneously protecting citizens from the complex and widespread pernicious uses of these technologies. Ultimately, AI needs to coexist with humans as it becomes increasingly integrated into our daily lives. The role that governments will need to play is that of mediating interactions between humans and AI through effective policy and regulation, as well as facilitating innovation and fair practice. There are several means of achieving this, including integrated policies, law, regulation, public discourse, stakeholder consultation, collaboration within and between countries, and strong, forward-looking leadership. A full set of recommendations for governments is provided at the end of this report.

Access the full UNESCO report here

[197] Smith, M.L., Neupane, S., Leonard, G. and Mendonca, C. (2018). "Artificial Intelligence and Human Development: Towards a research agenda." IDRC.

[198] Taken verbatim from Technopolis & Research ICT Africa & Tambourine Innovation Ventures. (2019). "Potential of the fourth industrial revolution in Africa: Study report. African Development Bank." African Development Bank.

Diversity in AI

Diversity is a critical component of an AI ecosystem that caters to users and citizens from varied backgrounds. A lack of diversity in AI has therefore been a hotly debated topic, particularly due to inherent biases in the sector in terms of workforce composition and AI systems themselves. This has highlighted a need to prevent racial, age, gender, disability and other discrimination by humans and AI.[199]

Diversity challenges in Centres of Higher Education and Training

For the Centres of Higher Education and Training research, there was a significant gender disparity in AI involvement amongst the respondents. Most respondents were male, and although several universities had notable AI-related activities, there were few incentives to support minorities and women in the AI ecosystem. Echoing the gender imbalances noted in the section on enrolment in AI academic offerings and other activities, several respondents highlighted the gender imbalances that they had experienced in AI and related fields:

> *It's pretty male dominated but has gotten better in the last few years. More females connect through intersections with AI in medicine or language processing... I would say we're lagging behind at [the institution] but we've been discussing how to bridge some of these divides and so on.*

> *Policy on gender is not very clear, if it does exist.*

Although one respondent noted that their institution was working with an industry partner to offer bursaries targeted at women and people with disabilities, most respondents indicated that their institutions did not offer incentives for women, people with disabilities, or people from other groups considered as minorities to participate in AI-related courses or qualifications. Several respondents mentioned broader merit-based programmes or opportunities:

> *We have a research fund to which everyone can apply, and when we are encouraging innovations and supporting them, we do not discriminate in selecting people. Since we don't have any specific AI programmes, it is difficult...*

> *I don't think there are incentives for anyone to go into AI related research and qualifications. We need to build the incentives for everyone. There are incentives for women at the university more broadly e.g. Women in Science.*

> *...There are a lot of bursary opportunities with specific targets they want to meet and those are aligned with trying to encourage more minorities. Some of the bursaries are from the universities, others from industry, and there are a lot from government.*

> *We try to encourage women to be part of these initiatives, but one of the stumbling blocks is a lack of funding. We have so many good initiatives, but there is less support from the government in terms of research, so it's really a challenge to get these things off the ground.*

> *We do not discriminate against anybody. Some express interest and others don't, but we give everybody a level playing field. We have scholarship funding where if*

[199] Diversity.ai. (2020). "Homepage."

> *you apply and are successful, you don't pay any university fees (people with disabilities and women can apply for these opportunities).*

Some respondents were unsure whether their institutions offered incentives for the minority groups:

> *I doubt it. I think there would be some incentives for minorities etc, but not within a specific field. Our faculty has activities to recruit women because the gender breakdown from undergrad to postgrad is skewed.*

> *Not sure if those things are properly carved out as a policy but I know that in engagements with faculty and recruitments, it is present.*

Notwithstanding this, efforts are being made to try to encourage women, people with disabilities and minorities to pursue AI-related paths. These efforts are being made at all levels, from undergraduate to postgraduate, as well as within communities of practice. They appear to mostly be aimed at gender imbalances as the following comments illustrate:

> *We're trying to engage more by doing more outreach events. We've been pushing a lot ... to have enough diversity in terms of things like race and gender.*

> *... there are initiatives for women in STEM, and AI falls into that... There [are] women in computer science network – a lot of community engagement in terms of recruiting women in STEM.*

> *I don't know if I can speak on behalf of faculty level initiatives, but our Dean is encouraging participation from women in particular – especially in male-dominated fields. In terms of specific incentives, I'm not so sure.*

> *We are seeing a lot of work going into this. We had a recent call for research funding, but one of the key things that the committee is looking for is what balance do you have in the team and how is the solution going to contribute to gender equality.*

These efforts suggest a significant opportunity to build AI capacity in SSA. Because the field is relatively new, it is possible to lay a foundation that is inherently supportive of women and minorities, compared to countries where AI is more established, and the disparity is institutionalized.

The diversity gap in the AI Community

UNESCO's latest publication on gender biases in AI like Apple's Siri and Amazon's Alexa, entitled *I'd Blush if I Could*, shares strategies to close gender divides in digital skills through education. The first part of the paper highlights the persistence and extremity with which the gender gap in digital skills is reinforced, provides a rationale for interventions, and offers recommendations to facilitate an environment in which women and girls can develop strong digital skills. The second part of the paper outlines the 'ICT Gender Equality Paradox' – the fact that countries with the highest levels of gender equality tend to have the lowest proportions of women pursuing advanced degrees in computer science and related subjects. Conversely, countries with lower levels of gender equality have the highest proportions of women completing advanced technology degrees. The report concludes by offering 18 recommendations to help prevent digital assistant technologies like Siri and Alexa from perpetuating existing gender biases and creating new forms of gender inequality. These recommendations comprise four themes, which are:

- Document and build evidence on AI technologies and the gender biases that they may hold, perpetuate, or facilitate.
- Create new tools, rules, and processes that do not reinforce gender stereotypes or biases.
- Apply gender-responsive tools to digital skills development.

- Ensure oversight and incentives to promote gender equality.[200]

Similarly, a WEF-LinkedIn study found that Germany, Brazil, Mexico, and Argentina have among the world's most significant AI gender gaps, with just 16% of the AI talent pool being female. The smallest AI gender gaps are in Italy, Singapore, and South Africa, where 28% of the talent pool is female. Globally, the WEF has found that just 22% of AI professionals are female, accounting for a gender gap of 72%.[201]

Gender inequality is a pervasive issue, permeating all social and professional spheres. Technology, and AI in particular, has the potential to perpetuate or even worsen gender inequality. As AI becomes more prevalent, there remains underrepresentation of marginalised groups in these and related fields. Because AI and its applications are known to hold inherent bias, there exists the possibility of gender biases being perpetuated and stimulated through these technologies.[202] A report by the WEF on gender gaps in AI notes:

> *The gender gaps evident within the AI talent pool reflect both the broader gender gaps within specializations in Science, Technology, Engineering and Mathematics (STEM) studies; gender gaps across industries; and gender gaps in the acquisition of emerging skills.[203]*

However, organisations in Africa are making an effort to equalise the field. For example, the Benin-based startup femCoders is a community of women who train their peers in robotics and programming such as logic and languages, Blockly and Scratch games, drawing and 3D printing, and creating websites using HTML. The initiative aims to build the technical capacity of women and provides an environment for them to share their knowledge with their peers.[204]

Diversity issues persist when looking at racial diversity. A report from New York University's AI Now Institute found that only 2.5% of Google's workforce is black, while Facebook and Microsoft are each at 4%. The report highlights what the authors refer to as a 'diversity crisis' in the AI sector across gender and race, explaining:

> *The overwhelming focus on 'women in tech' is too narrow and likely to privilege white women over others. We need to acknowledge how the intersections of race, gender, and other identities and attributes shape people's experiences with AI.[205]*

Not only are there gaps in human involvement in AI and related areas, there are also biases within the AI themselves. As Professor Tshilidzi Marwala from UJ notes in a published opinion piece, 'the social, political and economic conditions that are prevailing at this time, which is that Europe and North America are dominating the social, economic, technological and political spaces, are being reproduced by artificially intelligent machines and thus making these machines biased.'[206] He explains that AI holds inherent biases that favour the identities of those who build them. To make AI more inclusive there needs to be diverse representation of people who work in AI-related fields. Governments and organisations also need to build this diversity into the AI themselves – something that is much easier with a diverse workforce.

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[200] UNESCO and EQUALS Skills Coalition. (2019). "I'd Blush if I Could: Closing Gender Divides in Digital Skills through Education."

[201] MacGregor, K. (2019). "Greater gender diversity vital for AI to serve needs of society." University World News.

[202] Kumar, S. (2019). "AI could perpetuate gender inequality through inherent bias." BizCommunity.

[203] World Economic Forum. (2018). "Global Gender Gap Report." World Economic Forum.

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Figure 26 Do you see diversity as being an issue in AI in your country/ institution/organisation?

Most respondents (58%) from the AI community survey saw diversity as being an issue in AI in their country, institution or organisation. When asked to explain further, respondents indicated diversity issues in three aspects. First, they pointed out gender disparities in the AI sector and beyond:

> *Generally in the tech space, there are very few women involved at all levels from research, design and use of these innovations*

> *There are not enough women, people of colour and other minority groups in AI. This is a problem because fairness and bias are very pressing and important issues in AI at this point in time and we cannot solve these problems without a diverse group of AI practitioners.*

> *I do think it is a problem in AI, but I do not think it is a problem *only* in AI. It is a problem in general in our society, and I think it is reflected in tertiary education and academia, and therefore in AI/ML as well. In science and engineering in general, gender diversity is a big problem, and in all forms of education in South Africa racial diversity is a problem.*

Second, respondents highlighted a lack of racial diversity in some instances, explaining that there were 'not enough Africans' in the sector and that people of colour have been underrepresented in the sector. The three respondents who noted this were all from South Africa, a country that has a history of racial segregation and oppression, the effects of which have left an enduring legacy and unequal access to opportunities.

Third, respondents noted that class dynamics came into play within the sector, including employee requirements for postgraduate degrees and a concentration of activities in urban areas:

> *Required skillset often requires postgraduate degrees - most of whom come from a privileged space.*

> *Besides lower engagement of women, there is also a concentration of AI activities in urban areas and barely anything being done in rural areas.*

In response to these disparities, respondents called for greater diversity and representation in the AI sector:

> *At the end of the teaching / training funnel, our talent pool is small. Having role models from across the spectrum of cultural and other backgrounds, will make the pool of youngsters at the start of the funnel much bigger!*

While these findings are sobering, they provide a significant opportunity for the burgeoning AI market in SSA, where AI and related technologies can create and reinforce equality through skills development and concerted efforts to level the playing field for marginalised groups in the industry. Critically, this requires moving beyond paying lip-service to the diversity and inclusion gap and instead creating an AI ecosystem where diversity is as an entrenched norm.

Key Takeaways and Recommendations

As the information age continues on its rapid course towards increasingly sophisticated technology, the development of AI has become inevitable. For SSA countries, progress in this regard has been slow, but can be accelerated through concerted efforts by governments, Centres of Higher Education and Training and the AI community to research, collaborate, and invest in a future that harnesses the power of AI for the benefit of their citizens. This research has demonstrated that these stakeholders have begun to lay the groundwork for a future in AI through compelling research, early-stage policy development, implementing ICT infrastructure and responding to community needs using AI. Although this research has reported various successes within the AI ecosystem in SSA, it has cast a critical eye on the potential for misuse of this powerful set of technologies. Below are the key takeaways from this research.

Key Takeaways

Taking available data into account together with the desktop review of literature and the findings from UNESCO's AI Needs Assessment in Africa, below is a summary of the key takeaways from this research.

AI-related Academic Activities

- Formal education, on-the-job experience and teaching oneself are regarded as the most beneficial ways to develop AI expertise. Respondents evidently derived value from teaching themselves about AI and related concepts, implying that the role of upskilling people with technical skills should not be limited to formal education, although formal education also has a key role to play.

- Comprehensive formal education that equips students with knowledge and skills across their school careers will better position them to enter AI-related fields. This includes education that focuses on building competencies in the hard sciences such as Science, Technology, Engineering and Mathematics (STEM), as well as building soft and critical thinking skills in the Humanities and Social Sciences.

- Skills related to training ML algorithms and associated competencies are one of the most important skills sets required to develop AI activities. This is followed by programming skills and probability and statistics.

- There was considerable enrolment across the region in AI-related courses and qualifications at both undergraduate and postgraduate levels, with males in the majority. Being mindful of the small number of courses for which enrolment data was provided, the graduate output and enrolment data suggests that a number of students are participating in AI-related qualifications and courses and that in many cases, demand exceeds supply.

- The difference in enrolment figures between undergraduate and postgraduate students shows that large numbers of students do not go on to pursue postgraduate training in AI-related fields. There are likely to be various reasons for this, including that there are generally fewer postgraduate than undergraduate enrolments in any field, but the specific reasons were not clear in the data available so further research is needed to explain this trend.

- Several institutions that participated in the study did not provide detailed enrolment data. This lack of enrolment data from a broad sample of institutions indicates a need for comprehensive data collection and sharing practices on enrolment, graduation and attrition rates for AI-related degrees and qualifications, together with national level higher education data collection and reporting. This data will be critical to ensuring the success of

AI-related academic offerings at universities, as well as measuring how they relate to broader institutional and national goals of promoting AI-related activities.

- The majority of institutions who participated in the research are planning on offering new AI-related courses or qualifications in the next three to five years, as well as adding AI-related aspects to existing degrees or courses instead of creating standalone degrees. This includes offering courses on image processing, ML, Robotics and Natural Language Processing. It was clear that new offerings were dependent on both student demand for AI qualifications and institutional capacity.

- It is crucial to consider demand and supply of AI-related courses and qualifications at these institutions – building capacity for AI at Centres of Higher Education and Training depends significantly on raising awareness amongst students about the option of studying these types of programmes, as well as upskilling them with the foundational skills to be eligible to enrol.

- There is a need for greater capacity – both in terms of the number of Centres of Higher Education and Training working on AI and in terms of potential employers – to ensure employment opportunities for their graduates. This should take a holistic view of the AI ecosystem in SSA. Just as it is important to ensure that Centres of Higher Education and Training prepare students to work in AI-related fields and sectors, so too is it important to build capacities within the organisations that employ them, particularly because countries all over the world are expected to experience significant job displacement across all industries as a result of AI.

- Other capacity issues included a need for AI experts and lecturers, time constraints in undertaking teaching and research duties, and needing more capacity to supervise larger numbers of postgraduate students. Some of these constraints might be addressed by developing joint academic programmes in partnership with other Centres of Higher Education and Training, supported by industry or government partners.

- There was an interest in and attendance of AI-related short courses, training opportunities and workshops, although events were still mostly attended by males. Respondents also noted considerable involvement in AI communities of practice, including Data Science Africa and the Deep Learning Indaba. These provide a basis for further development of AI work and demonstrate that there is a growing African AI community of practice. Integrating communities of practice into Centres of Higher Education and Training would be a useful way of consolidating and growing AI activities.

- At the national level, governments require greater support for AI education, research and training. This includes ensuring that education systems are responsive to AI skills and competency requirements, improving research capacity, and providing AI-related trainings for workers.

Research and Development

- Respondents provided numerous examples of research in various AI-related fields, including Robotics and Autonomous Intelligence, Health and Biology Agriculture and Disaster management, Development, Language and Physics.

- Although most interview respondents indicated that AI research and development is a priority for their institutions, some noted that their department or school was prioritizing AI as opposed to their institution more broadly.

- There is considerable engagement between academia and organisations working with AI and related technologies. This included R&D, lecturing, providing content for course materials, supervising theses, hosting events, providing internships and bursaries, as well as developing programmes, streams, and modules in Data Science, AI, and ML. However,

there was a lack of engagement between government and diverse stakeholders in the broader AI community.

- Creating a robust AI ecosystem in SSA will require institutional commitment to AI-related activities – it will be necessary to implement solutions in higher education with a view to changes we want to inspire and capacities that we want to develop in broader society. This will require institution-wide support for AI-related R&D, particularly given the emphasis of respondents on the multi-disciplinary nature of AI work.

- At Centres of Higher Education and Training, most respondents indicated that their institutions did not have mechanisms solely available to fund AI research and development. Many noted, however, that there were general funding mechanisms available that could be used for AI research and development. Partnerships with government and industry could raise additional funding for AI-related research and development.

- There is a need to increase output of AI-related educational resources, to increase fundamental and applied AI research, and provide access to resources for research, including AI research networks.

Policy Environment

- The research identified very few policies aimed directly at AI-related activities at Centres of Higher Education and Training, with respondents indicating that many of them were general policies that governed their institutions and not AI teaching and research in particular. Despite this, respondents did seem to derive some value from existing policies.

- While it might hold true that an over-regulated environment can sometimes stifle innovation and that this is particularly applicable to AI, encouraging Centres of Higher Education and Training to adopt a few critical policies can go a long way to ensuring fair practices.

- At the national level, countries in SSA need to create legal and regulatory frameworks for AI governance, as well as improving and implementing policy initiatives for AI governance. This might include implementing legal measures for new applications of AI and related technologies; launching AI strategies and policies; implementing legislation; and developing ethical guidelines for AI.

Challenges and Capacity Building Needs

- Respondents noted a diverse set of challenges that they thought were hindering the development of AI in their countries. One of the most prominent of these was a lack of quality education in AI and related fields. Other requirements include a need for capacities in AI governance; and human capacity for addressing the ethical implications of AI.

- Respondents also highlighted funding issues regarding AI-related activities – early-stage start-ups struggle to raise capital, universities have difficulty in securing funding for their equipment and research, and governments are operating in resource constrained and often corrupt environments.

- They also noted a lack of technical expertise and issues with funding and infrastructure – including a lack of reliable internet.

- In considering which sectors would see the most growth in demand for AI applications over the next five years, healthcare applications were most popular. Respondents also noted commercial enterprises, financial services, and education.

- Although SSA countries' AI priorities are diverse, they provide an opportunity for collaboration on key priority areas such as personal data and data governance; leveraging AI for economic growth; and supporting start-ups and digital innovation.

Diversity in AI-related Activities

- Many respondents saw diversity as being an issue in AI in their country, institution or organisation, the most prominent of these being a lack of gender diversity.

- In the Higher Education and Training sector, there were more males involved in AI-related activities than females. This is perhaps unsurprising given global gender imbalances in the sector as well as a general lack of diversity. Most respondents indicated that their institutions did not offer incentives for women, people with disabilities, or people from other groups considered as minorities to participate in AI-related courses or qualifications. There were, however, broader merit-based programmes or opportunities. It became clear over the course of the research that some efforts were being made to try to encourage women, people with disabilities and minorities to pursue AI-related paths. These efforts are being made at all levels, from undergraduate to postgraduate, as well as within communities of practice and the broader AI community. They appear to mostly be aimed at gender imbalances.

- The findings indicate a significant opportunity for the AI market in SSA, where AI and related technologies can be used to create and reinforce diversity. Key to this will be to facilitate and promote skills development of diverse people and make concerted efforts at levelling the playing field for women and other minorities in the industry. There is a clear role for Centres of Higher Education and Training in these efforts. These institutions can introduce funding schemes to improve the uptake of diverse groups, remove biases from staff recruitment procedures and ensure that women and other minorities are supported and incentivized to study further than the undergraduate level.

Recommendations

Drawing from the findings of this report, the following detailed recommendations are offered to each of the three stakeholder groups:

Centres of Higher Education and Training

AI-related Academic Activities

- Create data and ethics committees to protect human research subjects and regulate activities to ensure that there are no rights violations. Centres of Higher Education and Training can begin by engaging with institutional stakeholders and forming a balanced, experienced team for each committee. Committees can meet regularly but will need to strike a balance between providing ethical direction and not stunting innovation by burying activities in bureaucratic processes.

- Encourage the development of open data standards, which will facilitate access to AI training data and allow different datasets to be used interoperably. Note that in promoting open data standards, privacy and security should remain a priority.

- Develop frameworks to allow individuals to cultivate the skills that they need to thrive in a rapidly changing environment. This will include the following key actions:

    - Update curricula regularly so that they remain responsive to job market trends and skills requirements.

    - Create research repositories, promote open educational practices and offer online courses to increase access to AI-related content.

    - Improve university offerings to ensure that they are interdisciplinary in nature and that they equip students with both hard and soft skills. For example, disciplines such

as Art, History, Economics, Ethics, Languages, Philosophy and Psychology might be used to teach critical, philosophical, and ethical skills which will be key to R&D and management solutions for AI. New academic offerings are dependent on student demand and institutional capacity in several forms. Centres of Higher Education and Training might consider auditing all existing academic offerings (including their content and the demand for them) to get a sense of how current offerings align with institutional and national AI-related skills development plans. These findings can guide plans for new offerings or changes to existing offerings.

- Provide opportunities for students to develop skills outside of the academic environment through internships facilitated by the institution; and

- Cater to those wanting to engage in continuing professional development activities through additional offerings (such as short courses and workshops) and flexible timelines. Steer the institutional ethos (through both policy and academic activities) in a direction that promotes lifelong learning.

- Encourage inter-institutional collaboration by inviting visiting Professors with AI-related knowledge and skills as well as collaborating on research with institutions in the region and international institutions.

- Encourage students to pursue postgraduate training, ensuring that academia is an attractive career prospect that can compete with a career in industry. This includes providing incentives for students to pursue further studies and careers in the sector such as funding for studies, research grants, teaching contracts, and travel opportunities for conferences and other international engagements.

- Undertake comprehensive and regular data collection on enrolment, graduation and attrition rates for AI-related degrees and qualifications. Make this data openly available. This data can be used to tailor AI-related academic offerings at universities, as well as to measure how they relate to broader institutional and national goals of promoting AI-related activities.

- Undertake awareness-raising and promotional activities aimed at current and prospective students so that they understand what their options are with regard to study in AI-related fields.

- Partner with potential employers to ensure employment opportunities for graduates and align academic offerings with skills requirements. This should take a holistic view of the AI ecosystem in SSA.

- Build human capital capacity in key areas by employing AI experts and lecturers, providing sufficient time for staff to undertake teaching and research duties, and increasing capacity to supervise larger numbers of postgraduate students. Resource constraints in this regard might be addressed by developing joint academic programmes in partnership with other Centres of Higher Education and Training, supported by industry or government partners.

- Integrate communities of practice into Centres of Higher Education and Training to consolidate and stimulate AI activities. AI-related short courses, training opportunities and workshops, as well as involvement in AI communities of practice provide a basis for further development of AI work.

Research and Development

- Provide institutional support for AI-related R&D. This can be achieved through facilitating strategic partnerships with industry and government and hosting AI-related activities such as symposia, conferences and communities of practice.

- Bolster institutional funding sources – both general funding and AI-specific funding for R&D. Partnerships with government and industry could raise additional funding for AI-related R&D, as could redirecting institutional funds where possible to support these activities.

- Provide support for African researchers to attend conferences and work with international governments, Centres of Higher Education and Training, and private sector to encourage their support for researchers from SSA.

- Promote multi-disciplinary research on the socio-economic and political effects of AI.

- Conduct research into how to create a sustainable AI ecosystem that responds to the needs of communities in SSA. Encourage further research on current AI capacity and requirements to gain a better sense of what types of infrastructure, technology, access, support, systems and personnel institutions require to contribute meaningfully to the AI ecosystem.

Policy Environment

- Review existing policies from other institutions to gain insight into pertinent issues that should be covered in institutional policies.

- Lobby government to develop national policies for AI Centres of Higher Education and Training that promote access, enable security, facilitate privacy and rights protection, encourage multistakeholder collaboration in the field, and provide support for these institutions through funding and human capital.

- Participate in policy formulation processes on AI-related activities at Centres of Higher Education and Training.

- At the institutional level, encourage governance structures to adopt a few critical policies as a start in developing a robust institutional policy environment. The following policies might be considered:
-
    - Ethics, data management and privacy policies;
    - Intellectual property policies as they relate to AI; and
    - Policies setting out institutional AI priority areas, how resources will be allocated and encouraging collaboration across faculties and departments.

Promoting Diversity in AI-related Activities

- Provide incentives for women, people with disabilities, or people from other groups considered as minorities to participate in AI-related courses or qualifications. Incentives might include bursaries, opportunities for on-the-job training and mentorship programmes.

- Support minority groups already involved in AI-related academic activities or research.

- Use AI and related technologies as an opportunity to create and reinforce diversity. Key to this will be to facilitate and promote skills development of diverse people and to make concerted efforts at levelling the playing field for women and other minorities in the industry. Centres of Higher Education and Training can also remove biases from staff recruitment procedures and ensure that women and other minorities are supported and incentivized to study further than the undergraduate level.

- Develop open access datasets so that developers can train algorithms on minority datasets.

Members of the AI Community

The research has shown that the AI community in SSA is diverse and contains several stakeholders including – but not limited to – developers, data scientists, entrepreneurs, SMEs, venture capitalists, researchers, manufacturers, service providers and big business. The recommendations below, aimed at the AI community as a whole, take this diversity into account. As such, certain recommendations are applicable to specific stakeholders within the AI community.

Promoting Holistic Education

- Members of the AI community, including industry, NGOs and civil society, can facilitate exchanges with educational institutions, including Centres of Higher Education. This includes collaboration on R&D, lecturing, providing content for course materials, supervising theses, hosting events, providing internships and bursaries, as well as developing programmes, streams, and modules in Data Science, AI, ML, the Humanities and Social Sciences.

- Promote the development of educational opportunities for staff and students in the AI community. For institutions that work with students, this might include funding formal education opportunities or internships. Organisations who employ staff might consider allocating funding for their staff to attend conferences, creating in-house educational content to upskill staff, and collaborating with partners in the education space to offer upskilling opportunities.

- Encourage staff to undertake self-learning activities by giving them time off for professional development and facilitating secondment opportunities for them.

Engagement with other Sectors

- Collaborate with government on AI-related R&D and form public-private partnerships that aid this.

- Lobby government for regulatory and policy development that supports AI-related activities and creates a fair playing field that protects citizens. This might include policies for ethics, data and privacy protection, intellectual property, and innovation. It might also include supporting implementation of these policies, engaging with government representatives and petitioning for laws.

- Provide guidance on technical issues to steer the national strategic direction with regard to AI.

- Encourage the formation of professional bodies in AI and related fields, which will promote regulations, codes of conduct and ethical standards.

AI Capacity Building

- Support infrastructure development by providing technical expertise, human capital and other resources.

- Donate time, skills and resources to organisations and institutions who seek to promote AI-related activities. This might include zero-rating websites with useful resources for skills development, developing open educational resources, and gifting equipment like servers to NGOs.

Encouraging Diversity in the AI Community

- Support the work of NGOs and organisations that promote diversity in AI.

- Direct funding to organisations that promote diversity and organisations that are doing research to combat the lack of diversity.

- Ensure that recruitment processes are fair and seek to create a diversified workforce (in terms of gender, race, sexual orientation, differently-abled individuals and other minorities)

- Include the diversity dimension in organisational policies, highlighting practical activities to promote inclusivity and ensuring compliance to diversity requirements.

- Create fora and guidelines to discuss diversity and devise concrete plans for making the AI community more inclusive.

Government

UNESCO's AI Needs Assessment in Africa provides a detailed view of current AI capacities that governments possess as well as key development areas. Drawing on UNESCO's report and the desktop research that AI4D undertook, the following recommendations are offered to complement those in the UNESCO report:

Building national AI capacity

- Prioritise infrastructure development in key areas, including internet provision and networking infrastructure, storage capacity and security provision. Building capacity in these areas will also encourage foreign investment.

- Leverage the social benefit of AI on behalf of citizens by supporting initiatives that improve peoples' lives in health, education, agriculture and other sectors. Support may include funding, facilitating partnerships, developing tax incentive programmes and reducing barriers to entrepreneurship.

- Collaborate with Centres of Higher Education and the AI Community at large in aid of responsive policy formulation by including these stakeholders in processes and consultations.

- Give intensive focus to AI ethics, privacy and data protection and human rights protection measures. This may include appointing advisors on these issues, formulating policies in favour of privacy and data protection, as well as passing laws and conducting national drives to implement these laws.

- Conduct regular monitoring and evaluation on government activities and funding allocations with respect to AI.

- Build internal government capability and capacity that sufficiently equips public servants to procure, use, manage and evaluate AI initiatives. This might include soliciting the services of academic institutions and the private sector to provide training for public servants; employing AI specialists in government; and providing AI-related funding schemes and employment opportunities for students in AI-related fields.

Policy development and Creating a Fair AI Ecosystem

- Include a diversity dimension in national policies and strategies, highlighting practical activities to promote inclusivity and ensuring compliance to diversity requirements

- Where applicable, focus on curbing corruption through effective law enforcement, reforming financial management and promoting transparency and accountability for government activities. This will free up funding that can be directed into AI-related activities.

- Promote responsible use of AI by keeping the public informed on what AI is, how it is used, and what their rights are.

- Ensure that those creating AI are accountable by advocating for excellence and consistency in regulatory systems and imposing strict penalties on transgressions.

- Countries need more comprehensive data collection on AI activities and capacity building needs. Government can assist by keeping archival material, supplying open datasets and creating data repositories.

- The AI sector in Africa has received hundreds of millions of dollars in government and private sector investments over the past decade. To accompany investment strategies in AI, governments can develop effective instruments to co-ordinate investment across local and national government, engage with stakeholders throughout the investment cycle to reorient investment where necessary and as new trends come to light, and coordinate efforts with the private sector and financial institutions to diversify funding streams and increase capacities.

Facilitating Regional Integration

- Participate in the development of a regional vision for AI and technological innovation. The AU's African Digital Transformation Strategy (2020-2030) provides a good basis for this that can be built upon to respond to AI capacity building requirements more directly.

- Establish working groups that tackle the application of AI for education, health and other key areas. This would curb the chances of duplication on the continent and would be an efficient way to channel resources.

- Prioritise regional integration and cooperation to increase SSA's standing in the global community. Participate in regional and interregional dialogue, create mutually beneficial skills development programmes, and enter into goods and services trade agreements. SSA countries can make use of instruments such as the African Free Trade agreement to this end.

Setting an agenda for AI capacity building in SSA

The results of this research demonstrate that there are notable AI-related activities in all three stakeholder groups. One of the main limitations of this research was a lack of accessible data on involvement in AI-related academic offerings, R&D and AI community activities. Despite this, the available data points to a burgeoning ecosystem that uses AI in innovative ways. But there is a long way to go to ensure that SSA becomes globally competitive. To fully harness the opportunities that AI offers, SSA as a region will, amongst other things, need to change governance structures to support innovation, institute consumer protection laws and revamp education systems to cater more directly to AI-related fields, while supporting the AI community with resources. If the region will not or cannot move beyond existing infrastructure and capacity challenges, SSA countries risk falling behind in AI adoption. This will, in turn, accentuate the digital divide and decrease their ability to compete globally.

In line with the recommendations presented in this report, the key to creating a vibrant AI ecosystem is committed stakeholder engagement that pushes individual countries and the SSA region as a whole forward by building capacity in key areas. Building this ecosystem will require institution-wide changes, funding, cross-institutional and cross-sector collaboration, as well as a commitment to prioritizing AI activities. This process also provides an opportunity for the burgeoning AI market in SSA to employ AI and related technologies to facilitate and reinforce equality through skills development and concerted efforts to level the playing field for marginalised groups in the sector. Critically, this creates an imperative to develop an AI ecosystem where diversity is an entrenched norm.

Appendix 1: Research Methodology

Centres of Higher Education and Training

This research was conducted using two instruments, a survey for Centres of Higher Education and Training and a follow-up interview schedule for key institutions and AI thought leaders/ champions who are involved in AI-related activities in SSA.

The research team compiled a list of 89 individuals at institutions across SSA. This included individuals in Computer Science departments or involved in AI-related activities at universities. The Centres of Higher Education and Training survey was first distributed on 25 June 2019. This was followed by four weekly email reminders to respondents who had either partially completed the survey or who had not completed it at all. Snowball sampling was also used, working from the original list. Based on referrals from these individuals, additional people were contacted to complete the survey and/or to be interviewed. Following a poor response rate in the first three weeks after the survey was released, responses to the surveys improved after submitting the Centres of Higher Education and Training survey link to Knowledge for All's (K4A's) network.

To get better representation from Francophone speaking countries, the IDRC distributed the Centres of Higher Education and Training surveys at the Francophone Open Data Conference, which was held from 17-20 December 2019 in Abidjan, Ivory Coast. There was, however, no increase in the response rate during this period.

Once the survey was closed, the dataset was cleaned, removing all incomplete responses and irrelevant responses.[207] Following this, the total number of responses analysed in the dataset was 43, 39 of whom responded to the English survey and four to the French survey. There were no responses to the Portuguese survey.

In addition, the research team conducted 24 follow-up telephone interviews with representatives from Centres of Higher Education and Training who are involved in AI-related activities, most of whom had submitted survey responses. These structured interviews were conducted using the interview schedule and took place predominantly over Skype, except for one face-to-face interview and two respondents who provided written answers. Each interview lasted about an hour, the purpose being to elicit greater detail than the survey on AI-related activities.

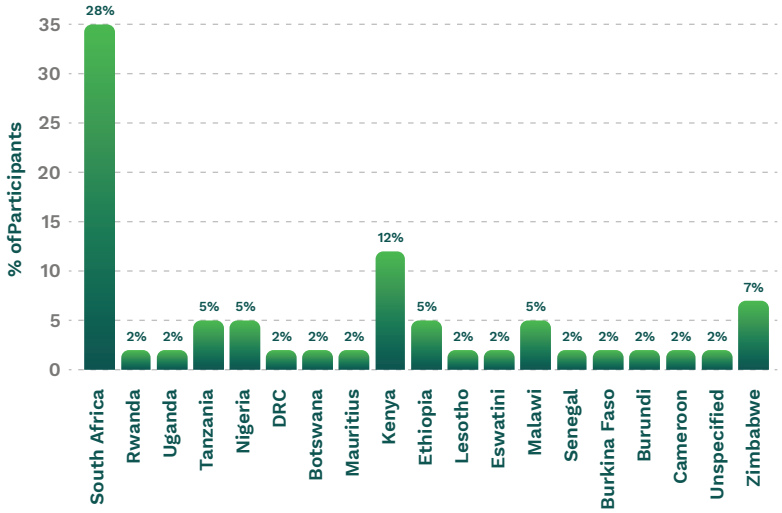
Demographic Breakdown of survey and interview respondents

The results of both the survey and interviews have been integrated across relevant themes. Where results are reported per institution, responses were only counted once for institutions where more than one respondent answered the survey. After the survey data was cleaned to remove incomplete and duplicate responses, a total of 43 responses were included in the analysis. The sample (Figure 27) represented institutions from 18 countries in SSA, including South Africa (35%), Kenya (12%) and Zimbabwe (7%). One of the responses was from an unspecified country.

For most institutions, one representative responded on behalf of their institution, although five institutions provided responses from more than one respondent.

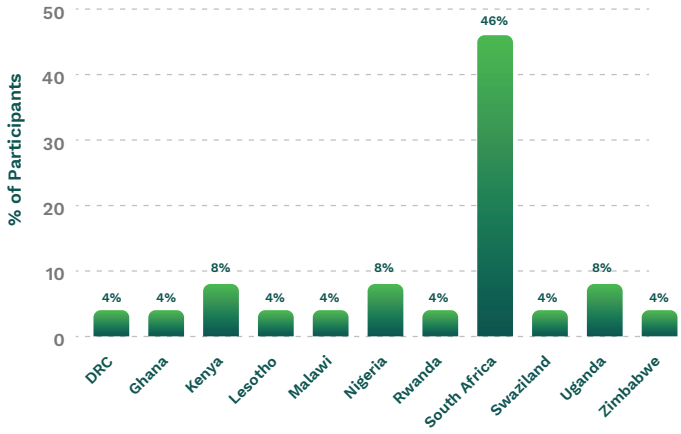
[207] Incomplete responses included all responses where respondents had only provided demographic information. Irrelevant responses refers to responses where individuals were not from Centres of Higher Education and Training and/or not from Sub-Saharan Africa. There were six such responses that were removed from the dataset. These individuals were from institutions in Canada, Morocco, South Africa, UK, and Japan

Figure 27 Survey Respondents by Country



The 24 interview respondents (Figure 28) represented 11 countries and 19 institutions. Countries represented included South Africa (46%) and Kenya, Nigeria, and Uganda (8% each). One representative from each university was interviewed, except for four institutions in Nigeria, South Africa and Uganda, where more than one respondent was interviewed.

Figure 28 Interview Respondents by Country



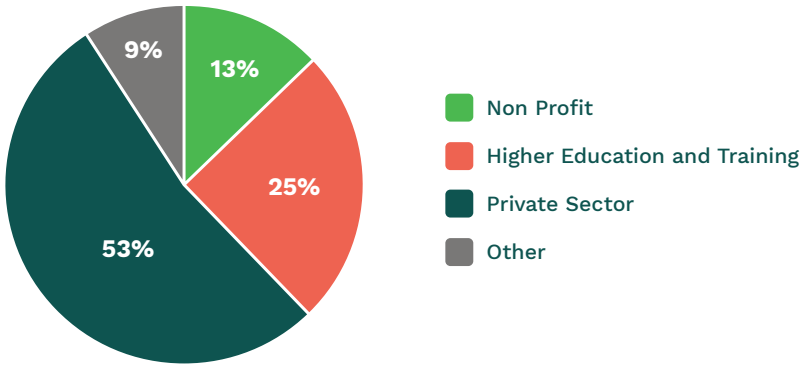
Although every attempt was made to ensure that the sample was representative of AI-related activities across SSA, there was a bias toward South African respondents in both the survey and interview data. There are likely to be multiple reasons for this. First, follow-up interviews were conducted in English, therefore favouring respondents from English-speaking countries. Second, the survey data and desktop research pointed to several AI-related activities occurring in South African Centres of Higher Education and Training, therefore necessitating follow-up interviews at those institutions.

Limitations

The major limitation of this research has been the difficulty in obtaining responses from individuals at Centres of Higher Education and Training. Repeated attempts were made to contact individuals either to complete the survey or agree to an interview. On average, the team contacted each potential respondent five times.

A related limitation was the challenge of obtaining comprehensive enrolment data on AI-related degrees, courses, and other activities at Centres of Higher Education and Training. The team made several attempts to follow up with interview respondents to provide this data but in many instances, enrolment data was not shared. Respondents provided various reasons for not being able to provide this data, including not having access to enrolment data and not being sure whether they were permitted to share the data.

Figure 30 Respondents by country



AI Community

Research on the AI community was conducted using a survey that was sent to the AI community in SSA. Through desktop research, the research team compiled a list of contact details for individuals and organisations who were undertaking notable AI activities in SSA. The community survey on capacity building needs was translated from English into French and Portuguese. All three surveys were first distributed to representatives of 57 AI-related organisations from SSA on 25 June 2019 via SurveyMonkey. This was followed by four weekly email reminders to individuals who either had not completed the survey, or who had only partially completed it. A snowballing method was used during data collection where the team sent the survey to individuals that respondents recommended. Following a weak response rate, the team began contacting individuals on the list via email or telephone to request that they complete the survey.

In addition to the above, K4A distributed the survey to their network. To get better representation from Francophone speaking countries, the IDRC distributed the French version of the AI Community survey at the Francophone Open Data Conference, which was held from 17-20 December 2019 in Abidjan, Ivory Coast. There was, however, no increase in the response rate during this period.

All data was compiled into an Excel spreadsheet, where the dataset was cleaned to remove any duplicates as well as invalid and incomplete responses.[208] Following this process, the final dataset included 32 responses. This set of responses comprised 30 English responses, two French, and no Portuguese. One of the respondents who is originally from a Sub-Saharan African country was based at a university in the USA but answered the survey with the South African context in mind. Another respondent, based at a higher education institution in the UK,

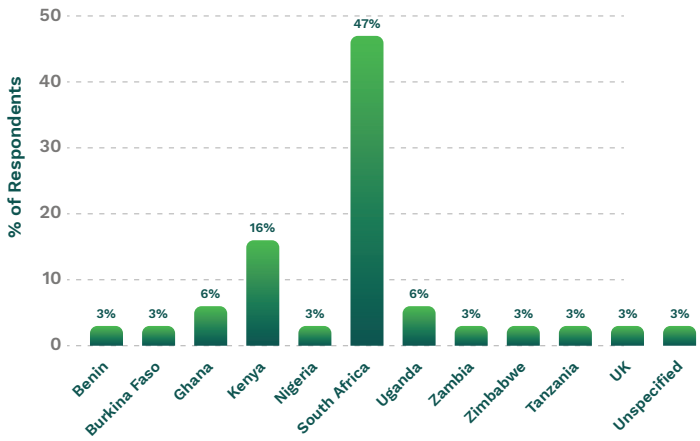
[208] Incomplete responses included all responses where respondents had only provided demographic information. Invalid responses were those where the individuals who completed the survey did not represent a Sub-Saharan African organization. There were three such responses that were removed from the dataset. These individuals were from initiatives in The Netherlands, the UK, and Canada.

is involved in a Community of Practice based in SSA. As such, these responses were included in the final dataset.

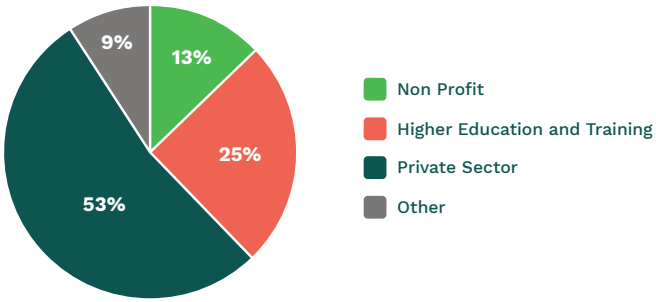
Demographic information

The sample comprised 32 respondents from 11 countries and one from an unspecified location who represented a global organisation that operated in SSA countries (Figure 30). The greatest number of respondents (47%) were from South Africa, followed by Kenya (16%). A breakdown of the number of respondents per country can be found in Figure 30.

Figure 29 Respondents by sector



Considering respondents in terms of the sectors that they presented (Figure 29), the majority were from the private sector (53%), followed by those representing higher education (25%).



Respondents represented several industries, many of them undertaking AI or ML research in that industry. These industries included:

- Software development, innovation and IoT (4)
- Manufacturing (1)
- Information Technology (IT) (3)
- AI/ML Research, Development and Community Building (5)
- Agritech (1)
- Speech and language processing (1)
- Education (2)
- Government (1)
- Makerspace (1)
- Healthcare (1)
- Inter-governmental organisations (1).

Limitations

One of the main limitations in the data was the disproportionate representation of South African initiatives. There might be several reasons for this, for example, there could be a greater number of AI-related South African initiatives in the region or these initiatives might be more comprehensively documented and therefore easier to locate to include in the sampling frame. A related limitation was the very low Francophone and lack of Lusophone responses. Although every effort was made to garner wide representation in the initial sample – including widening the desktop review for identifying contacts to include French and Portuguese websites and following up with respondents to complete the survey an average of four times – it was difficult to elicit responses from these initiatives. A third limitation was the overlap between responses – 25% of respondents represented the higher education sector in different capacities, including through government or higher education focussed organisations. This overlapped with related research that the team was conducting on AI capacity of Centres of Higher Education and Training in that two AI Community survey respondents represented a university that was accounted for in the Centres of Higher Education and Training report. However, these respondents were not the same ones as those who answered the Centres of Higher Education and Training survey, so their responses were retained in this dataset. Other universities in this dataset were based in Benin, the UK and the USA (the latter two involving respondents who were familiar with the AI context in SSA).

Government

Building on recommendations outlined in UNESCO's report *Steering AI and Advanced ICTs for Knowledge Societies*, UNESCO sought to bridge the information gap about the strategic priorities, policy measures, developmental challenges, human and institutional capacity needs, and legal frameworks concerning AI in African countries. AI4D contributed to UNESCO's research process and is proud to draw on the results from the UNESCO report in this compendium.

The report is divided into two sections. Section One presents results of a survey that UNESCO conducted. The survey consisted of six sections with 34 questions that captured information on 91 data points. It was distributed to UNESCO National Commissions in Africa and relevant national authorities working on the development or coordination of AI programmes within the ICT policy landscape were encouraged to respond. It explored policy initiatives, legal and regulatory frameworks, and capacities for AI governance. The final sample included 32 African countries that responded to the survey. This section also explores the priorities of these countries, with a focus on AI capacities for education, research, training and data. Section Two discusses AI governance in Africa within the context of global digital cooperation and provides a set of recommendations for policy development and capacity building in Africa based on the findings of the survey.[209]

A detailed outline of the methodology for this research is provided in the UNESCO report.

[209] Sibal, P. and Neupane, B. (2021). "Artificial Intelligence Needs Assessment in Africa." UNESCO.

Appendix 2: AI-related postgraduate academic offerings at Centres of Higher Education and Training in SSA

AI-related postgraduate academic offerings at Centres of Higher Education and Training in SSA [210]

Postgraduate Diplomas	Honours Programmes	Master's Programmes	PhD Programmes
PG.Dip Business Intelligence and Analytics	BSc (Hons) Computer Science	MSc in Artificial Intelligence	PhD Computer Science
PG.Dip Digital Logistics	BSc (Hons) Big Data Analytics	MSc in Robotics	PhD in Data Science (specialisations include Econometrics, Data Mining, Actuarial Science, Biostatistics)
PG.Dip Industrial Engineering (specialising in Data Science)	BSc (Hons) Statistical Sciences	MSc in e-Science	PhD Computer Engineering
PG.Dip Data Analytics and Business Intelligence	BSc (Hons) Information Systems	MSc in Computer Science	PhD in Bioinformatics and Computational Biology
	BCom (Hons) Mathematical Statistics (specialising in Data Science)	MSc in Big Data and logistics	PhD Informatics
	BSc (Hons) in Bioinformatics and Computational Biology (submitted for accreditation)	MSc Informatics	
	BSc (Hons) Computational and Applied Mathematics	MCom Informatics	
		MSc in Statistical Science	
		MCom Information Management	
		MSc Business Computing	
		MSc Information Technology	
		MSc Computer Engineering	

		MSc Data Science (specialisations include Econometrics, Data Mining, Actuarial Science, Biostatistics)	
		MPhil Computer Science	
		MEng Industrial Engineering (specialising in Data Science)	
		MSc Computational and Applied Mathematics	
		MSc in Bioinformatics and Computational Biology (submitted for accreditation)	
		MSc Computational Intelligence	
		MSc in Machine Learning and AI (submitted for approval and accreditation)	
		MSc in Biostatistics	

[210] This list is compiled based on interview data and online desktop research. It includes a spread of institutions from several countries in SSA, including Rwanda, Ghana, Uganda, South Africa, Nigeria and Kenya.

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