AFRICAN DEVELOPMENT BANK

AN ANALYTICAL NOTE ON "HIGHER EDUCATION SCIENCE, TECHNOLOGY AND INNOVATION, RESEARCH & DEVELOPMENT AND ENTREPRENEURSHIP IN AFRICA"

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Acronyms

4IR	Fourth Industrial Revolution
AFD	French Development Agency
ACDE	African Council for Distance Education
ADF	African Development Fund
AVU	African Virtual University
AUDA	African Union Development Agency
AAS	African Academy of Sciences
ADI	African Development Institutes
ATPS	African Technology Policy Studies Network
AI	Artificial Intelligence
AIST	African Institute of Science and Technology
ACEIoT	African Center of Excellence in Internet of Things
AIMS	Africa Institute for Mathematical Sciences
ACBF	African Capacity Building Foundation
AfDB	African Development Bank
APMEP	Agricultural Productivity and Market Enhancement Project
ATPS	African Technology Policy Studies Network
AU	African Union
AUC	African Union Commission
AUST	African University of Science and Technology
BBSRC	Biotechnology and Biological Sciences Research Council
CESA	Continental Education Strategy for Africa
CoE	Centre of Excellence
CoC	Control of Corruption
CFE	Coding for Employment Program
CS-OGET	Center of Studies for Oil and Gas Engineering and Technology
CMU	Carnegie Mellon University
CUE	Commission for University Education
CBC	Competence Based Curriculum
CASE	Council for Advancement and Support of Education
DFID	*Department for International Development*
DRC	Democratic Republic of the Congo
DP	Development Partners
DSIP	Development of Skills for Industry Project
ESRC	Economic and Social Research Council
E4D/ SOGA	Employment and Skills for Eastern Africa
GCRF	Global Challenges Research Fund
GDP	Gross Domestic Product

HCS	Human Capital Strategy
HE	Higher Education
HEIs	Higher Education Institutions
HC	Head Count
HERQA	Higher Education Relevance and Quality Agency
HESTEM	Higher Education Science Technology Engineering and Mathematics
HESTI	Higher Education, Science, Technology and Innovation
HEST	Higher Education, Science and Technology
IAEA	International Atomic Energy Agency
ICT	Information Communication Technology
ITU	International Telecommunication Union
ToT	Internet of Things
ISO	International Organization for Standardization
IDA	International Development Association
JfYA	Jobs for Youth in Africa Strategy
JICA	Japan International Cooperation Agency
KBE	Knowledge Based Economy
KIIs	key informant interviews
KENIA	Kenya National Innovation Agency
KCB	Kenya Commercial Bank
KENET	Kenya Education Network
MIT	Massachusetts Institute of Technology
MRC	Medical Research Council
NSFAS	National Students Financial Aid Scheme
NAB	National Accreditation Board
NCB	National Computer Board
NM-AIST	Nelson Mandela African Institution of Science and Technology
NRF	National Research Fund
NORAD	Norwegian Agency for Development Cooperation
NUC	National Universities Commission
NCTE	National Council for Tertiary Education
NCHE	National Council for Higher Education
NESSP	National Education Sector Strategic Plan
NERC	Natural Environment Research Council
NACOSTI	National Commission for Science, Technology and Innovation
ODA	Official Development Assistance
PASET	Partnership for Applied Science, Engineering and Technology
PAVEU	Pan African Virtual and E-University
PPP	Public-Private Partnership

R&D	Research and Development
ROL	Rule of Law
RDB	Rwandan Development Board
RI	Research and Innovation
RECs	Regional Economic Communities
RMCs	Regional Member Countries
RECP	Renewable Energy Cooperation Programme
SBIR	Small Business Innovation Research
SDGs	Sustainable Development Goals
SOGA	Skills for Oil and Gas
SDS	Skills Development Strategy
SSA	Sub-Saharan Africa
SEEP	Skills, Employability and Entrepreneurship Programme
SBDP	Skills and Business Development Programme
SSA	Sub-Saharan Africa
STEM	Science, Technology, Engineering and Mathematics
STI	Science, Technology and Innovation
SMEs	Small Medium Enterprises
SAGA	STEM and Gender Advancement
STISA	Science, Technology and Innovation Strategy for Africa
TEVET	Technical, Entrepreneurial, Vocational Education and Training
TOR	Terms of Reference
TEC	Tertiary Education Council
TVET	Technical Vocational Education Training
TWAS	The World Academy of Science
TYS	Ten-Year Strategy
UK	United Kingdom
EU	European Union
USAID	United States Agency for International Development
UNCST	Uganda National Council for Science and Technology
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNICEF	United Nations Children's Fund
UR-CE	University of Rwanda-College of Education
UNDP	United Nations Development Programme
UNRISD	United Nations Research Institute for Social Development
UNN	University of Nigeria, Nsukka
UNES	University of Nairobi Enterprise Services Limited
WEF	World Economic Forum
WHO	World Health Organization

WCP	Women Community Programmes
WGP	Women Graduate Programmes
WEP	Women Executive Programmes
WGI	Worldwide Governance Indicators
WIPO	World Intellectual Property Organization

Acknowledgment

I wish to express my gratitude to the African Development Bank for giving me the opportunity to undertake this assignment aimed at preparing an analytical note on "**Higher Education Science, Technology and Innovation, Research & Development and Entrepreneurship in Africa."**

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Executive Summary

This report provides an analytical note on Higher Education Science, Technology and Innovation (HESTI). The study is premised on the fact that HESTI; Research and Development (R&D); and Entrepreneurship development are strategic to the African Development Bank's efforts in enhancing human capital for Africa's economic transformation in the context of the Bank's High 5 operational priorities. It examines the HESTI, R&D, and Entrepreneurship development ecosystem in Africa with a view to understanding the statuses, successes, failures and why (reasons for successes and or failures). The report provides the bases and impetus for developing and framing an analytical note on three selected broad priority areas namely: Training Infrastructure; Financing; and Governance. Whereas the Training Infrastructure aimed to provide a deep dive on the current state, gaps and emerging infrastructure needs for HESTI, R&D and Entrepreneurship development for socioeconomic transformation in Africa; the Financing component aimed to provide evidence and insights on the current state of financing, gaps and innovative mechanisms to finance HESTI and R&D in Africa; while the Governance component assessed the policy environment, curriculum, management and administration, and underlying social issues (such as inclusion, gender, linkages, and networks among others) in the HESTI and R&D arena. In addition, some crosscutting issues that provide deeper insights and understanding of the above-mentioned priority areas have been discussed. They include: Gender and equity in access to HESTI; Harnessing HESTI and R&D to leapfrog technology innovation and entrepreneurship; Enhancing flexibility and responsiveness of HESTI and R&D; Linking HESTI and R&D to productive sector; and Regional centers of excellence, regional networks of knowledge and research.

A multidimensional approach was deployed consisting of in-depth review of relevant literature on the subject matter; key informant interviews (KIIs); case studies linked to each of the broad priority areas; and validation of reports relevant to the study objectives. All the approaches were made to be inclusive with respect to geographical coverage, language, and current economic statuses of countries in Africa. The report contains high-level recommendations to advance skills development in Africa with particular emphasis on the role of the AfDB.

The findings in the analytical note shows that the infrastructural gaps witnessed in many African states continue to pose a challenge in developing skills for employability and job creation. Nevertheless, the Bank has made significant contribution having supported various projects around Africa. In areas of HESTI, the Bank has supported regional centers of excellence (CoE) by upgrading, rehabilitating and equipping them with training infrastructure needed to develop employability skills. On skills development, the Bank has supported several initiatives in different countries such as Uganda's HEST and ground breaking CoE in higher education institutions (HEIs) in Mali, Uganda and Rwanda among other initiatives. With regards to financing, the Bank has continued to work with both the private sector and the public sector in providing financial and technical supports particularly in supporting entrepreneurial activities through lending and promotion of sound financial management systems. Some of the projects financed include: financing government of Ghana to establish a national development bank and a $56.3 million project for the private sector agribusinesses in northern Ghana. On governance, poor governance structures and ineffective policies currently in place in most African countries do not support HESTI, R&D and entrepreneurship development in producing competent skilled human capital

for employment, increased productivity and sustainable livelihoods. The Bank has supported African states by mobilizing resources needed in various institutions needed to support education. On gender, the Bank and several other partners including United Nations Educational, Scientific and Cultural Organization (UNESCO), are providing supports to bridge the gap of inequality between men and women as well as the inclusivity challenges in the STEM and R&D fields.

In an effort to support HESTI, R&D and Entrepreneurial development, the Bank should use its comparative advantage in its capacity to deliver high quality projects in Africa by supporting select RMCs in rehabilitating, upgrading and developing new training infrastructure, providing more funding supports to collaborative research projects that involve HESTI and the private sector/industry as well as support reviews of existing HESTI and R&D policies in RMCs to understand what works (successes), what does not work (failures) and why (reasons for successes and or failures) with a view to supporting required changes that will enable the countries leapfrog economic transformation in the sector. In supporting the economic growth of Africa, there should be strong linkages between HEIs, industry and the government. In resolving several challenges facing African states such as poor governance, low funding and poor infrastructure, Africa should arise and make efforts in creating conducive ecosystem that will sustain endogenous leadership in the sector while attracting external supports that align with the aspirations of African development in HESTI, R&D and entrepreneurship.

1.0 INTRODUCTION

The African Development Bank (AfDB) has been working with its regional member countries (RMCs) since 1975in supporting education in Africa. This is evident in their many supports to the RMCs including; support for national and regional centers of excellence; and construction, upgrading and rehabilitation of training infrastructure for Higher Education, Science, Technology and Innovation (HESTI) across Africa. For instance, between 2005 and 2017, the Bank invested $2 billion in 70 education projects, with a primary focus on science and technology benefiting 7 million youths[1]. Also, from 2014 to 2018, the Bank approved a total of40 skills development projects amounting to UA 771.2million that contributed to scaling up Skills and Technology in African countries. Half a million people benefited from better access to education in 2017 from the Bank's operations across the continent. The share of HE student's enrollment in STEM education rose from 30% in 2010 to 38.5% in 2017[2].Worthy of particular mention are the Bank's High 5 priorities; the Bank's Human Capital Strategy for Africa (HCS) 2014-2018 which focuses on "Skills and Technology" to create jobs and increase competitiveness; and the Jobs for Youth in Africa Strategy (JfYA) 2016-2025. The JFYA strategy aims to create 25 million jobs for the youths and also, improve the employability of 50 million youths by: (i) mainstreaming job creation objectives into the Bank's operations; (ii) implementing skills training and entrepreneurship development in agriculture, industry and ICT; and (iii) establishing mechanisms that expand access to finance for young entrepreneurs.

The subsequent extension of HCS to February 2021 and the new strategic framework being envisaged is anchored on the Banks's high 5 priority of "Improving the quality of life for the people of Africa" with the sole aim of supporting a healthy, skilled, productive and innovative workforce which is employable and entrepreneurial enough to yield significant demographic dividends and contribute to inclusive growth and creation of decent jobs. The Bank's new Skills for Employability Strategy for (2021-2025) aims to guide the Bank in achieving its High 5-5priority. This analytical note particularly was designed to provide adequate insights to inform how the Bank can support the re-skilling/upskilling of Africa's workforce with demand-driven science and technological skills under a conducive environment. It also aimed to strengthen the relevance of HESTI and Research and Development (R&D) to the industry, and build resilient enterprises that can weather economic shocks and pivot businesses to models that meet the changing demands of the market, which is required now more than ever.

[1]https://blogs.afdb.org/investing-gender/international-day-women-and-girls-science-calls-africa-address-gender-gap-stem

[2]UNESCO Institute for Statistics. Percentage of students in tertiary education enrolled in STEM programmed 2017

1.1 Context and Background

In the recent years, HESTI, R&D, and Entrepreneurship Development have attracted attention from various stakeholders due to its significant role in economic transformations particularly, in supplying productive and skilled human capital. Several stakeholders comprising of international agencies, development organizations, public and private institutions have made huge contributions in supporting HESTI in developing institutional capacities to carry out research and training for socio-economic transformation in Africa. Similarly, Africa's Higher Education (HE) as a system that promotes development of skills has responded in building infrastructural needs for HESTI, R&D and Entrepreneurship Development (Jowi *et al*, 2013).

Despite all the strategies in place in supporting HESTI, R&D, and Entrepreneurship development, most countries in sub-Saharan Africa (SSA) face shortages in human resources and capacity within the Science, Technology, Engineering and Mathematics (STEM) fields needed to support HESTI, R&D and Entrepreneurship development in developing enough skills for employability, productivity and sustainable livelihoods. For instance, whilst the global average number of researchers per million inhabitants is slightly above 1,000, in SSA the number is under the 100 mark[3].

Again, the poor quality of HE in many African countries is barely able to support HESTI and R&D in providing enough skills for employability among graduates. Many graduates in SSA graduate from HEIs of learning without basic skills to advance their lives. As such, they have found it hard to get employment due to mismatch of the skills they have with what the industry wants hence many enterprises in Africa struggle to fill open job positions due to skill's mismatch. For instance, in Egypt, about 1.5 million youth were unemployed in 2012 while at the same time, private sector firms were unable to fill 600,000 job vacancies[4]. **The existence of high vacancy rates in the presence of large-scale unemployment among youths in Africa confirm the existence of skills mismatches.**

Information and Communication Technology (ICT) has played a significant role in facilitating learning in HE and also as a skill for employability. However, due to low ICT investments many Africa's HEIs are unable to offer online learning programmes compared to universities in Europe, North America and some countries in East Asia. Estimates from the International Telecommunication Union (ITU) show that 21% of learners in Africa cannot be reached by 3G mobile networks[5]. In terms of internet access, 82.2% of households in Africa lack access in their

[3]https://www.universityworldnews.com/post.php?story=20190415151518157
[4]https://www.universityworldnews.com/post.php?story=20130103154436919
[5]http://uis.unesco.org/en/blog/importance-monitoring-and-improving-ict-use-education-post-confinement

homes[6] compared to 43% worldwide[7]. Additionally, lack of digital skills amongst the faculty and students has made it difficult for HE to provide virtual learning. With regards to entrepreneurial opportunities, the lack of ICT skills needed for employability and productivity due to low internet penetration has put many youth and women at a disadvantage in harnessing the emerging new entrepreneurial businesses and other economic activities. For instance, as at 2019, the internet penetration in Africa averaged at 39.6% compared to 62.7% in the rest of the world[8](AfDB, 2019a[9]). **These shortfalls have negative implications on productivity and technology-driven economic transformation on the continent and improvements on it will require public-private collaborative actions**.

1.1.1 Global Perspective

Around the globe, STEM education has been acknowledged as an enabler in enhancing development of employability skills. However, the shortages in STEM professionals witnessed in several countries particularly given the forecast for increased demand for jobs that require STEM skills has seen considerable concerns and needs to meet the labour market demands (OECD (2017a). In 2015, South Korea revised its national curriculum to reinforce software education in enhancing student's capacity targeting a total of 60,000 elementary school teachers with a specialized training in software education[10]. The new national curriculum is expected to be implemented by the end of 2020 with the key objective being to cultivate a 'a creative and integrative learner'[11].With regards to enrollment, in 2016, China had the highest number of STEM graduates at 4.7 million STEM graduates followed by India, U.S.A, Russia, Iran, Indonesia and Japan (Figure 1)[12].

[6]http://uis.unesco.org/en/blog/importance-monitoring-and-improving-ict-use-education-post-confinement
[7]https://www.internetworldstats.com/stats1.htm
[8]https://www.brookings.edu/blog/africa-in-focus/2020/02/07/shooting-for-the-moon-an-agenda-to-bridge-africas-digital-divide/
[9]https://am.afdb.org/2019/sites/default/files/AfDB18-16_Jobs_English.pdf

[10]https://www.oecd.org/education/ceri/Spotlight-15-A-Brave-New-World-Technology-and-Education.pdf
[11]https://bangkok.unesco.org/content/new-education-policies-and-practices-south-korea
[12]https://www.forbes.com/sites/niallmccarthy/2017/02/02/the-countries-with-the-most-stem-graduates-infographic/#17157a8a268a

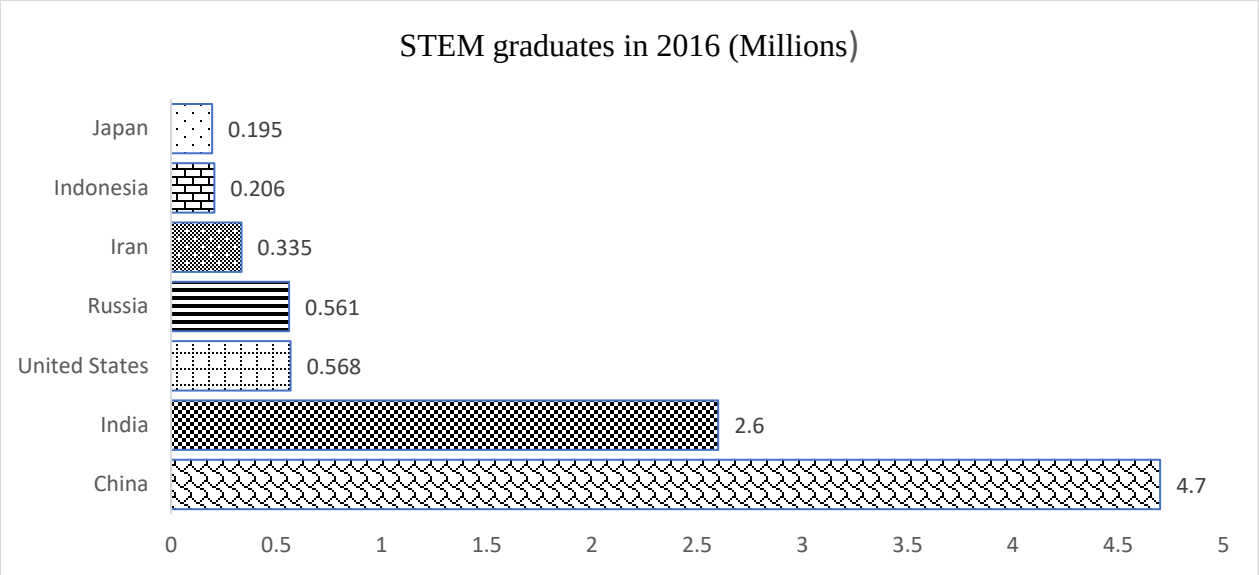

Figure 1: Countries with most STEM graduates
Source: World Economic Forum (2016).

Participation of women in STEM and R&D has not been optimal since women still remain under-represented (UNESCO, 2017). Further, when it comes to choosing courses, less than a third of female students choose technical courses like mathematics and engineering. These factors continue to widen the gap that exist in the STEM and R&D fields. According to the AAS (2020), statistics show that globally, the percentage of women in R&D is about 28.8% [Figure2]. In Central Asia, women make up almost half of the researchers at 48.1% but drops to 18.5% in South and West Asia.

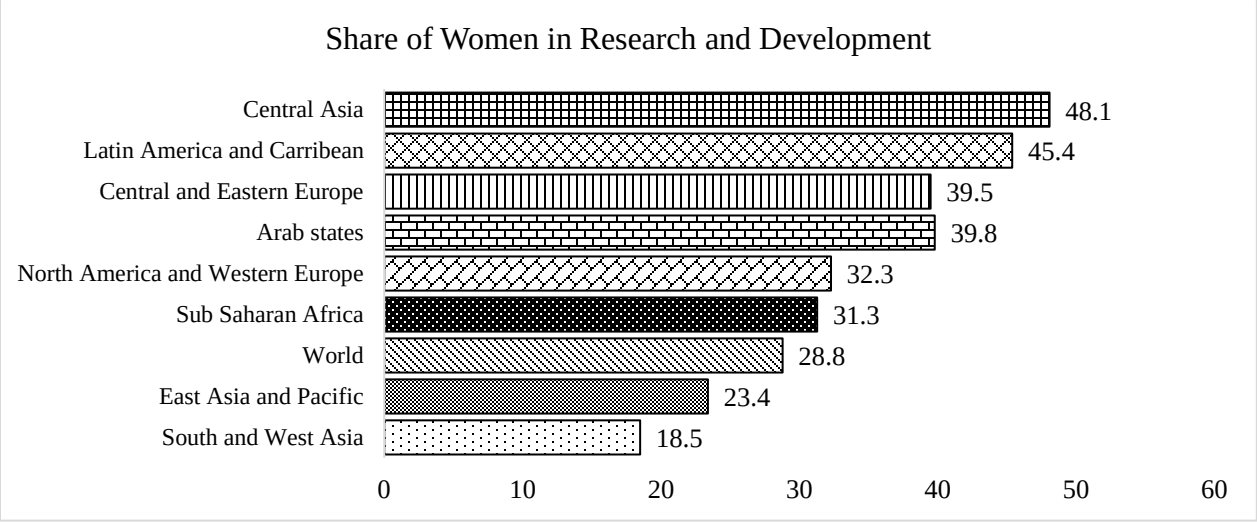

Figure 2: Share of Women in Research and Development. **Source: The AAS, 2020[13]**

[13]https://www.aasciences.africa/sites/default/files/Publications/Women%20in%20STEM%20Report_Final.pdf

Across the globe, industries are working with HESTI and R&D institutions in skills development aimed at reducing the skills gap and mismatch between industry and HESTI. Work-based learning programs such as apprenticeship which seeks to address industry-education gaps have been touted as a solution to the skills gaps. Countries like Germany, have embraced youth apprenticeship to ensure a channel of skilled workers. The German model combines several elements including: effective proven training methods and mutual beneficial partnerships between industry and educational institutions. This has helped many German companies remain world leaders in manufacturing (Arthur-Mensah, 2020). In US and UK, universities and industries have launched successful partnership programs to bridge the skills gap (AfDB, 2019). The tech giant, Microsoft, is working with many universities around the world to embrace digital transformation and about 120 Microsoft Innovation Centers are currently in operation across 33 countries[14].

1.1.2 Regional Perspective

Africa as a whole lacks robust policy and plans on STEM skills which slows down its progress in attaining industrialization and economic transformation. Despite Africa holding about 17% of the world's population, its STEM capabilities fall behind the rest of the world. Current statistics show that over 60% of Africa's population are under 25 years. Africa also comprises of19% of the global population for those between the ages of 15-24 years who have huge untapped potential occasioned by lack of skills needed in the labour market[15]. Statistics show that in SSA alone, 2.5million engineers are needed to address the continent's severest problems particularly, SDG 6 (Clean Water and Sanitation (UNESCO, 2017). **There is need to support policy reviews in the RMCs that will prioritize STEM skills development that target the youth population and other vulnerable and disadvantaged populations.**

Even with Africa making a positive economic growth, it finds itself at the bottom of major indices that define the STI capabilities on the continent. Africa produces less than 1% of the world's scientific knowledge which includes publications and other contributions (African Capacity Report, 2017; Duermeijer et al, 2018). The bigger portion of Africa's scientific production originates from South Africa, Egypt, Nigeria, Tunisia, Algeria, Morocco and Kenya [Annex 2]. From the year 2007 up to 2017, a total of 35,819 reputable scientific publications came from East African academics. According to SJR (2020), South Africa produced a total of 303,863 publications from 1996-2019, followed by Egypt, Nigeria, Tunisia, Algeria, Morocco, Kenya, Ethiopia, Ghana, Tanzania. During the period, the whole of Africa produced 1,165,469 publications. In terms of scientific and technical journal articles[16], most African countries have

[14]https://u2b.com/2019/05/13/can-university-business-collaborations-solve-the-global-skills-gap/

[15]https://thestempedia.com/blog/stem-education-in-africa-the-past-present-and-future/

[16]Scientific and technical journal articles refer to the number of scientific and engineering articles published in the following fields: physics, biology, chemistry, mathematics, clinical medicine, biomedical research, engineering and technology, and earth and space sciences.

made slight improvement. Between 2017and 2018, statistics in [Figure 3] show that Egypt had the highest number of scientific and technical journal articles (13,327) in 2018 compared to 11,393 in 2017.

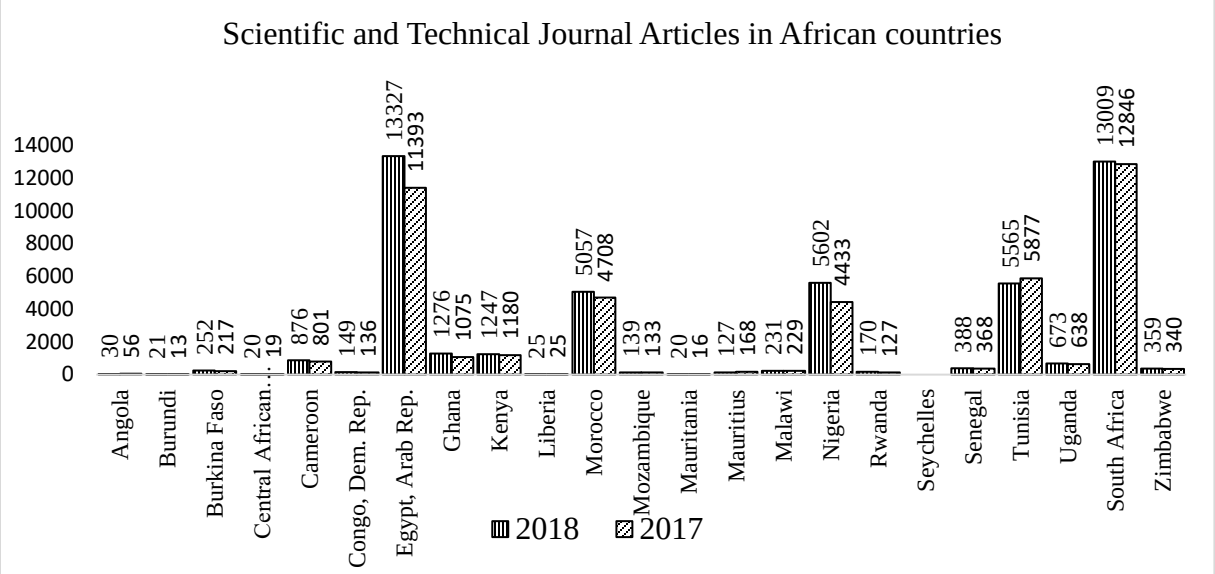

Figure 3: Scientific and Technical Journal Articles in African countries (2017-2018)
Source: World Bank's World Development Indicators, September 2020
https://data.worldbank.org/indicator/IP.JRN.ARTC.SC

The African Union Commission (2014) reported that in many African countries, more than half of the investments in R&D are internationally funded and as such, puts the African continent strategically at a disadvantage in designing home grown solutions to her societal challenges[17]. For instance, in 2010, the proportion of international funding for R&D by country was 78.1% for Mozambique, 59.6% for Burkina Faso, 57.3% for Uganda, 47.1% for Kenya, 40.5% for Senegal, 31.2% for Ghana and 12.1% for South Africa (Beaudry and Mouton, 2018). In 2014, the World Bank provided supports amounting to US$ 150 million to finance 19 university centers of excellence in 7 countries in West Africa and Central Africa[18]. **It therefore becomes very pertinent for African countries to increase their R&D investments as proposed in the 1980 Lagos Plan of Action.**

1.2 Rationale

The fact remains that the available training programs in HESTI does not often match with the quality of soft and hard skills' needs of the industry in most African countries. This

[17] https://au.int/sites/default/files/newsevents/workingdocuments/33178-wd-stisa-english_-_final.pdf
[18] https://www.wipo.int/edocs/mdocs/africa/en/wipo_aripo_oapi_inn_hre_19/wipo_aripo_oapi_inn_hre_19_c1_4_a.pdf

mismatch of skills is attributed to the high unemployment rate on the continent and is fueled by poor linkages with industry in general and the poor mainstreaming of the culture of entrepreneurship in HEIs. This prevents Africa's private sector from investing in R&D and as a result, Africa's private sector suffers from low innovation and productivity which contributes to the low level of economic development (AfDB, 2020a). Statistics show that half of Africa's employed youth perceive their skills as mismatched to their jobs, while around two-thirds of youth are either overeducated or undereducated (AfDB, 2020a)[19].

STEM enrollment in Africa remains low. Between 2012-2016, the enrolment growth in HEIs on the continent was 43% compared 38.5% in STEM fields where there are high prospects for job opportunities. Majority of the students in HEIs are studying humanities and social sciences[20]. These shortfalls have negative implications on production and technology-driven economic transformation on the continent. As at 2020, in countries such as Southern African nation of Namibia where girls outpace boys in all levels, the gap widens in STEM education where 8% of female students have attained STEM education compared to 21% of males. In Mauritania, the attainment in STEM is at 29% among females compared to 31% among males[21]. Further, the sector is peppered with inadequate and undiversified funding regimes which have posed major challenges to the development of more vibrant scientific research and innovation infrastructure needed to power Africa's much needed knowledge economy (AfDB, 2020a).

Despite the improvement in Scientific publication in Africa, the levels are still low. Reports from the Elsevier B.V *Scopus* database analyses show that while the global count of scientific publications for the 2012-2018 period rose by 38.6% over the five-year period, Africa's world share rose only from 2.4% to 3.1% (AfDB, 2020a). **Improvement of Africa's major indices that define its STI capabilities including scientific publications will be key in fostering Africa's innovation, R&D and entrepreneurship development.**

Most countries in Africa aspire to increase rapid digitization as a result of the Fourth Industrial Revolution (4IR) and the COVID-19 pandemic which has become an unexpected accelerator of the digital transformation worldwide. More than one third of all jobs in all industries are expected to require complex problem-solving as a core skill[22]. Further, ICT literacy is expected to be a growing part of the core skill requirements for many industries. However, 60.7% of Africans still lack access to internet and digital infrastructures[23]. The disruptions caused by the pandemic have had profound impacts on the world's mindset, which is now ready and open to embrace the change aimed at curtailing these impacts and return to normality[24]. For instance,

[19] Source: African Development Bank 2020 Africa Economic Outlook Report
[20] https://thestempedia.com/blog/stem-education-in-africa-the-past-present-and-future/
[21] http://www.ipsnews.net/2020/01/addressing-low-female-representation-stem-education/
[22] World Economic Forum, The Future of Jobs, 2016
[23] Internet World stat - https://www.internetworldstats.com/stats1.htm
[24] https://www.unido.org/sites/default/files/files/2020-07/UNIDO_COVID_Digital_Transformation_0.pdf

the pandemic has exposed the unpreparedness of many African HEIs in migrating to online learning. It has also pushed African HEIs to rethink what the future of education would look like and **take practical steps to adopt a blended learning approach for improving access and equity**[25]. Further, it has been estimated that technology will be a source of over 133 million new jobs - this is the opportunity that Africa must not miss (AfDB, 2020a).

2.0 THEMATIC AREAS: HESTI, R&D AND ENTREPRENEURSHIP DEVELOPMENT ECOSYSTEM IN AFRICA

This section provides the current state of HESTI in Africa, evolution of interventions that have enabled or impeded the HESTI/STEM models and practices.

2.1 Higher Education, Science, Technology and Innovation (HESTI)

In Africa, HE training institutions do not have enough qualified human capacities to teach STEM courses required to meet the stipulated standards. As such, the performance of STEM fields is relatively poor. Statistics show that in Kenya, less than 20% of faculty in STEM discipline hold PhD (Blom *et al* 2016[26]; The AAS, 2020[27]). Additionally, STEM related field require high costs compared to humanities because of the need to invest in expensive equipment and other research infrastructure needed to deliver STEM based courses. For instance, in the Central Africa region, Chad relies on foreign labour from Cameroon to meet up with the shortages of STEM skills and human capital in most sectors due to the country's discrimination to enroll STEM and technical based programs in its education sector (AEO, 2020c). **Supporting HEIs in filling these shortfalls through scholarships, loans and bursaries will boost learning, skills development and employability.**

Low skill production has posed a challenge for African economies. The current trends in skills production particularly in the HE landscape do not match with the labour market demand. Many African countries continue to exhibit unsatisfactory educational outcomes and their graduates often lack the appropriate skills and qualifications needed by employers in many industries and sectors (Morsy and Mukasa, 2019). Further, statistics show that skill and educational mismatches are prevalent in Africa: 17.5% of employed youth are over skilled, 28.9% under skilled, 8.3% overeducated and 56.9% undereducated (Morsy and Mukasa (2019[28]). Majority (50%) of the

[25] https://www.weforum.org/agenda/2020/06/higher-education-africa-covid19-coronavirus-digital-online/

[26] Blom, Andreas, Reehana Raza, Crispus Kiamba, Himdat Bayusuf, and Mariam Adil. 2016. Expanding Tertiary Education for Well-Paid Jobs: Competitiveness and Shared Prosperity in Kenya. World Bank Studies. Washington, DC: World Bank. doi:10.1596/978-1-4648-0848-7

[27] https://www.aasciences.africa/sites/default/files/Publications/Women%20in%20STEM%20Report_Final.pdf

[28] https://www.afdb.org/sites/default/files/documents/publications/wps_no_326_youth_jobs_skill_and_educational_mismatches_in_africa_f1.pdf

respondents in the survey conducted under this study indicated that the level of unemployment of graduates was high. Further, 46%of the respondents in the survey indicated that there was low graduate skills match with the industry needs. Even though efforts are being made to increase the enrollment and sustainability of the STEM courses, the humanities courses outshine the STEM course enrollments in universities and colleges across Africa. As at July 2019, the average enrollment in STEM fields stood at 29% in SSA[29]. Besides the enrollment, about 4-12% of students graduate in STEM related fields[30]. Further, there are low numbers of students transitioning from secondary level of education with the skills and qualifications required for enrollment in STEM programmes[31]. In South Africa, university graduation in STEM related fields is about 20%[32]. In Kenya, majority of PhD program are still in non-STEM fields[33].Investing more on HESTI in African states through consolidated efforts will increase the enrollment rates as in the case in Uganda's Higher Education, Science and Technology (HEST) Project which is supported by the AfDB (Box1). In Ghana, the implementation of the Development of Skills for Industry Project (DSIP) between 2013 and 2019 with $95.2 million from the AfDB has achieved significant results with about 2,010 students enrolled in two technical universities and 10 technical institutes (40.7 percent of whom were women) were provided with scholarships, with the goal of increasing the participation of disadvantaged groups over the period[34]. Also, a total of 4,510 people including 2,173 disadvantaged students benefited from the project[35]. These initiatives towards skill development offers the Bank a better opportunity to invest more in HESTI scholarships, capacity building and academic supports to its RMCs with greater emphasis in the STEM fields using its huge financial capability. **Therefore, the involvement of the private sector in the co-design and co-delivery of curricula becomes very important in Africa as is seen in most developed societies**. **There is also need to increase supports and investments in STEM scholarships in the RMCs with robust partnerships and linkages with other leading HEIs worldwide.**

[29]https://www.universityworldnews.com/post.php?story=20190712062128970
[30]https://ja-africa.org/our-work-in-stem/
[31]https://www.education.go.ke/images/NESSP/MOE-NESSP.pdf
[32]http://www.samefoundation.org.za/stem-education-science-technology-engineering-maths-for-south-african-underprivileged-schools/
[33]https://sciafmag.com/2020/04/03/covid-19-a-wake-up-call-for-rd-collaboration-in-africa/
[34]https://www.afdb.org/en/news-and-events/press-releases/ghana-african-development-bank-funded-training-builds-skills-economy-future-report-36946

[35]https://www.afdb.org/en/news-and-events/afdb-approves-usd-124-million-for-centers-of-excellence-in-mali-uganda-and-rwanda-8459

Box 1: Higher Education Science and Technology (HEST)-Uganda

The Uganda's HEST project aims at contributing to building the country's human capital skills development capacity, particularly in education, science and technology in a bid to respond to labour market demands and spur productivity. The objective of the project is to improve equitable access, quality and relevance of skills training and research leading to job creation and self-employment. Upon completion, the program strives to attain an increased STI enrollment in HE/tertiary levels (12,000 with at least 40% being women); increased number of people accessing equitable STI training at university/tertiary levels targeting 44.1% across HEST indicators. In an effort to improve the quality, efficiency and relevance of HEST in target public universities and degree-awarding tertiary institutions, the program targets to increase the ratio of researchers per members of the workforce (1.5 researchers per 1000), and increase the percentage of HEST students that successfully graduate. Achievements so far include; 49.8% (228 graduates of which 102 [44.7%] were females) and 828 researchers were registered in 2018 per 1,000 in members of the workforce. The project is funded by AfDB.

Source: AfDB, (2019); Implementation Progress and Results Report (IPR), 2019

In sub-Saharan Africa, women account for only 31.1 % of scientific researchers (AAS,2020). In Kenya, the enrolment of women in HE is lower than males particularly in STEM related courses. According to WHO (n.d)[36], women are under-represented in Science, Technology and Innovation (STI) and R&D in SSA. Data from the UNESCO Institute for Statistics (2019) shows that in most African countries where data was available, the female researchers in Africa as a percentage of total R&D personnel (Head Count-HC) is relatively low [Table 1]. The low numbers notwithstanding, in 2018, Tunisia had the highest female researchers 55.84%.**There is need to increase more women enrolment in STEM related programmes by deploying gender-friendly initiatives such as scholarships and bursaries specifically targeting women and girls.**

Table 1: Female Researchers in African countries as a Percentage of Total R&D Personnel (HC), 2014-2018

Country	2018
Angola	..
Burkina Faso	..
Burundi	18.4
Cameroon	..
Central African Republic	..
Democratic Republic of Congo	
Egypt	44.4
Ghana	..
Kenya	..
Malawi	..
Mauritania	24.4
Mauritius	42.1

[36]https://www.who.int/tdr/research/gender/Women_overview_piece.pdf

Morocco	..
Mozambique	..
Nigeria	..
Rwanda	..
Senegal	..
Seychelles	..
South Africa	..
Tunisia	55.8
Uganda	..
Zimbabwe	..

Note: data are unavailable for some countries; figures rounded off to one decimal place
Source: UNESCO Institute for Statistics, September 2020[37]

Africa as a whole lacks significant investment in education that is required to develop its human and social capital through an education and skills revolution which focuses on STI. For instance, most African countries have universities which offer STEM courses, with some countries having more than two institutions (**ANNEX 1**). Despite these efforts, majority (40%) of the respondents in the survey conducted under this study indicated that the current investment in HESTI had moderate contribution to industrial growth and development.

Africa's Agenda 2063 strategy purposes to reduce poverty and create wealth through offering of technical and vocational training relevant to the job market (UNESCO, 2018). For instance, the establishment of the African University of Science and Technology which is the first of the Nelson Mandela Institutions in 2017 as a center for excellence in science and technology and has made strides in contributing to the continent's economic growth using science and technology [Box2].

[37] http://data.uis.unesco.org/index.aspx?queryid=64

Box 2: Nelson Mandera Institutes: African University of Science and Technology (AUST)

The programme supports at total of 3 institutions of which two are in the ECOWAS region (African University of Science and Technology AUST in Abuja; International Institute for Water and Environmental Engineering, 2iE in Ouagadougou) and one institution in the EAC region (Nelson Mandela African Institution of Science and Technology, NM-AIST in Arusha). Also, the programme supports the harmonization of programs at regional levels through ECOWAS and EAC. In a mid-term review conducted in 2019, the bank's investment in scholarship has amplified the enrolment rates in these institutions and has further catalysed more female participation in STI- 35% of scholarships in AUST, 44% in Institut International de l'ingéniérie et de l'Eau (2iE) and 51% in African Institute of Science and Technology (AIST). The project has graduated 1,477 numbers of PhD and MSc (out of which 676 were women) thus indicating an increased enrolment rate. A total of 35 partnership have been brokered with private sector to enhance the quality and relevance of research. Jointly all three institutions have produced a total of 335 internationally recognised publications to inform scientific interventions in various thematic areas of STI. Activities aimed at improving the employability of graduates has been implemented. For instance, the Institut International de l'ingéniérie et de l'Eau (2iE) is the most advanced in this component and has attained a stage of maturity, with a well-established incubation center/program (which has graduated mature start-ups and are already creating jobs in the community), a private sector liaison secretariat and entrepreneurship as a core requirement for all students. Further, activities related to the implementation and harmonization for STI policies for EAC and Certificates for ECOWAS is well on track. Some of the major donors/development partners include; ACBF, World Bank, and AfDB.

Source: AfDB, (2019); Mid-Term Review Report (2019)

2.2 Research and Development (R&D)

R&D has been recognized as a key factor in moving global technological frontiers as well as facilitating new scientific innovations. The failure to invest in R&D by the African governments makes it challenging for the scientists and researchers to develop homegrown, sustainable solutions for African problems leading to slow economic growth. For instance, majority (36%) of the respondents in the survey conducted under this study indicated that the current investment in R&D witnessed in many African states has contributed to industrial development and economic transformation moderately. Equally, the COVID-19 has put the African continent on the spotlight in scientific research endeavours[38] as many states are relying on foreign aids for assistance. For instance, the World Health Organization made a massive effort in providing 47 of its member states in Africa with early detection testing kits. In Egypt, WHO has conducted 200,000 tests in 17 different labs[39].The US government through the United States Agency for International Development (USAID) donated 200 brand new state of the art ventilators[40]. On the other hand, researchers at the Pasteur Institute in coastal Senegal — a WHO partner that has battled viral outbreaks for more than a century — revealed that they are as little as three months away from

[38]https://sciafmag.com/2020/04/03/covid-19-a-wake-up-call-for-rd-collaboration-in-africa/
[39]https://sciafmag.com/2020/04/03/covid-19-a-wake-up-call-for-rd-collaboration-in-africa/
[40]https://ke.usembassy.gov/the-united-states-provides-200-ventilators-to-kenya-to-respond-to-covid-19/

releasing $1 diagnostic kits that can detect the respiratory contagion in 10 minutes[41]. In Kenya, 15 engineering students from Kenyatta University have also made the country's first home grown ventilators to treat patients severely affected by coronavirus[42].

Despite the African Union's target advocating for African states to contribute 1% of their GDP to R&D, progress towards achieving these targets has been slow as many African counties are focusing on other pressing issues such as fighting hunger and poverty (World Economic Forum, 2020[43](African Innovation Outlook, 2019[44]). Available data for 2018 shows that few countries in SSA have been close to achieving this target. Kenya and South Africa have invested0.8% and 0.7% respectively (UNESCO, 2018).To put the African spending in an international context in Table 2, the highest spending on R&D (Kenya) is three times less than the OECD average which is 2.4%[45]. In 2017, Burkina Faso was spending 0.7% on R&D whereas Egypt spent 0.7%, Mauritius 0.4%, and South Africa spent 0.8% of its GDP on R&D. In 2018, available data shows that Egypt's GDP expenditure on R&D was 0.7%, Burundi 0.2%, Ghana 0.4%, Kenya 0.8%, Mauritius 0.3%, Nigeria 0.1%, Tunisia 0.6%, and South Africa 0.7%. A study done in 2018 found that investment of R&D in SSA averaged at 0.4% compared to the world average of 1.7%[46]. **There is need for African countries to increase their R&D investments as a percentage of their GDP.**

Table 2: Public Expenditure on R&D Investment as % of GDP (2017-2018)

Country	2017	2018
Angola	..	..
Burkina Faso	0.7	..
Burundi	..	0.2
Cameroon	..	..
Central African Republic		
Democratic Republic of the Congo	..	..

[41]https://www.washingtonpost.com/world/africa/a-10-minute-coronavirus-test-for-1-researchers-in-senegal-say-its-coming/2020/03/17/43f82cb6-67ab-11ea-b199-3a9799c54512_story.html

[42]https://www.rfi.fr/en/africa/20200425-kenyan-students-innovate-to-fill-covid-19-ventilator-shortage-coronavirus-innovation-ghana-uganda

[43]In 2018, ten African heads of state committed to increase their investment in education, science and technology

[44]https://au.int/sites/default/files/documents/38122-doc-aio_3rd_edition_final_eng_repro.pdf

[45]http://documents1.worldbank.org/curated/pt/831821566966279688/pdf/Improving-Higher-Education-Performance-in-Kenya-A-Policy-Report.pdf

[46]https://www.africaportal.org/features/surveying-impact-covid-19-africas-higher-education-and-research-sectors/

Egypt	0.7	0.7
Ghana	..	0.4
Kenya	..	0.8
Liberia		
Malawi		
Mauritania	..	0
Mauritius	0..4	0.3
Mozambique	-	
Morocco	..	..
Nigeria	..	0.1.
Rwanda	..	..
Senegal	..	..
Seychelles	..	..
Tunisia	..	0.6
Uganda	..	..
South Africa	0.8	0.7
Zimbabwe		

Note: data are unavailable for some countries; figures rounded to 1 decimal place
Source of data: UNESCO Institute for Statistics September, 2020. http://data.uis.unesco.org/

The statistics for the years 2017 and 2018 show that those countries in Africa which have invested more than 0.6 % of their GDP towards R&D are; Egypt, Kenya, South Africa and Burkina Faso. Further, those which have invested between 0.4-0.6% are; Tunisia and Algeria. Those countries who have invested between 0.2-0.4% are Burundi, Mauritius, Mali and Ethiopia. Those with 0.1-.2% is Nigeria while those with 0<0.1% are; Gambia, Mauritania, and Madagascar [Figure 4] Simpkin *et al* (2019). These numbers show that R&D in Africa is still under-developed when compared to other regions. For instance, different regions have set their own spending targets; the best known being European Union (EU) target to raise overall R&D to 3% of their GDP by 2020[47], however, data shows that only six countries worldwide have managed to surpass the target,

[47]http://www.globaleducationmagazine.com/countries-invest-rd-unesco-data-tool-reveals-emerging-players/

including 3 from the EU: Sweden, Denmark and Finland. These results align with the survey conducted under this study where majority (70%) of the respondents indicated that investment in R&D was low in Africa.

Figure 4: Levels of gross domestic expenditure in R&D (% of GDP 2017-2018
Source: Author's Compilation

In many African states, R&D has been largely supported by the public sector with international sources forming a substantial percentage [Figure 5]. In 2015, the foreign sources towards R&D in Ghana was 31%, Senegal 41%, and Burkina Faso 60%. In South Africa, most of its funding was from the private sector particularly in the mining sector (Simpkin *et al*, 2019).

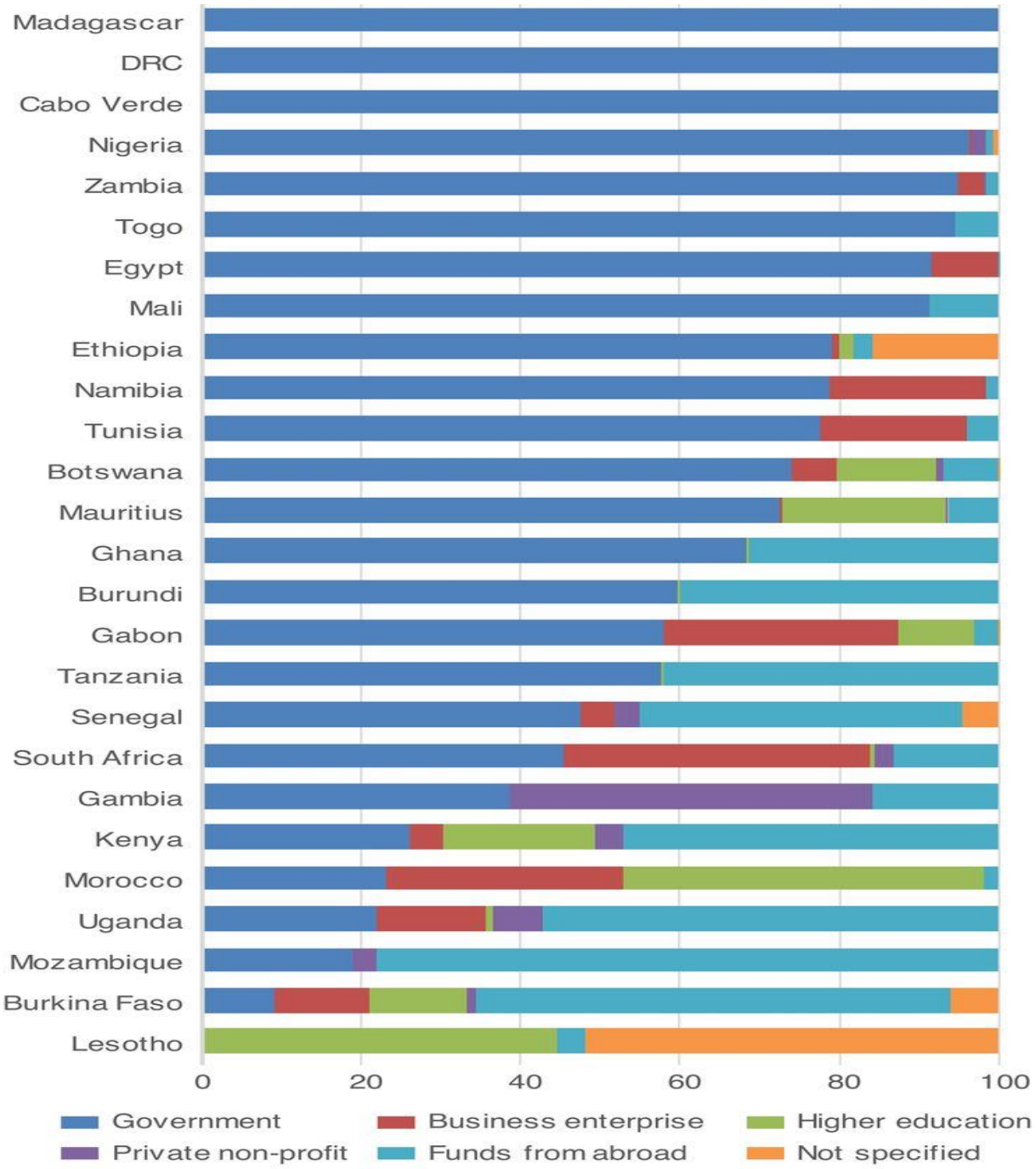

Figure 5: Source of funding for gross expenditure on R& D by some African countries
Source: Simpkin *et al* (2019).

The average growth in patents for Africa between 2007-2017 was 7.4% compared to the world average of 6.1%. Despite the percentage rise, Africa's contribution to patents is still low compared to other regions. For instance, in 2017, Africa as whole was granted 9,400 grants, Asia 803,100, Europe 1,203,600, Latin America and the Caribbean 20,300, North America 342,900, Oceania 25,300.

Further, statistics in Table 3 show that in the African continent, South Africa recorded the highest number of patents, followed by Tunisia, Morocco, Rwanda, Kenya, Ghana, and Uganda (WIPO, 2018). **Statistics show that countries which have invested high in R&D are likely to have high growth of patents a case in point being South Africa**. Further, majority (40%) of the respondents in the survey under this study indicated that the low investment in R&D witnessed in many Africa states has resulted to low number of patents. **Therefore, more efforts need to be put in place by African governments and the private sector actors to increase funding in R&D which is positively corelated with patent growth.**

Table 3: Patent grants by office and origin, 2017

Country	**2017**
1. Angola	-
2. Burkina Faso	-
3. Burundi	-
4. Cameroon	-
5. Central African Republic	-
6. Democratic Republic of the Congo	-
7. Egypt	-
8. Ghana	5
9. Kenya	43
10. Liberia	-
11. Mauritania	-
12. Mauritius	4
13. Morocco	413
14. Mozambique	-
15. Nigeria	-
16. Rwanda	176
17. Senegal	-
18. Seychelles	-
19. South Africa	5,535
20. South Sudan	-
21. Tunisia	555
22. Uganda	2
23. Zimbabwe	

Source: World Intellectual Property Indicators (2018)[48] Note: In most countries, equivalent grants by origin are incomplete because some offices do not report by origin.

[48] WIPO (2018). World Intellectual Property Indicators 2018. Geneva: World Intellectual Property Organization.

2.3 Entrepreneurship Development

Entrepreneurship development in HEIs of learning has gained support due to its influence on socio-economic development. Studies show that there is a strong relationship between entrepreneurship education, employability and job creation (Vuuren, Alemayehu 2017). About 38% of the respondents in the survey conducted under this study indicated that investment in entrepreneurship has led to increased business opportunities and start-ups in many African states. Further, majority (46%) of the respondents in the survey indicated that entrepreneurship has contributed to economic transformation in many African states. For instance, the Massachusetts Institute of Technology (MIT) innovation centers for entrepreneurship have raised billions of dollars and created jobs off the back of student formed enterprises and good models are good examples for Africa to replicate. Companies started by MIT alumni have created 4.6 million jobs[49], generated up to $2 trillion in revenue, with African companies representing a small fraction of this amount[50]. In Rwanda, the, Skills Employability and Entrepreneurship Programme II (SEEP II) which is supported by the Bank has aided policy reforms that address skills gap, education relevance and entrepreneurship development issues in the country. Achievements as of 2015 include; increased number of TVET student/trainees by 37% overall during 2011-2014 period, about 13,610 new SMEs were registered surpassing the target of 13,500. Business development trainings have been conducted (about 7,484 start-ups and 1500 toolkits to start-ups have been provided) (AfDB, 2015). **Increased collaboration between the private sector entities and the HEIs will yield more fruits skills acquisition, employment generation and sustained livelihoods.**

Box 3: Skills, Employability and Entrepreneurship Programme II (SEEP II)- Rwanda

The programme aimed at supporting policy reforms in addressing skills gap, education relevance and entrepreneurship development. Achievements as of 2015 include; increased number of TVET student/trainees by 37% overall during 2011-2014 period, about 13,610 new SMEs were registered surpassing the target of 13,500. Business development trainings have been conducted (bout 7,484 start-ups and 1500 toolkits to start-ups have been provided.

Source: AfDB (2015), SEEP II Implementation Progress and Results Report (IPR), 2015

In SSA, entrepreneurship ecosystem is becoming vibrant and recording high scores on opportunity perception, but low on start-up skills. Majority (46%) of the respondents in the survey conducted under this study indicated that the contribution of entrepreneurship development to the economic transformation in many African countries was high. However, SSA would achieve more gains by improving the start-up skills through improving education access and skills that

[49]https://news.mit.edu/2015/report-entrepreneurial-impact-1209
[50]https://medium.com/frontier-vc/mind-and-hand-mit-and-the-pursuit-of-african-entrepreneurship-3d29ac81646

support careers in entrepreneurship. For instance, in 2019 Tunisia was the only African country to rank among the top 50 countries in the global entrepreneurship index having been ranked at 40 with a score of 42.4 out of 100. The report further showed that 70% of African countries ranked at bottom twenty of the index due to poor entrepreneurial skills. In Rwanda, the Skills and Business Development Programme (SBDP) which is supported by the Bank has supported entrepreneurship development leading to growth of businesses [Box 4].

Box 4: Skills and Business Development Programme (SBDP)-Rwanda

The programme supports policy reforms for boosting domestic production through skills development and enterprise growth for job creation. The end target of the project includes; increased survival rate of SMES to 60% from 35% (2016), decreased imports to 30% from baseline value of 37% (2016), increased exports to 22% from baseline of 17% (2016), increased credit to SMEs as share of GDP from 7.8% (2016) to 10%. The 2019 implementation progress and results report show that 'Made in Rwanda Policy' was approved by the Cabinet in in December 2017, Revised Special Economic Zone Policy was approved by Cabinet in 2018, and the Professional Certification Programme for Financial Sector has been developed and operationalized.

Source: AfDB (2019); SBDP Implementation Progress and Results Report (IPR), 2019

Across Africa, there has been a massive increase in innovation driven entrepreneurship as evidenced by the rise of technology hubs in many African states. In 2018, a total of 442 innovation hubs had been established within prominent cities like Lagos, Cape Town, Accra, Nairobi and Cairo. The rapid rise in entrepreneurship has been reflected by an increase in startup funding of up to $560 million towards establishment of IT related innovation in 2017 (African Union, 2019). The results show that 36% of the respondents in the survey conducted under this study indicated that investment in entrepreneurship development had led to the creation of employment opportunities especially for the youth. Further, the majority of respondents indicated that investment in entrepreneurship development has led to transformations including in skills acquisition (60%), transforming productivity of goods and services (42%) and transforming sustainable livelihoods (36%). **As such, there is need for African States to build a strong entrepreneurial ecosystem which is embedded in skills development and training that have the potential of promoting job creation and business development.**

Innovation and creativity are the backbone of entrepreneurship, a reality that is beginning to be absorbed by the business community in Africa. Therefore, its development needs to be associated with the development of human capital skills as well in order to make it sustainable (Ndemo and Aiko, 2016). Even though HEIs in African countries have increased entrepreneurship development in the recent past, little has been achieved due to inadequate application of technology in business models, lack of linkages between entrepreneurship and R&D, and lack of public policies that support technology-based companies. **Promoting entrepreneurship in HESTI institutions is crucial in addressing complex societal challenges.**

In Africa, HE has enhanced entrepreneurial capacities and technological transfers aimed at improving linkages between the private sector and HEIs. Entrepreneurial capacities are being improved by having technical and vocational institutions offering courses which require the students to have hands-on experience in whatever they have learned. Furthermore, more courses that are being offered are shifting from theory to practice. Higher education is also linking these institutions to the industries in that students are now able to take time and get practical experience through mandatory alignments in industries through industrial attachments within the same fields. This has led to transformations particularly, in creating public-private partnerships, development of new inventions and innovations, and increased number of qualified graduates guided to start new businesses. About 40% of the respondents in the survey conducted under this study indicated that investment in entrepreneurship has led to new innovations and inventions whereas 44% of the respondents indicated that there was a moderate creation of public-private partnerships.

T**he application of Triple Helix Model in Africa has impacted skills development needed in the job market.** The model is based on the interactions between the government, the industry and research (university) in a bid to foster socioeconomic development [Figure 6]. The linkages between research and industry is very important in skill development due to the fact that the university provides education and basic research to learners. In East Africa, the model has been introduced as a catalyst for skill development for mega projects aimed at supporting economic growth. For instance, a customized Triple Helix program is being tested in the oil and gas sector in Kenya which is aligned with SOGA-project (Skills for Oil and Gas) and is currently implemented by the Technical University of Kenya[51].It **therefore becomes imperative to promote more collaborations between HEIs, government and industry to develop relevant skills that are needed for the job market.**

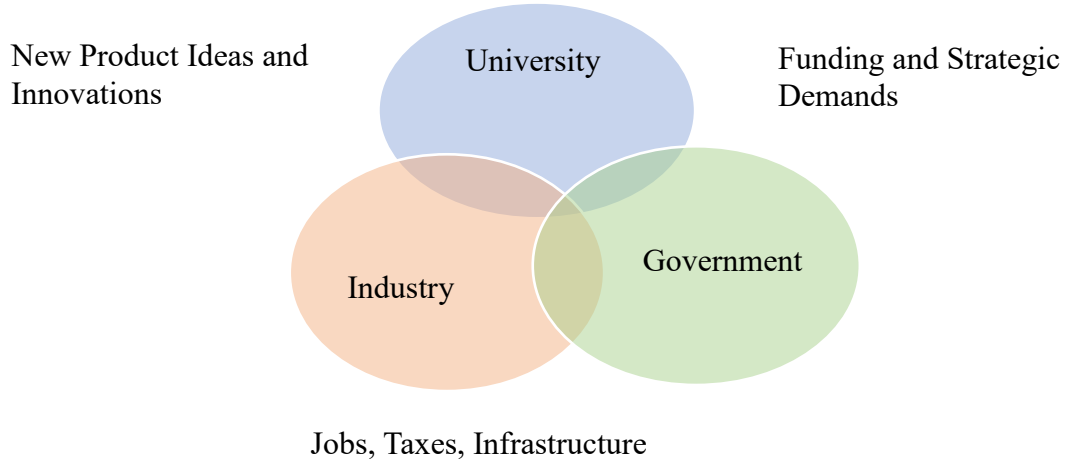

Figure 6: Triple helix model of innovation
Source: Author

[51]https://www.msm.nl/consultancy/project-references/triple-helix-approach-to-support-economic-growth

3.0 PRIORITY AREAS: TRAINING INFRASTRUCTURE, FINANCING, AND GOVERNANCE

3.1 Training Infrastructure

Training infrastructure is an important aspect in developing HESTI in Africa. The training infrastructure includes labs, libraries, ICTs and communication networks, databases, and electricity among others. However, the infrastructural gaps witnessed in many African states have posed a challenge in developing requisite skills for employability and job creation. Universities in Africa cannot compete in a fast-moving world of research and development due to lack of basic infrastructure[52].This is alluded to by the findings from the survey conducted under this study which showed that 70% of the respondents indicated that inadequate training infrastructure was the highest barrier to HESTI, R&D and entrepreneurship development in most African states.

3.1.1 State of the Current Infrastructure in HESTI, R&D in Africa

Information and Communication Technology (ICT)

While Information and Communication Technology (ICT) continuous to advance in western and Asian countries, most Africa countries continue to lag behind in its deployment, and that continues to widen the gap in the digital divide and increase digital literacy challenges[53]. Lack of digital skills amongst faculty and students has made it difficult for HEIs to provide virtual learning. Up to 72% of respondents in the survey conducted under this study indicated that usage of smart classrooms was low. Furthermore, the lack of ICT skills needed for employability and productivity is exacerbated by the low internet penetration and has put majority of the population especially the youth and women at a disadvantage in harnessing the emerging new entrepreneurial businesses and other economic activities that generate new employments. According to the International Telecommunication Union (ITU), 21% of learners in Africa cannot be reached by 3G mobile networks[54]. On the general state of training infrastructure in HESTI and R&D, 54% of the respondents in this study survey indicated that they are not satisfied. **This presents good opportunity for investors to develop state-of-the-art training infrastructure including digital classrooms, internet connectivity, and other technological devices that aid learning in selected regions of Africa starting from countries that will present matching funds and other technical supports.** For instance, the Coding for Employment Program (CfE) by the AfDB seeks to develop, scale and replicate proven models that will unlock millions of jobs for African youth.

[52] Atuahene, F. (2011) "Re-thinking the Missing Mission of Higher Education: An Anatomy of the Research Challenge of African Universities" in Journal of Asian and African Studies, Vol. 46 (4), 321-341.

[53]https://www.ictworks.org/12-challenges-facing-computer-education-kenyan-schools/#.X8faB2gzZPY

[54]http://uis.unesco.org/en/blog/importance-monitoring-and-improving-ict-use-education-post-confinement

The program aims to develop and launch Africa's next generation of digitally enabled youthful workforce [Box 5].

Box 5: Coding for Employment (CFE)

The programme aspires to achieve the following: 1) equip 130 centers of excellence with ICT infrastructure by 2025, (2) train young people in demand driven ICT skills and entrepreneurship and 3) provide graduates with linkages to the ICT ecosystem for internships and job opportunities. Each center of excellence is expected to train at least 1,800 young people which will contribute to the wider program objective of training 234,000 youth and creating 9 million jobs over the next decade. Five (5) countries have been identified to pilot the program namely Kenya, Rwanda, Nigeria, Senegal and Cote d'Ivoire. Some of the achievements so far include, 47% of women and girls have been trained in the centers of excellence, 219 trainers in 12 centers across Africa have been trained, 23,200 youth have been trained through online learning platforms and onsite centers of excellence, 14 centers have been identified in Nigeria, Kenya, Rwanda, Côte d'Ivoire and Senegal, while 9 centers under development have established partnerships with Microsoft and Facebook and have worked closely with other companies - Safaricom, LinkedIn and Orange. The Program has linked over 100 youths who have been trained in Nigeria with online work in Image annotation for AI applications. Some of the challenges witnessed include; risk of drop out in online training, lack of access to devices, software and internet by the youths, and ineffectiveness of volunteer trainers who have little or no experience in delivering curriculum in a distance learning setting. The Coding for Employment program is a partnership between the Bank and The Rockefeller Foundation and other private sector knowledge partners such as Microsoft and Facebook.

Source: AfDB (n.d); **Coding for Employment** -Project Appraisal Report

Fourth Industrial Revolution (4IR)

The Fourth Industrial Revolution has the potential to transform Africa's economy. However, Africa's readiness for future productions is still low [Table 4]. According to Stankovic, Mirjana (2019[55]), African countries are in the top third of the global ranking with only Mauritius and South Africa making it to the middle third while other countries fall in the bottom third. Majority (70%) of the respondents in the study survey indicated that inadequate use of emerging technologies such as ICT and 4IR remain the greatest barrier to HESTI, R&D and Entrepreneurship development in many African states.

Table 4: Africa readiness for future production score

	Structure of production		**Drivers of production**	
Country	**Scores (0-100)**	**Rank [Out of 100]**	**Scores (0-100)**	**Rank (out of 100)**
Cameroon	1.84	98	3.24	100
Egypt	4.99	46	4.46	68
Ghana	1.96	97	4.14	77
Kenya	2.97	88	3.83	83

[55]https://www.researchgate.net/publication/337167501_Unlocking_the_Potential_of_the_Fourth_Industrial_Revolution_in_Africa

Mauritius	3.84	73	5.37	39
Morocco	3.67	77	4.35	73
Nigeria	1.66	100	3.68	88
Senegal	3.11	87	3.74	85
South Africa	5.03	45	5.02	49
Tunisia	4.83	51	4.41	72
Uganda	2.25	94	3.31	97

Source: AfDB (2019)

In light of the low level of preparedness of developing countries in Africa, several indicators essential for the 4IR particularly infrastructure, education and technology access show that many African states still lag behind (Adam, 2019). With regards to technology access in Africa [Figure 7] shows that the international internet bandwidth per Internet user (Bit/s) in Africa is 51, 000 compared to 74,464globally. The percentage of household with a computer in Africa is 10.7% compared to 49.7% globally. Further, the percentage of household with internet access in Africa is 17.8% compared to 57% globally. In terms of technology use, fixed (wired)-broadband subscriptions per 100 inhabitants in Africa was 0.4% while active mobile broadband subscriptions per 100 inhabitants was 22.9%. In terms of technology preparedness particularly in tertiary gross enrollment, the ratio in Africa was 9.49 compared to 38.69 globally. The internet penetration in Africa as at March, 2020 was 39.3% compared to world average of 58.8%[56]. Further, the countries that have surpassed or equal to the world average of 58.8% include Kenya with internet penetration of 87.2%, Libya 74.2%, Seychelles 72.5%, Mauritius 67.0%, Tunisia 66.8%, Morocco 64.3%, Cabo Verde 63.3%, Reunion 61.8%, Mali 61.6%, Nigeria 61.2%, and Gabon 58.8%[57].Majority (54%) of the respondents in the study survey indicated that the current status of internet connectivity is overall low. **This again presents a good public-private partnership investment opportunity as well as technical supports mostly to countries below the global averages.**

[56]https://www.internetworldstats.com/stats1.htm

[57]https://www.statista.com/statistics/1124283/internet-penetration-in-africa-by-country/

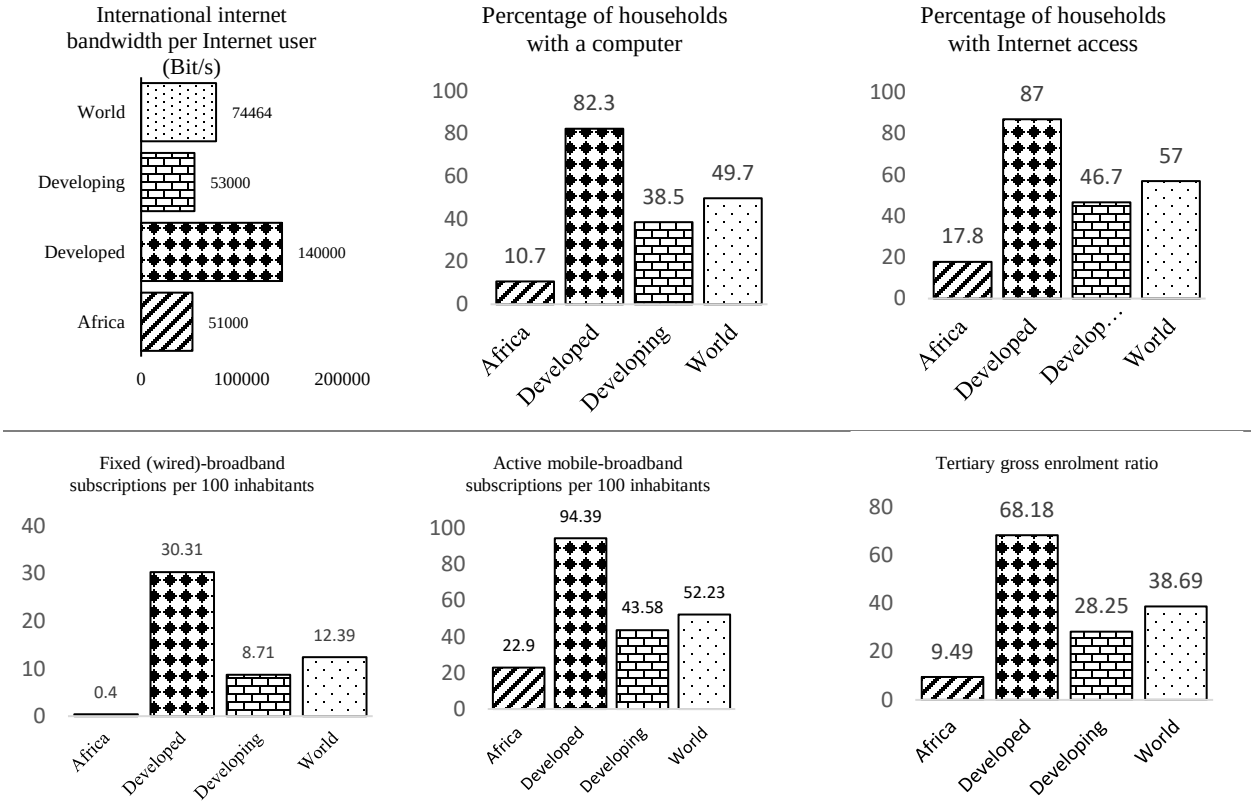

Figure7: Africa's preparedness for Fourth Industrial Revolution 2020.

Source: Adam, (2019) for international internet bandwidth, fixed broadband subscriptions, active mobile broadband and tertiary gross enrollment ratio; ITU (2019)[58] for percentages of households with a computer/internet access.

In Mauritius, the cyber caravan has been launched to improve digital literacy by making access to internet and ICT facilities [Box 6].

[58]https://www.itu.int/en/ITU-D/Statistics/Documents/facts/FactsFigures2019.pdf

Box 6: Cyber Caravans of the National Computer Board -Mauritius

The Cyber Caravan was launched in November 2000 in Mauritius and aimed to make ICT facilities available for the isolated areas in Mauritius through the National Computer Board (NCB's) Cyber Caravans. NCB operates two cyber caravans which are equipped with computers, laptops, broadband internet connections and travel around the island to deliver training assistance to the public on the use of ICT by the IT support officers. As of December 24, 2018, a total of 217,588 persons have followed the above training courses. Also, 8,796 persons (children, adolescents, students, women and unemployed people) have been initiated for the period July 2017 to date. The initiative aims to convert Mauritius into a regional ICT hub. It also, strives to improve digital literacy through building an all-inclusive information society, promote and encourage ICT literacy and ensure that all computer users understand the benefits of using a computer. To enhance employability of all people. In providing special attention for women, ICT literacy courses have been provided to women of different regions across Mauritius after which a certificate of attendance is issued.

Source: National Computer Board – http://ncb.intnet.mu

Tech Hubs, Incubation Centers, Innovation and Information Labs

Innovation and information labs have been acknowledged as catalysts for supporting entrepreneurship, innovation incubation programmes, partnerships, and new idea generation. In many African countries, there has been an increase in the number of incubators and accelerators (tech hubs) due to an increased adoption of smartphones and reduction of internet costs. According to GSM reports, active tech hubs across Africa had increased from 314 to 442 hubs as at 2018 representing 50% growth (AfDB, 2019b). This has seen high profile and tech-giant organizations such as Google and Facebook invest heavily across the African continent recording a 40% increase in the number of tech hubs for a period of 2 years as at March 2018 (AfDB, 2019b).As at 2019 [Figure 8], Nigeria had the highest (85) tech hubs compared to Tanzania which had the least (17).[59]

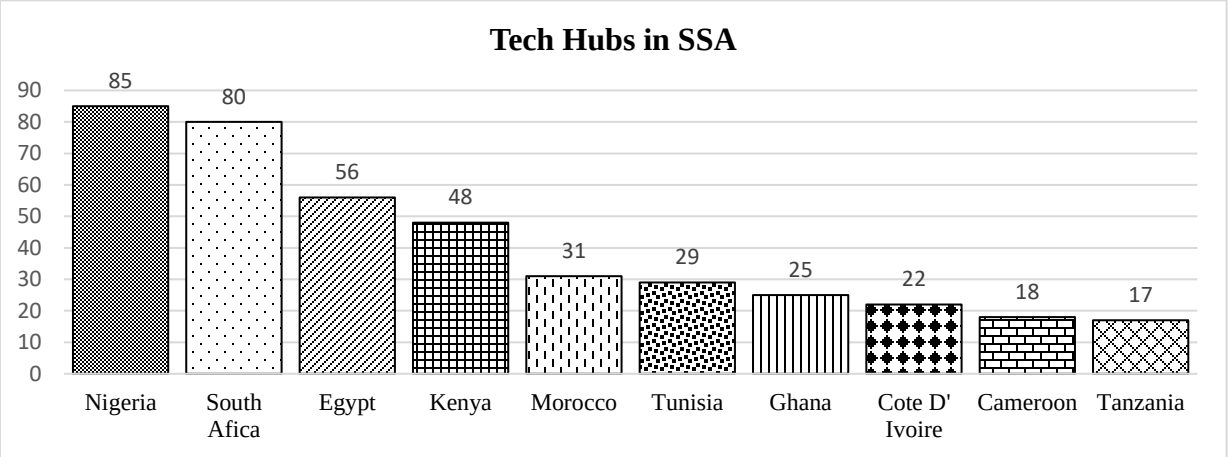

Figure 8: Sub-Saharan African countries leading in number of technology hubs.
Source: Atlas, 2019

[59]https://qz.com/africa/1777241/the-biggest-trends-in-african-tech-startups-and-innovation-2019/

The rising number of tech hubs show that the continent is starting to specialize beyond its individual ecosystems leading to growth of local talents and business opportunities. In Rwanda [Box 7], the establishment of Klab has opened opportunities for women to acquire digital skills.

Box 7: kLab-Rwanda

KLab-Rwanda is a free collaborative space tailored for budding young entrepreneurs. It was founded in 2012 in Kigali Rwanda. It is one of the many new initiatives in the Rwandan government's strategy and partnership with private sector in promoting ICT.K-Lab aims to become a beacon for Rwanda's ICT hopes and dreams where youths can nurture innovation and find opportunities. It aims to overcome challenges in the field such as lack of entrepreneurial opportunities in HEIs. K-Lab is supported by the government with ither development partners. The high-speed internet was donated by the Rwandan Development Board (RDB). Rwanda's ICT Chamber and RDB play a crucial role in managing the growth of the space. Renovations and furnishing inside the space have been funded by JICA, a Japanese development agency. K-Lab encourages women and as an evidence, as at 2018, women count more than 30% of the projects in incubation.

Source: https://klab.rw/

In Kenya, tech hubs have opened an opportunity for new investors and corporates to seize the fast-growing pool of tech talents within the country [Box 8].

Box 8: iHub Kenya

The iHub was opened in2010 as a place for the tech community in Nairobi to gather and build connections to each other and work on innovative ideas. iHub provides support system for ICT focused entrepreneurs who aspire to create companies leveraging the unique opportunities in Africa. iHub intends to be 100% self-funded and aims to ramp up its contributions to become a preferred global service provider.

Source: https://ihub.co.ke/; https://techmoran.com/2016/03/14/ihub-raises-funding-to-build-profitable-startups-that-can-scale-regionally-globally/

In DRC Congo [Box 9], an Ingenious city was established to give back to the young Congolese a place where entrepreneurship is stimulated and supported. The initiative aims to address a number of deficiencies in the DRC entrepreneurial ecosystem including; lack of stable working space with reliable infrastructure for startups, the shortcomings in available mentorship, and poor incubation programmes as well as the gaps in access to investors.

Box 9: Ingenious City DRC Congo

The Ingenious City incubation platform was launched in partnership between DRC's Sycomore Ventures and Ukaid in 2018 bringing together five local startup incubators in a single space to address the deficiencies of the entrepreneurial ecosystem in the country. Since 2018, the initiative has created a training and mentoring programme which aims to give young startups in the country a boost as well as assisting incubator managers in developing their models further. Up to 52 mentors from various entrepreneurial and corporate backgrounds have been enrolled to assist startups pleading to spend at least 2 hours of their time each month coaching/advising start up entrepreneurs. The initiative aims to become a point of reference for the ecosystem in DRC: a place where aspiring entrepreneurs can be trained and meet with mentors and investors at the local level and at the national level. A place where the media and institutions both private and public can come when seeking information on the ecosystem as well as someone to talk to regarding startups. The platform provides an easy entry point for donors/sponsors. It aims to be a space where incubators can use shared services (desk space, internet, event space) at affordable rates. In articulating gender-specific services, out of the 6 existing incubators that form the Ingenious City, one is dedicated to female entrepreneurs that were already active at Kinshasa, but struggling to finance their space and with difficulties in internet connections. Sponsorship deals have been signed with Vodacom. Sycomore Ventures and Ukaid have also supported the initiative. The initiative however still faces budgetary challenges to meet its expectations. Apart from budgetary challenges, there is the lack of suitable personnel to run Ingenious City on a day to day basis as finding people with the required expertise and experience in this field has been difficult.

Source: https://ingeniouscity.com/; https://disrupt-africa.com/2018/05/ingenious-city-incubation-platform-launches-in-drc/

Despite the positive contributions made by the tech hubs, there are still inadequate capacities. Twenty-five percent of the active hubs offer co-working facilities instead of tech-focused support programmes or funding[60]. Majority (60%) of the respondents from this study indicated that usage or/ availability of infrastructure for incubation, fabrication laboratories (Fablabs), deep technology start-up companies is still low. **Increased investments especially by private sector entities have always yielded greater fruits in this regard. However, they need to be supported with interest free or highly subsidized loans especially for African entrepreneurs and investors.**

3.1.2 Role of ICT-Power Nexus in HESTI, R&D and Entrepreneurship Development.

Connectivity/ICT-Power Nexus is directly proportional to technological advancement. In SSA, the energy access rate is about 43% which is much lower in comparison to other regions (Blimpo and Malcolm, 2019). This means that the available energy occasioned by frequent power outages is not enough to support emerging infrastructure needs of HESTI, R&D, and

[60]https://www.gsma.com/mobilefordevelopment/blog/618-active-tech-hubs-the-backbone-of-africas-tech-ecosystem/

entrepreneurship in developing the required skills for employability. Majority (46%) of respondents in this study indicated that the available power supply in many African states for training infrastructure is low. They (68%), however, acknowledged that energy access/ ICT collaboration lead to technological advancement in HESTI, R&D and Entrepreneurship development. **Supporting HEIs in providing these relevant training infrastructures will boost learning, skills development and employability. The role of the private sector in this regard still remains paramount.**

3.1.3 Despite several existing best practices on sustained maintenance of HESTI and R&D infrastructure in many African countries, the maintenance culture still remains low. Several best practices on sustained and continued maintenance of HESTI and R&D has been recorded in many African countries. The Bank has supported several ICT projects in RMCs in this regard. A case in point is the Bank's ground breaking support in HE Centres of Excellence (CoE) up to the tune of US$124.3 million in Mali, Uganda and Rwanda in 2011. The CoE receiving the funds included the Mulago Teaching Hospital in Kampala, Uganda (USD 88.8 million), the Bamako Digital Complex in Mali (USD 22.5 million) and Carnegie Mellon University in Rwanda (USD 13 million[61]. In Rwanda, Carnegie Mellon University -Africa (CMU-Africa) is receiving USD 13 million from the Bank and USD 95 million over 10 years from the Rwandan government to operate the program. The Center aimed at driving Rwanda's economic growth through digital transformation. As of May 2020, CMU-Africa has 262 alumni, 83% of them working in their home countries impacting the development and application of ICT on the continent[62].

Ogunleye et al (2020) notes that, following the COVID-19 pandemic, countries have been forced to embrace smart classrooms as an emerging trend in a quest to deal with the pandemic. HEIs have resorted to conducting their operations remotely via digital platforms such as Zoom, Skype and Vimeo among others. Countries like Kenya and South Africa have been conducting their learning programmes via online platforms. In an effort to promote and sustain scientific research and development in African countries, some governments have developed national bodies that regulate and oversee all the research that is being carried out within their countries.

Despite several best practices on sustained and continued maintenance of HESTI and R&D equipment in many African countries, it still remains inadequate. Majority (46%) of the respondents in this study survey indicated that maintenance culture on training infrastructure was moderate. In most of the African countries particularly SSA countries such as Burkina Faso, Central African Republic, Mauritania, Senegal and Lesotho, sustaining and maintaining the HESTI

[61]https://www.afdb.org/en/news-and-events/afdb-approves-usd-124-million-for-centers-of-excellence-in-mali-uganda-and-rwanda-8459
[62]https://www.africa.engineering.cmu.edu/alumni-impact/index.html

system is challenged by the fact that the government spend less than 0.5% of their GDPs in R&D in their respective countries compared to the 1% target set by African Heads of States. With many African governments struggling to sustain STEM courses in public HEIs, private owned institutions in most cases tend to perform better than those owned by government. **Capacity building and re-orientation will be required to boost the maintenance culture in the HESTI institutions. Sustaining maintenance culture of HESTI and R&D infrastructures can also be achieved through relevant policies and its effective implementation.**

3.2 Financing

The role of knowledge – its generation, transfer, uptake and utilization has become a key topical issue as countries transition to the knowledge-based economy (KBE). HESTI and R&D – the two methods of generating and utilizing knowledge can only be sustained through adequate financing/funding[63] and investments. Yet 40 years after the adoption of the Lagos Plan of Action, countries in Africa have not fully complied with the commitment by the Heads of States to allocate at least 1% of their GDPs to R&D. The low domestic funding and investments in R&D in particular and in STI in general has been worsened by the 2007 global financial crisis and the 2008–2012 global recessions which resulted in reduced budgetary allocations for R&D globally. The financing gaps witnessed in Africa's HESTI have caused a major challenge in meeting its education and skill needs. Majority (62%) of the respondents in the survey conducted under this study indicated that poor funding and investment in many African countries remain the greatest barrier to HESTI development. Studies have shown that in order to increase the funding/financing opportunities for R&D under the current global financial crises and national cutbacks budgets, new approaches and considerations must be made (Ozor, 2015 and World Bank, 2008). These conditions have already been made worse by the ravaging effects of COVID-19 and has provided more impetus to increase the funding of R&D in African countries.

3.2.1 Innovative Financing Mechanisms (Models, Schemes, Approaches)

Innovative financing refers to a range of non-traditional mechanisms aimed at raising additional funds for development (Navin, 2009). Innovative financing mechanisms can be assessed based on the following principles: **Scaling-up (**should significantly increase funding in order to bridge the financing gap necessary to achieve development); **Additionality**(as it is created to fill a gap, this mechanism cannot replace the Official Development Assistance (ODA) nor will they be sufficient

[63]Whereas the terms funding and financing are used interchangeably here, it is important to note the slight difference between them. While "**funding**" refers to an amount of money provided by an organization or government on the basis of an agreement for the provision of goods and services and with no requirements to pay back the capital, "**financing**" on the other hand refers to an amount of money provided to an organization with the expectation to pay back the capital amount along with a certain percentage of interest. The most common facilitators that normally fulfill the funding needs of an organization are the donations made by governments or philanthropists while financing needs are usually provided by financial institutions such as banks, or investors like venture capitalists, business angels, shareholders, etc.

if countries decide to renounce the commitments that they have made in the target sectors); **Complementarity**(should raise new funds for existing organizations and not to add new actors and complexities to the development landscape; and **Sustainability** (should have the objective and ability to finance long-term programs in collaboration and cooperation with other entities).

Several innovative financing mechanism and models have emerged to spur growth of technological innovations that are needed to contribute and support HESTI in creating employability, skills and productivity in the labour market (Mugwagwa, Banda, Ozor, Bolo, Oriama,2019). Top among them include; government funding, private sector funding, public-private sector funding, foundations and philanthropies, impact investors, non-governmental organizations, international collaborative grants, charity organizations, patent buyouts, corporate funding, development partners, loans schemes, consultancy services, and diaspora financing. Despite the introduction of various financing mechanisms to fill the gap in HE financing, majority (54%) of the respondents in the study survey indicated that they are not satisfied with the current status of funding for HESTI and R&D development. **This calls for increased collaborations in education investments as well as in adopting new and emerging mixes of financing mechanisms for HESTI by RMCs.**

Government Funding

HE funding in many African countries has remained the responsibility of the State. Traditionally, governments have funded basic, applied and translational research in higher institutions of learning and research organizations as investment in economic growth and development. Governments predominantly use either direct funding in the form of grants and subsidies or indirect funding in the form of tax incentives, soft loans and other fiscal policies. In South Africa, the State remains the largest source of funding to public universities with some universities receiving more than 30% of their total income while others receive almost 65% of their total revenues from the government (Wangenge-Ouma et al, 2008). In Tanzania, 90% of the costs needed to run the operations of the public universities are borne by the State (Mgaiwa, 2018).Even though government funds HE, majority (46%) of the respondents in the survey conducted under this study indicated that government funding such as research funds and budgetary allocations has been inadequate.There is need for the government to mobilize more resources for HE and R&D. For instance, the National Research Foundation (NRF, South Africa) [Box10] and the National Research Fund (NRF, Kenya) have instituted functional STI research grants schemes[64] while countries such as Ghana, Rwanda and Nigeria are in various stages of establishing their own national research funding schemes.

[64] https://www.nrf.ac.za/sites/default/files/documents/NRF%20Annual%20Report%202019-2020%20final.pdf

Box 10: National Research Foundation (NRF) South Africa

NRF was established as an independent government agency through the NRF Act (Act No 23 of 1998) following a wide system review conducted by department of Arts, Culture, Science and Technology. The mandate of NRF is to promote and support research through funding, human resource development and the provision of the necessary research facilities in order to facilitate the creation of knowledge, innovation and development in all fields of ST including indigenous knowledge thus contributing to the improvement of the quality of life for all South Africa citizens. During the 2019/2020 financial year, 11,918 postgraduate students including 3,883 masters and 2,831 doctoral students were funded. A total of R2.4 billion in grants and bursaries was invested to support students, researchers and research infrastructure, Also R827 million was spent on strategic interventions, consisting of 232 active Research Chairs and 14 operational Centres of Excellence (CoE's). The number of NRF rated researchers continues to grow from 3,957 in 2018/19 to 4172 in 2019/20 of which women researchers grew from 1,358 to 1,455 and Black researchers from 1,207 to 1,322).

Source: NRF South Africa

Private Sector Funding

The private sector funding for HESTI and R&D are usually directed towards applied research and commercialization of innovations. According to Shankar (2016), in most markets, private sector is characterized by profit motives, however when it comes to education, they are required to operate on a not-for-profit basis. Some private HEIs, fund themselves through tuition fees collected from the students as they are run as not-for-profit trusts. The private HE does not receive any direct benefits from the government; however, they apply for tax waivers on some imported equipment (Gudo, 2014). In other countries, the private sector funds HE through providing affordable student loans. For instance, in Ghana, Brighter Investment pays for the university costs as well as provide mentorship programs to talented students with flexible repayments usually after beneficiary graduates get jobs (AEO, 2020). Despite its use, majority (64%) of the respondents in the study survey indicated that deployment of private sector financing is generally low Additionally, the results show that only 26% of the respondents felt that private sector actively funded the HESTI and R&D while 74% said it does not. The following were the reasons cited: that government policies are assumed as barriers; most R&D are funded by government and development partners; private sector is interested in immediate revenue and do not have interest on R&D; the private sector rarely provides funds for scholarships; and that the private sector has not seen much interest about HESTI and R&D. They further noted that most investors that run private sector businesses are sole proprietors and they provide all amenities and infrastructure for their businesses which makes the cost of doing the business to be very high while leaving little or nothing to support HESTI and R&D; there is also lack of trust when it comes to collaboration between the private sector and the public sector as they see each other as competitors rather than as collaborators.

Diaspora financing

According to Panigrahi, (2018), diaspora bonds has been acknowledged as an innovative method of funding HE. Itis a kind of philanthropic contribution towards one's country development such as education and it is driven by a sense of nationalism. Capital inflows to Africa in the form of Diaspora remittances outperformed ODA according to recent estimates of the World Bank. In 2015, official remittances to SSA were estimated at US$ 40 billion[65]. This is potentially game changing because remittances are only a fraction of annual Diaspora savings, stated by some estimates to be more than 3% of regional GDP for SSA alone (Rustomjee, 2018). In Africa, South Africa is one of the countries that has been in the forefront of raising hard currency from their diasporas living abroad. In this regard, the diaspora holds significant untapped potential in the fight against climate change, yet there has not been significant continent-wide effort to strategically engage this huge resource. Despite diaspora financing mechanisms being deployed in many African states, majority (64%) of the respondents in the survey indicated that deployment of diaspora funding financing in HESTI, R&D and entrepreneurship development remains low. This is because this funding stream is often unstructured and individually-driven. The African continent needs to strategically engage the diaspora resource to fill the gaps witnessed in HESTI and R&D investments.

Domestic and Global Tax Bargains

According to Kangave *et al* (2015), tax bargains which is also known as fiscal contract refers to a negotiation between the taxpayers and the government, where the tax payer agrees to comply with tax obligations in exchange for provision of government services. Tax bargains can be made with specific groups of taxpayers or they can be "negotiated" generally. African countries have embraced domestic and global tax bargains to fill the financial gaps in dealing with their development projects including allocating a percentage of their GDP to R&D; and allocating mineral export tax revenues from local mining projects towards STEM development among others. In Sierra Leone, under the domestic bargain agreement, the community development allocates about 3% of diamond export tax revenues towards local mining projects (Kangave *et al*, 2015). This ensures that the researchers, scientists, engineers as well as the innovators get funds annually from the revenues which sustain their work. **There is need for African countries to develop and utilize financing opportunities offered through domestic and global bargains to fill the financial gaps in dealing with their development projects especially in the areas of HESTI and R&D development.**

Charities

Charities are organizations that are set up to provide help and raise finance for those in need. According to Kundu and Matthews (2019), charity is a voluntary act of giving someone in need. Across the globe, charities have played a key role in financing research. Mugwagwa et al (2019)

[65]https://www.bu.edu/africa/files/2016/11/Boston-University-Report-African-Diaspora-and-Remittances.pdf

noted that charities provide grants and co-fund academic and small and medium scale enterprises (SMEs)in neglected areas. For instance, Stanford University which is a leading centre of innovation and research has been recognized as a product of charitable giving. The Royal Academy of Engineering- a UK based national academy of engineering and a charity, offers prizes for engineering innovations in Africa and for Africans. Additionally, it awards commercialization support to ambitious African innovators from SSA (Ettridge and Sharma, 2020). Despite its importance in bridging the financing gaps, majority (68%) of the respondents in the study survey indicated that deployment of charities as financing mechanism for HESTI, R&D and entrepreneurship development is still low.

Corporate Funding

Corporate financing mechanism is a type of funding where companies and private sector entities fund HEIs by supplementing the cost of education and research[66]. With the declining public funding in the recent years at the public universities, private companies have come in to finance aspects of HE costs thus reducing financing gaps in many HEIs in Africa. The funds from companies are very critical for scientific advancements. For instance, the International Atomic Energy Agency (IAEA) offers fully funded scholarships to students especially women who undertake STEM courses in HEIs (World Economic Forum, 2020). The scholarship aims to promote global scientific and technological innovation in building skills that match the industry. In the same line, IAEA in an effort to support and promote research carries out coordinated research activities with countries such as the DRC, Mali, Cameroon, Kenya, Mauritania and other African member states. This helps to fund research that would otherwise be difficult for the African states to carry out on their own due to the inadequate financial resources. Despite usage of corporate funding in Africa, majority (64%) of the respondents in the study indicated that its deployment is still low and inadequate to sustain HESTI, R&D and entrepreneurship development. **There is need for financial institutions to support the private sector organization to unlock and expand their businesses and be able to effectively contribute an agreed percentage annually towards HESTI and R&D in HEIs.**

Public-Private Partnership (PPP)

Public-Private Partnership (PPP) is a cooperative arrangement between a public entity and private entity typically on a long-term basis. The PPP in HE entails a model of financing where the private and the public sectors share the costs and risks of education in a manner that involves contracts to acquire a certain service, of the right quality and quantity and at a particular price. Through these partnerships, service delivery is enhanced to students and staff in the learning education institutions. In an effort to develop skills that match the industry, governments in Africa have collaborated with the private sector and HEIs to develop training and apprenticeship programs through subsidized internship, co-funding training centers with industries and corporate funding

[66]https://gmoanswers.com/our-take-corporate-funding-public-universities-and-research

of innovation and research universities. In Sierra Leone, these partnerships have helped to make education accessible to the poor as well as to the majority of students in Democratic Republic of Congo. In Tanzania, PPP has enabled the establishment of private learning institutions which have provided more than 30% of the total higher education institutions student population (Mgaiwa et al, 2016). In the North Africa region, Morocco provides best practices in skills with multinational companies such as Safran collaborating with the state and aerospace industry associations in creating a training center. In East Africa region, the government of Kenya and Rwanda have zero rated ICT equipment as capital goods in an effort to increase access to ICT which is key in supporting development of human capital (AEO, 2020). This type of financing has seen skills development gradually increase. In an effort to strengthen the entrepreneurial development, several clients within the RMCs in Africa have sought the Bank's intervention as a priority in developing projects thus giving the bank the comparative advantage in supporting several projects within HESTI, R&D and Entrepreneurship. For instance, in 2020, the government of Ghana sought the support of the Bank to establish a national development bank. As such, the government has pledged to work with the Bank to look at global arrangements for cheaper financing. In supporting the private sector, the Bank has funded a $56.3 million project designed to provide incentives for private sector agribusinesses in northern Ghana to increase yields. Also, the ministry of Agriculture is seeking additional US$ 150 million to implement its "Planting for Food and Jobs" policy[67]. Despite the efforts to upscale the PPP, majority (60%) of the respondents in the study survey indicated that the lack of PPP in many African states remains the highest barrier to HESTI, R&D and Entrepreneurship development. With regards to PPP financing, majority (62%) of the respondents in the study survey indicated that deployment of PPP financing is low. **African government need to create enabling environment to accelerate PPP. This can be achieved through implementable policy frameworks.**

International Collaborative Grants

Many research organizations in Africa get their funding by submitting proposals for grants to donor organizations that offer funding. For example, the Norwegian Agency for Development Cooperation (Norad) is a directorate under the Norwegian Ministry of Foreign Affairs and supports many African countries such as Zambia, Uganda, Malawi, Angola, Kenya Tanzania, Nigeria, Zimbabwe and the DRC by giving out development funds to support research in the areas of global health, economic development and natural resources. Norad usually funds the countries on a five-year basis. Again, the Fogarty International Center based in USA offers financial support for research projects in SSA. The organization cost shares research projects by offering close to a third funding support on health projects. Countries that receive support include Angola, Benin, Burkina Faso, Central Africa Republic, Lesotho, Seychelles, and Rwanda. Despite the supports that these countries receive in terms of funding, the research and development projects in the

[67]https://www.afdb.org/en/news-and-events/ghana-seeks-african-development-bank-support-domestic-development-bank-34688

African countries still remain poor as in most cases, the funds get misappropriated and squandered for other uses by selfish individuals and corrupt politicians. A report by World Bank shows that research collaborations in Africa range from 0.9% in West and Central Africa to 2.9% in Southern Africa (Fonn *et al,* 2018). The report by World Bank (2019) calls for increased collaboration between African countries through scaling up existing research and research-based education programs. Majority (44%) of the respondents in the study survey indicated that deployment of international collaborations financing in many African states is low. African governments need to create efficient structures such as capacity, transparency and accountability so as to attract more international collaborative grants.

Foundations and philanthropists

Philanthropists are persons who seek to promote the welfare of other people through generous donations for a good cause whereas philanthropic foundations are non-profit organizations with assets provided by donors and managed by its staff with income expended for socially useful purposes[68]. Philanthropic foundations have provided an important role in HE by not only covering financial aid and operational costs but also subsidizing tuition fees (Thelin and Trollinger, 2014). In South Africa, domestic philanthropic support for HE has greatly outpaced funding from international organizations and funders. For instance, the Kresge foundation's 13-year partnership with Inyathelo has supported South African universities in building its capacity, forge relationships with key stakeholders and in attracting resources needed for their sustainability (The Kresge Foundation, 2019)[69].Other institutions, foundations and philanthropists from developed countries support the development of STEM and R&D in African countries by providing grants and scholarships. The Bill and Melinda Gates foundation has continuously supported skills development in innovations that are required in the labour market. Additionally, Loughborough university in partnership with Council for Advancement and Support of Education (CASE) and HE institutions in Africa have supported African universities to develop new digital resources including; mobile phone apps, websites, videos and podcasts. Among the universities they have supported include; University of Ibadan and Lagos Busines School in Nigeria, Strathmore University in Kenya, University of Cape Town and the University of Witwatersrand in South Africa, and University of Ghana[70]. Despite these milestones, majority (68%) of the respondents in the study survey indicated that deployment of foundations and philanthropies financing is still inadequate calling for more endogenous financing as a more sustainable financing mechanism **The African governments needs to establish an appropriate policy and legal framework for local philanthropy**.

Consultancy Services

[68]https://www.britannica.com/topic/philanthropic-foundation

[69]https://kresge.org/news/domestic-philanthropic-support-south-african-universities-outpaces-giving-international-donors

[70]https://www.lboro.ac.uk/news-events/news/2019/august/digital-resources-support-african-universities/

Consultancy is a practice where experts offer professional advice or service to other parties, normally at a fee (Ozor et al, 2020). Consultants provide expert knowledge in the form of recommendations, advice, opinions or implementation of specific projects. Thus, consultants are specialists hired to perform a specific task for a specific period of time under specific terms by individuals or organizations. Consultancies therefore enable experts to share their knowledge. The HE institutions and their professionals have undertaken various relevant elements of research activities as consultants for the state, industrial units, universities, and the private sectors among others. Through these engagements, they can generate resources towards meeting their urgent expenses such as in infrastructure development which otherwise would have been difficult when there are shortages of government funding (Pouris, 2012). The Science system actors can use consultancies as capacity building opportunities through which experts expose their knowledge and also strengthen the capacity of their clients. Given the costs associated with employing experts fully, consultancy provides an affordable option of benefiting from them without having to keep them in fulltime employment. The best way to benefit from the skills of consultants is to build a training aspect to all consultancies which enables the organizations to acquire some knowledge from the experts (Ozor et al, 2020). Despite its use, majority (64%) of the respondents in the survey indicate that deployment of consultancy services financing mechanism for HESTI and R&D is low. In addition, HE institutions lack the marketing capacity and promotional ability to showcase their consultancy competencies as a strategic service worthy of patronage and fund generation. In cases where this is available, it is mostly carried out privately by individual staff with little institutional structures for remuneration. A typical example of consultancy service is obtainable at the University of Nigeria, Nsukka (UNN) with an outfit tagged "UNN Consults". This consultancy outfit engage in a broad range of consultancy services in academic, professional and technical fields of endeavour with the purpose of generating income for the university. Experts from the University are usually engaged in delivering these services at agreed terms and conditions.

Enterprises /Commercial Ventures

Enterprise/commercial venture type of funding model is where HEIs establishes some income generating activities to supplement the operational costs of the institution. The fiscal distress in HEIs has exerted pressure for them to generate more resources to supplement the deteriorating capitation from the treasury/or exchequer. Many governments have stated that it is no longer possible for public HEIs to rely on government funding. As such, they have been directed to generate their own sources of funds (Gebreyes, 2015). It is with response to this that many HEIs in Africa have decided to establish income generating enterprises to supplement their budgets with proceeds going into research and development. Some of the enterprises which are of different kinds include bookshops, hotels, petrol station, university schools among others. For instance, according to World Bank (2010:74), on average, HEIs generated about 28% of their revenue with Madagascar and Zimbabwe recording 5% or less and Guinea-Bissau recording 75%. In Kenya, the University of Nairobi has established a limited company under the name of University of Nairobi

Enterprise Services Limited (UNES) which handles all its income generating activities. In Nigeria, the University of Nigeria, Nsukka operates the UNN Agriculture Limited which runs purely as a profit-making independent enterprise in the university focusing on agricultural goods and services. Through the enterprise, students can also be interned to learn basic agribusiness practices. In Baraton University, it has established agricultural firms to handle its agricultural products (Malechwanzi et al, 2016). **HE institutions should establish more income generating activities to supplement their operational costs**.

Fees Supported Funding Model

In the recent past, there has been a surge in the number of student enrollments in HEIs. Further, there has been a greater diversity in terms of the number of courses offered and the type of universities available all designed in one part to meet societal needs. According to Oketch (2016), in the last four decades, the enrollment in tertiary education grew faster in SSA more than any other region in the world. This rapid expansion of the universities both traditional, newer state universities as well as private universities have had mixed impacts in the education sector. The witnessed changes are a welcomed development for some since they are associated with the introduction of a fee and a shift from the dominance of free funded education to the involvement of the market in HEIs. For others however, they have commodified and affected the quality and standards of HE. The fees paid come in the form of meeting the whole economic cost or through cost-sharing where students meet part of the cost of their university education and the government pays the rest. In countries like Kenya and Uganda in East Africa and Ghana in West Africa, the universities have adopted a dual-track model where few students are enrolled under government funding and another group is enrolled to pay the full economic cost on their own (Oketch, 2016). Other African HEIs should adopt dual track model to fill the financing gaps in HESTI.

Loans Dependent Model

Globally, loans have been used to fund university education. The loans scheme tends to increase access to university education, make the richer students to contribute to the HE budgets since their parents can afford to service the loans facilities, therefore making the students more focused on their studies. However, such loans add to student debt upon completion of their university education and leaves open a potential for absolving the loans if students do not get jobs or are unable to pay for reasons of force majeure. In Africa, students' loans have been rushed without considering their longer-term impacts. For one, they are expensive, they have high nonrepayment period and lack effective system to track the defaulters (Oketch, 2016). Countries like Uganda and Kenya offer student loans to students from underprivileged backgrounds to support their HE studies. In Kenya, most public universities receive their funding from the government of which about 80% of the funds are used to pay emoluments with only 20% for operations and maintenance (Gudo, 2014). The funding from the Higher Education Loans Board are usually not adequate due to the fact that their main source of funding is usually from the government. Yet funding from the

government usually tend to be little due to budgetary constraints. All loaned students are required to start repaying their loans immediately they finish their studies, failure to which an interest starts accruing on their loans (Oketch, 2016 and Gudo, 2014). This is seen not to be sustainable as those who had been awarded the loans come from underprivileged backgrounds and increasing interests on their loans strains them financially especially considering that most graduates fail to secure employment immediately after graduation. In South Africa, the student loan board is known as the National Students Financial Aid Scheme (NSFAS). It allocates funds and bursaries to eligible students, raise funds for the allocation as well as recover the loans from the students once they complete their education. South Africa gives a grace period until the borrower is employed for them to start repaying the loan and the repayment scheme depends on how the borrower's income is set up (World Bank, 2010). Despite the use of loans, majority (60%) of the respondents in the study survey indicated that deployment of loans financing is inadequate. Additionally, many funding initiatives to STI in Africa has been supported by AfDB and World Bank. For instance, the AfDB approved a total of 70 educational /training projects valued at $2 billion over the period 2005 to 2007. This was necessitated by the fact that most development agencies focus on basic education as such, the AfDB has prioritized to provide funds to a number of governments for post basic education, HE and TEVET through loans and grants (African Union, 2019)[71].

Table 5: An overview of African Development Bank Country Financing Agreements with TVET components operational between 2014 and 2018

Country	Loan Type	Amount in UA (UA is the official currency for the AfDB projects. 1 UA=1 SDR (International Monetary Fund Special Drawing Rights)
Benin	Loan	16,000,000
Botswana	Grant	600,000
Cape Verde	Grant	800,000
Congo CG	Loan	7,300,000
Côte D'Ivoire	Grant and Loan	18,833,000
Eq. Guinea	Loan	34,617,886
Eritrea	Grant	12,020,000
Ghana	Grant and Loan	69,000,000
Guinea	Loan	15,000,000
Guinea-Bissau	Loan	3,510,000
Kenya	Loan	66,000,000
Malawi	Grant and Loan	33,500,000
Mauritania	Grant	2,000,000
Morocco	Grant and Loan	97,187,040
Namibia	Loan	53,077,711
Niger	Grant and Loan	25,500,000

[71]https://au.int/sites/default/files/newsevents/workingdocuments/37841-wd-stisa-2024_report_en.pdf

Rwanda	Loan	20,750,000
Sudan	Loan	24,950,000
Tanzania	Loan	49,000,000
Togo	Loan	20,340,000
Uganda	Loan	52,000,000
Zambia	Loan	42,770,000
Zimbabwe	Loan	30,000,000
TOTAL		694,755,637

Source: African Union (2019)[72]

Table 6: Spread of World Bank Funding for Core Projects in Higher Education in Africa between 2003 and 2016

Country	**Investment Loan US$ million**
Pan-African	150
Burkina Faso	15
Ethiopia	40
Malawi	51
Mali	33
Mauritania	15
Mozambique	100
Nigeria	180
Senegal	101
Tanzania	115
Uganda	30
Western Africa	15
TOTAL	845

Source: African Union (2019) [73]

The World Bank has also been supporting HE since 2003 to 2014, a total of US$1.9 billion has been allocated to cover core and non-core projects in HE and this has risen to US$2.1 billion in 2016[Table 6].

A summary of the old and new funding mechanisms for HESTI and R&D is presented in Table 7. Countries are to make situational determinations of what works best for them given their prevailing socioeconomic and political environment as well as other external factors regional and global environments.

[72] https://au.int/sites/default/files/newsevents/workingdocuments/37841-wd-stisa-2024_report_en.pdf
[73]https://au.int/sites/default/files/newsevents/workingdocuments/37841-wd-stisa-2024_report_en.pdf

Table 7: Old and new (green) funding mechanisms for HESTI and R&D

Funder	What is funded	Funding Mechanism	Rationale
Government	Basic Research, Applied Research, Translational Research, Commercialization, Entrepreneurship (SMEs)	Grants and grand challenges Public institution co-funding on interdisciplinary and multidisciplinary programmes Innovation brokerage Formation of national research funding consortia Co-funding with SGCIs in the Region Investment in high-end research programmes, incl. Chairs (240 in SA) and Centres of Excellence, with 15-year funding horizons	Traditionally governments have funded basic, applied and translational research as investment in economic growth and development. These are deemed public goods.
Private Sector	Applied Research, Commercialization	Retained profits and borrowing for capital markets Corporate Social Responsibility	Profit driven motives
Public Private Partnerships	Applied Research, Commercialization	Equity and project funding	Solving market failure issues
Impact Investors	Commercialization	Equity or debt	Solving market failure with a focus on social goods
Capital Markets	Commercialization	Equity	Attractive return on investment in the venture
Crowdfunding	Research and commercialization	Equity	Social investment because of market failure
Local and International collaborative research grants	Research	Grants	Scarcity of local funding for research in many African nations
Private sector	Take-over of applied research after proof of concept, safety and efficacy	Patent buyouts	Innovators either selling off patents to fund more innovation or researchers not interested in entrepreneurship

Charities	Basic and applied research as well as clinical trials	Grants and co-funding academia and SMEs working neglected areas	These tend to be niche areas such as rare diseases where market failure is common
Cities or regions	Land, labour and utilities	Grants given as incentives to firms that relocate to a city or region targeting industrial development	Attracting particular industrial activities to a particular city or region to boost economic activity and contribute to rejuvenation of de-industrialised places

Source: Mugwagwa et al (2019)

3.2.2 Current/Emerging Financing Models for HE in Building Skills

Around Africa, several best practices witnessed in HE has been very instrumental in building skills that match industry needs. In Mozambique, the government has promoted several initiatives to support entrepreneurship aimed at improving its level of development within the country. For instance, the Mozambique government has established Chibuto's School of Business and Entrepreneurship which is one of the HEIs dedicated to entrepreneurship education. Furthermore, collaborative networks within universities have been used as tools for the development of the entrepreneurial competencies for both learners and lectures (Libombo *et al*, 2015). The African Capacity Building Foundation (ACBF) has strengthened financial systems through capacity building in the banking and finance sectors in Southern and West Africa and has promoted critical skills in science and technology in Burkina Faso, Nigeria and Tanzania[74][Box 11].**Countries will need to undertake situational analyses to adopt some of the emerging funding models that will fit in their own contexts.**

3.2.3 Current/Emerging Financing Models in Research and Development

Emerging financing models such as patent buyouts; local and international collaborative research grants; rewards and incentives for specific outcomes; research infrastructure fund; human capital development pipeline; multi-institutional co-funding for inter and multidisciplinary research; and international strategic research partnerships have been used by many African countries (Mugwagwa et al, 2019) (Table 8). In Zambia, patent buyouts have played a critical role in encouraging innovations and has been largely embraced in financing models in R&D thus strengthening research programmes and dissemination initiatives. However, majority (78%) of the respondents in the study survey indicated that the deployment of patent buyouts financing model is low.

[74]https://www.acbf-pact.org/media/news/acbf%E2%80%99s-contribution-africa%E2%80%99s-transformation.

Table 8: Innovative funding mechanisms/models and areas of research and innovation

S/n	Funding model/mechanism	Features/characteristics of model	Countries adopted	Impacts recorded so far
1.	Patent buyouts		Zambia	Strengthening research programmes and research dissemination
2.	Local and international collaborative research grants		Zambia, Ivory Coast, Malawi	Strengthening research dissemination
3.	Rewards and incentives for specific outcomes		Zambia, Ghana	Enhancing research expertise and research dissemination
4.	Research infrastructure fund	Fund for renewal, replacement and acquisition of essential national research infrastructure	South Africa	Improvement of research infrastructure
5.	Public-Private Partnerships	Focused particularly supporting human capital development for R&I activities	Mozambique and South Africa	Strengthening of research and innovation expertise
6.	Investment in high-end research programmes	15-year funding horizons for research chairs and centres of excellence	South Africa	240 research chairs in post
7.	Multi-institutional co-funding for inter and multidisciplinary research		Kenya and Zambia	Strengthening research and innovation programmes
8.	International strategic research partnerships		Kenya, South Africa	Strengthening research and innovation institutions and policy
9.	Human capital development pipeline	Funding for emerging and established researchers	South Africa	Enhancement and retention of research and innovation expertise

Source: Mugwagwa et al (2019)

Despite the introduction of various financing mechanisms to fill the gap in HE financing, majority (54%) of the respondents in the survey conducted under this study indicated that they are not

satisfied with the current funding of HESTI and R&D. **This calls for increased collaborations in education investments as well as in adopting new and emerging financing mechanisms for HESTI and R&D. Countries need to undertake situational analysis to adopt some mixes of the emerging funding models that will fit in their own contexts.**

3.2.4 Current and Emerging Trends to Scale Triple Helix Model

The current and emerging trends to scale Triple Helix Model in Africa has been very key in supporting R&D across Africa. To scale up the collaborations in HESTI, R&D and entrepreneurship, a number of projects have been initiated and implemented through public-private partnerships that aim to develop relevant skills in the job market, thus fostering the economic and social transformations in Africa. Tech- giant organizations such as Google and Facebook have invested heavily in tech hubs across the African continent recording a 40% increase in the number of tech hubs for a period of 2 years as at March 2018 (AFDB, 2019b). In East Africa, the model has been introduced as a catalyst for skill development for mega projects aimed at supporting economic growth. For instance, a customized Triple Helix program is being tested in the oil and gas sector in Kenya which is aligned with SOGA-project (Skills for Oil and Gas) and is currently implemented by the Technical University of Kenya[75]. **Collaborations among the relevant institutions (government, research and the private sector) have proven to deliver better results for HESTI, R&D and Entrepreneurship development in Africa.**

3.3 Governance

Good governance is a major factor in improving the quality of higher education in any country of the world. The Worldwide Governance Indicators (WGI) cover three categories of governance indicators namely: political governance, economic governance and an institutional dimension of governance. These three categories are accompanied by six educational factors namely: higher education expenditures, higher education enrolment, higher education expenditures per student, literacy rate, research & development expenditures and economic growth (Zaman, 2016). Governance indicators act as a strong contributor for increasing educational effects, which further assist in formulating the policies for HEIs. Each of the three categories of governance have two indicators each for measuring good governance. They include:

i. Political Governance: a) Voice and Accountability and b) Political Stability and Absence of Violence. Voice and accountability include the assumptions that citizens are able to have a say in making their government, to have freedom of expression, to have freedom of association and to have a free open media. Stable political government and absence of violence/terrorism measures

[75]https://www.msm.nl/consultancy/project-references/triple-helix-approach-to-support-economic-growth

the perceptions that a government might be destabilized or dethroned illegally by violent means, including politically motivated violence and terrorism (WGI, 2012).

ii. Economic Governance: a) Government Effectiveness and b) Regulatory Quality Government effectiveness includes the sense of the quality of public and civil services, as well as the extent to which they are insulated from political interference. It also consists of the government's ability for developing quality policies, their capacity to implement them and how much an individual government values such policies. Regulatory quality takes into account the government's capability to develop and execute good policies and rules that allow and promote private sector development (WGI, 2012).

iii. Institutional Dimensions of Governance: a) Rule of Law (ROL) and b) Control of Corruption (CoC). ROL measures the confidence of citizens that an agent will follow the norms and rules of society, particularly ones related to contract enforcement, property rights, the police, the courts and the possibility of crime and violence. By contrast, the CoC evaluates the interference of a country's bureaucracy -i.e., red-tapism, which has been defined as corrupt office bearers and other parties interfering with the implementation of policy (WGI, 2012). Higher educational bodies have focused on strategies and setting priorities instead of day-to-day work activities.

One policy cannot be made for different countries, but some objectives are common to all. These include:

- More public funding for the higher educational system;
- Granting more autonomy to institutions regarding financial matters;
- Creating direct links between results and the public funding allocated;
- Diversifying funding sources to prove education is not only a public good but a positive step towards growth and social solidarity, i.e., the creation of partnerships with research institutes, businesses and regional authorities (EUROPA, 2008).

With the above in mind, it is unfortunate to note that the poor governance structures and ineffective policies currently in place in most African countries do not support HESTI, R&D and entrepreneurship development in producing competent skilled human capital for employment, increased productivity and sustainable livelihoods. Over the years, institutional and policy factors including inadequate gender-friendly policy frameworks and poor implementation of existing policies have continuously affected the volume and quality of productivity in HESTI and R&D. According to Rathgeber (2013), in 2006 only nine countries had equity policies aimed at providing greater opportunities for women to participate in HE. Weak policies in HE has provided loose ends for corruption and other malpractices to take place. For instance, in 2017, a total of 88 staff members at Makerere University, Uganda were arrested for corruption with alteration of student grades and issuance of fraudulent grades[76]. This is further buttressed by the findings from the study survey which showed that majority (70%) of respondents indicated that poor policy

[76]https://www.u4.no/publications/corruption-in-universities-paths-to-integrity-in-the-higher-education-subsector

implementation was a barrier to the development of HESTI, R&D and entrepreneurship in most African countries. Further,68% of the respondents in the survey study indicated that weak governance structures is the highest barrier to HESTI and R&D in most African states. **Efforts towards the strengthening of government institutions to be able to deliver on their mandates in terms of policy formulation and implementation becomes germane. This can be achieved through capacity building, in-service training, systemic re-tooling, study tours and exchange programmes among others. Institutional audits should be intensified as well.**

3.3.1 Policy environment on quality assurance mechanisms for HESTI, R&D and Entrepreneurship Development in Africa

Governments in Africa have exhibited strengths and weaknesses in regulating the quality assurance for both private and public HEIs. Whilst there has been no systematic evaluation of quality standards in most African HEIs in the recent past, rapid enrollment growth has come at the expense of quality. In Kenya for instance, the government's efforts to accelerate production of postgraduate degree holders for hire as university faculty staff members between 2011 and 2018 has led to the academic teaching capacity growing by 13% whereas the student enrollment rose five folds. This growing gap has resulted in many HEIs in Kenya having insufficient qualified staff thus undermining the quality of training with student -teacher ratio in government HEIs reaching closer to 70: 1 (World Bank, 2019). The findings are consistent with results from the study survey where majority (44%) of the respondents had indicated that there are inadequate quality assurance mechanisms for HESTI and R&D.

Nevertheless, the policy environment on quality assurance mechanisms for HESTI in some African countries is gaining significant momentum in recent times in ensuring that HEIs institutions offer courses that are relevant to the job market. The policy reforms witnessed in Rwanda's education sector which focuses on moving from knowledge-based curriculum to a Competence Based Curriculum (CBC) is a typical example of demand-driven quality assurance mechanism and will no doubt change the quality of skills development in the country. In 2016, UNICEF supported the government of Rwanda to implement the new CBC programme in ensuring more quality education with requisite skills for the labour market[77], particularly in the development of appropriate skills and knowledge relevant in real-life situations (Ngendahayo and Askell-Williams, 2016). In an effort to align the university to the new program, the University of Rwanda-College of Education (UR-CE) has been obliged to revive their programmes to the new curriculum where the graduates are equipped with skills and knowledge to cope with demands of the newly introduced curriculum in secondary education (Tabaro, 2018).Again, Egypt has established a national ranking committee which is supported by the Egyptian Ministry of Higher Education and Scientific Research. This is an example of a policy which sets out to ensure that the higher education institutions strive to offer

[77]UNICEF- https://www.unicef.org/rwanda/education

value for money for those who choose to invest in them. This is further supported by the survey finding under this study which showed that majority (46%) of the respondents indicated that there is moderate value for money in the investments in HESTI and R&D. **Aligning curriculum to meet the labour market demands is vital in sustaining any economy. Individual country assessments and situational analyses are able to provide the way forward to meet countries aspirations and visions.**

3.3.2 Current management and administration of HESTI, R&D and Entrepreneurship Development

The current management and administration in many African HEIs continue to suffer in capacity; resources, equipment, skills, personnel and technology. Many departments do not have more than 1 or 2 senior professors; and many are close to their retirement age. This prevents HEIs from developing vibrant research environments and professionals[78]. According to Okoche (2017), the Directorate of Quality in most HEIs is not properly integrated into university programmes thus rendering the quality assurance ineffective. In most cases, the universities emphasize the process of quality assurance during periods of accreditation of HE and its programmes with no systematic process of continuity in quality assurance improvement. Concerns and pressures over the quality of HEIs has led many African governments to establish institutions and bodies to manage and conduct regular internal and external surveillance audits to ensure quality delivery of HESTI, R&D and entrepreneurship development [Table 9]. In some countries, quality checks were initially targeted at private institutions on the faulty assumptions that everything was great with the public institutions. Apart from establishment of regional quality assurance agencies, a number of national quality agencies across the African continent has grown from 9 in 1990 to 21 in 2012 and to 32 in 2015 [79] . **Therefore, management, delivery and administration of HESTI, R&D and Entrepreneurship development require that proper structures, policies, and effective coordination are put in place in order to leapfrog its benefits.**

Table 9: Functions of External bodies in quality assurance in HE in Africa

Country	Organization	Function
Botswana	Tertiary Education Council (TEC)	Approve applications from persons seeking to establish private institutions (registration). Review and approve programmes of study in respect of private HEIs (programme accreditation). Institutional audit leading to institutional accreditation

[78]https://www.globalpartnership.org/blog/challenges-and-prospects-africas-higher-education
[79]https://www.theelephant.info/features/2018/07/05/the-giant-challenge-of-higher-education-in-africa/

Ethiopia	Higher Education Relevance and Quality Agency (HERQA)	Institutional quality audits (future) of all HEIs. Review requests from private HEIs for the accreditation of degree programmes and offering advice to MoE on accreditation
Ghana	National Accreditation Board (NAB)	Accredit both public and private tertiary institutions with regard to contents and standards of their programmes. Determine the equivalence of diplomas, certificates and other qualifications
Kenya	Commission for University Education (CUE)	Accreditation and licensing of academic programmes. Accreditation and licensing of institutions (Letter of Interim Authority, Award of Charter, Certificate of Re-inspection) which is mandatory for private universities. Validation of diploma programmes of post-secondary school institutions. Grant of authority to post-secondary institutions to collaborate with universities for purposes of offering degree programmes. Recognition and equation of qualifications. Planning and establishment and development of higher education institutions
Malawi	Ministry of Education and Human Resources Council for Higher Education (to be established)	Responsible for registration, accreditation and quality control. Advice on the establishment of private HEIs. Assesses physical facilities. Accredits programmes in private tertiary institutions.
Mauritius	Tertiary Education Commission (TEC)	Registration of private institutions and accreditation of their programmes. Determination of recognition and equivalence of qualifications. Making recommendations to the Minister on applications received for the setting up of private institutions or branches, centres, or campuses of overseas institutions. In the future: undertake quality audit
Nigeria	National Board for Technical Education (NBTE)	Accreditation of academic programmes in all TVE institutions. Recommendations for the establishment of private TVE institutions.
Nigeria	National Universities Commission (NUC)	Institutional licensing (private). Programme licensing (public and private).Develops minimum standards for all academic programmes and accredits them
South Africa	Higher Education Quality Committee (HEQC)	Programmes accreditation and co-ordination. Re-accreditation of existing programmes in specific disciplines through national reviews. Institutional audits. Quality assurance promotion at system, institutional and individual level.
Sudan	Ministry of Higher Education and Scientific Research	Setting the policies for evaluation and accreditation

Uganda	National Council for Higher Education (NCHE)	Institutional accreditation (provisional license, charter). Programme accreditation. Quality audit. Determine equivalences

Source: UNESCO (2007)[80]

3.3.3 Innovative approaches to Collate and Harness Data and Statistics Gaps in HESTI and R&D

Data gaps witnessed in many African countries threaten to hinder achievement of SDGs and African Union's agenda 2063[81]. Data is essential in providing a better understanding of processes and contextual situations necessary for decision-making. As such, many governments have given priority to data in their efforts to improve service delivery and evidence-based decision-making. Many HEIs and other research institutions have developed new innovative approaches to tackle challenges relating to HESTI, R&D and Entrepreneurship development by providing credible data and tools necessary for identifying existing research gaps aimed at supporting development of strategies to progress STI. The use of Regional Economic Communities (RECs) and Academic Associations as data points would provide the required information on what is happening around Africa[82]. For instance, the World Bank Group recently published extracted data from the employment records from 2015-2018 from LinkedIn. According to the report, the LinkedIn is able to provide industry data, skill data set at a very granular level, and industry employment growth among other information[83]. This shows that innovation and real time approaches in Big Data would actually provide information in understanding the statuses in the labour market migration and skills. Despite the importance of these innovative approaches in collating and harnessing data and statistical gaps in HESTI, majority (48%) of the respondents in the survey conducted under this study indicated that there is low usage of academic associations as data points to tackle challenges related to HESTI, R&D and Entrepreneurship. **Countries can be supported to invest heavily on Big Data in HESTI for evidence-informed policy and decision-making in the sector that will be beneficial to employment and job creation**.

3.3.4 Curriculum to Respond to Industry Skills' Needs

In most African states, the curriculum does not respond to industry skills' needs. With outdated curriculum which does not adapt well to the labour market, there is a resultant mismatch between skills supply and demand. This situation has been cited as a costly feature in many African

[80]https://unesdoc.unesco.org/ark:/48223/pf0000153368

[81]https://www.devex.com/news/data-gaps-threaten-achievement-of-development-goals-in-africa-95825

[82]https://medium.com/@undp.ric/how-we-are-leveraging-linkedin-data-to-explore-labour-dynamics-and-what-we-are-finding-513190d76cd7.

[83]http://documents1.worldbank.org/curated/en/827991542143093021/pdf/World-Bank-Group-LinkedIn-Data-Insights-Jobs-Skills-and-Migration-Trends-Methodology-and-Validation-Results.pdf

labour markets. According to Morsy and Mukasa (2019), 34.8% of employed youth jobs corresponds with their educational qualifications normally required for their current job. This implies that close to 2/3 of the youths in Africa are working with an educational attainment either lower or higher than their job requirements. The findings under the study survey show that the current HESTI curriculum does not respond adequately to industry needs. The skills mismatch brought about by the current education system has led to many graduates unable to land existing jobs in many industries (AFDB, 2019)[84].For instance, on average, only 53.6% of the employed youth consider their skills as appropriate for their current jobs (Morsy and Mukasa, 2019). **There is need to support countries to take bold steps in overhauling their existing curricula to be able to ensure that it meets the industry needs.**

3.3.5 Best Practices in Strengthening the Linkages in HESTI, R&D and the Industry

In Africa, many HEIs have made efforts to strengthen linkages with the productive sector through incorporating industry linkages into their strategic plans. The linkages between the industry and the academia can influence the investment of more resources to HEIs as well as promote innovations and technological transfers that ensures that graduates have the right skills needed in the labour market. In an effort to create and strengthen linkages, the private sector and development partners (DPs) can participate in curriculum development and collaborate in areas of entrepreneurship, provision of internships, and employments to graduates. In Africa, the Employment and Skills for Eastern Africa (E4D/ SOGA) has supported several countries in the region to develop skills needed in the job market. In Kenya, the E4D/ SOGA programme has worked with a number of HE institutions including; Strathmore University, Technical University of Kenya, and the Technical University of Mombasa. Through this arrangement, a total of 3,239 Kenyans was brought into sustainable employment in 2018 leading to an increase of job opportunities by 290%. Overall, 4,370 people have gained employment through this scheme in Kenya[85]. During a period between January 2015 and December 2019, the E4D/SOGA programme was allocated £22.5 million by DFID which represents 58% of the total E4D/SOGA budget[86]. This is an indication that the linkages can influence more resources and similar programmes should target partnerships with strategic partners to have the most transformative change in developing employability skills. In the survey conducted under this study, majority (54%) of the respondents indicated that there are inadequate linkages among government, industry and HESTI in Africa. **Therefore**, **providing developmental projects and grants that involve all the stakeholders in a tripartite arrangement can help to bring them together and cement their relationships for longer term development programmes.**

[84]https://4irpotential.africa/wp-content/uploads/2019/10/4IR_NIGERIA.pdf
[85]https://www.giz.de/en/downloads/PR%20report%20E4D-SOGA_%202019.pdf
[86]https://www.ecorys.com/sites/default/files/2020-08/Approved_E4DSOGA_FinalReport_forPublication2.pdf

3.3.6 Positioning HE in Delivering Quality Curricular, Digital Skills and Lifelong Learning Trainings

In Africa, several countries have taken up initiatives to prepare students at early stages of their education by equipping them with the skills required in the digital era. Many governments including Ethiopia, Rwanda and Togo are pressing on with reforms in making students prosper in schools. For instance, in Kenya, the launch of free laptops program tagged "one laptop per child" in primary schools was envisioned to provide a new avenue for eLearning. This became necessary because some of the children, especially in rural and slum areas do not have access to suitable educational materials, and their parents cannot afford the text books required. Hence, eLearning proposes an exciting way of improving the quality of their education via an interactive and engaging curriculum which also reduces the costs overall, by providing gadgets that could host thousands of eBooks[87]. In SSA, over 230 million jobs will require digital skills by 2030 thereby translating to about 650 million training opportunities. These opportunities represent $130 billion in revenue potential by 2030. However, lack of relevant digital skills in many African countries may limit its citizens from realizing these opportunities. Majority (56%) of the respondents in the study survey indicated that current curriculum does not meet other extracurricular needs and requirements for skills development. As such, governments should make more investments and collaborations between the public and private sector in ensuring that skill development is in-line with the labour market needs (AEO,2020).Also, **there is need for investments in both digital infrastructure and capacity building across all levels of education so as to build a strong foundation for skills development, innovation and entrepreneurship in the career path of students in order not to miss these opportunities.**

3.3.7 Ensuring Equitable Access: Gender Gaps in STI, People with Disability, Vulnerable Communities

Equitable access to STI without discrimination to gender, disability and vulnerability will be key in upscaling HESTI, R&D and entrepreneurship development in Africa. Africa lags behind other regions on progress towards gender equality in society. Its gender parity on women in leadership (top and middle positions) is 0.33 against the global average of 0.37[88]. Nevertheless, there has been several efforts by different governments to close this gap through inclusive laws and policies that accommodate women, youth, the vulnerable and people living with disability in the mainstream of affairs within HE, R&D and entrepreneurship development programmes. In countries like Nigeria, governments have made concerted efforts in ensuring equitable access to

[87]https://www.idgconnect.com/article/3577754/re-looking-at-kenya-s-digital-learning-school-project.html
[88]https://www.mckinsey.com/featured-insights/gender-equality/the-power-of-parity-advancing-womens-equality-in-africa

education for all. In this context, girls' access to education has received attention at the policy level with more women participation in STI being witnessed (Ekine, 2013). Also, several countries have created favorable environments for more women to pursue science programs. These initiatives are meant to provide valuable insights on how women can be drawn into science and work their way up the ladder to become leaders in STEM. Some of these initiatives include scholarships, science fairs, and some policy changes. Some of these countries that have provided these opportunities include Morocco, Mauritius, Nigeria, and Angola[89]. Additionally, several initiatives are in place that promote and motivate the female gender to be involved in STEM courses as well as in the research and development programs. For instance, the African Union Kwame Nkrumah Awards for scientific excellence program honors two outstanding African women scientists from each of the five geographical regions of Africa. In Cameroon, there are mentorship programs that train women in career-building scientific skills (World Economic Forum, 2020). Despite this progress being made, majority (46%) of the respondents in the survey conducted under this study indicated that the governance structures are not adequate and effective in ensuring inclusive and equitable gender balance and access by people living with disability and the vulnerable communities. **Supporting equal opportunities through policies and laws especially in HESTI is required to achieve sustainable development.**

3.3.8 Positioning ICT Technologies for Education Management and Service Delivery

Increased demand for continuous learning and access to education has risen in SSA. In many developing countries in Africa, the rapid spread of smartphones has made digital learning more viable. Several countries have taken initiatives in equipping the training institutions with modern ICT infrastructure to support service delivery in Africa. This includes affordable and reliable power and digital infrastructures, and high-speed internet facilities. In Ethiopia, under the Education Sector Development Programme 2015/16 - 2019/20, the government target is to enable all university students to access digital libraries by 100% and increase the percentage of smart (ICT-supported) classrooms to 25% by 2020[90]. In Rwanda, the government has laid over 2,500 km of fiber optic cables across the country to bridge the digital divide between the rural and urban areas[91]. The Kenya Education Network (KENET) which promotes ICT in education has increased the bandwidth from 50 megabits per second to 2.5 gigabits per second. KENET provides cost effective bandwidth to 114 educational institutions that reach more than 100,000 students and 5,000 faculty and staff[92]. **Countries can be supported to boost their ICT infrastructure (hard and soft) in order to improve service delivery in HESTI and R&D which will translate to skills for development and overall productivity.**

[89]https://www.globalpartnership.org/sites/default/files/2016-06-ethiopia-education-sector-plan-vi_0.pdf
[90]https://www.universityworldnews.com/post.php?story=20200210064903949
[91]https://www.itu.int/net/wsis/review/inc/docs/rcreports/WSIS10_Country_Reporting-RWA.pdf
[92]https://www.itu.int/net/wsis/review/inc/docs/rcreports/WSIS10_Country_Reporting-RWA.pdf

3.3.9 Best Practices in Regional Initiatives and its Scalability

Several best practices have been embraced by some countries and regions in supporting HESTI, R&D and entrepreneurship development in Africa. The AU's Agenda 2063 emphasizes the need for African states to invest in education to develop their human and social capital through an education and skills revolution agenda particularly in STI. The Pan African Virtual and E-University (PAVEU) which falls under the Agenda 2063 flagship projects aims at accelerating development of human capital and STI through increasing access to tertiary education in the African continent using digital revolutions. To date since its inception, 4-course programme have been identified for the launch. They include; Introduction to Virtualization; Entrepreneurship Knowledge and Skills and Digital Literacy with Cloud Computing; Skills for Employability; and Media and Information Literacy. Strategic secondary partnerships have been realized with four key organizations ready to support PAVEU in delivering the courses and they include; UNESCO, African Council for Distance Education (ACDE), VMware, and the African Virtual University. The infrastructure particularly ICT has been set up and guidelines and polices for operationalization of PAVEU have been developed (African Union Development Agency (AUDA-NEPAD), (2020)[93]. Additionally, the Pan African University (PAU) which is an African Union Commission (AUC)'s initiative intends to help in providing Africa with the skills needed to add value to its natural resources and enhance its competitiveness and sustainable growth [Box 12].

[93]https://nepad.org/agenda-2063/flagship-project/pan-african-virtual-and-e-university-paveu

Box 12: **Pan African University (PAU)**

The Pan African University (PAU) is an African Union Commission (AUC)'s initiative intended to help in providing Africa with the skills needed to add value to its natural resources and enhance its competitiveness and sustainable growth. In September 2013 the Bank, through a five-year PAU Support project, approved a grant of UA 30.00 million to the AUC to support this initiative in establishing of the PAU's central governance (Rectorate) and the following three of its five thematic institutes: the Basic Sciences, Technology and Innovation Institute, the East African Hub (PAUSTI) hosted by the Jomo Kenyatta University of Agriculture and Sciences in Nairobi, the Earth and Life Sciences Institute, the West African Hub (PAULESI) hosted by the University of Ibadan in Nigeria and the Governance and Human Sciences Institute, the Central African hub (PAUGHSS) hosted by the University of Yaoundé II, in Cameroon. Other PAU institutes include; The Institute for Water and Energy Sciences (including Climate Change (PAUWES), hosted by the University of Tlemcen in Algeria (Northern Africa) and The Institute for Space Sciences (PAUSS) to be hosted by the Cape Peninsula University of Technology with seven (7) south African Universities in the Republic of South Africa (Southern Africa). The 2019 annual report show that the 2018/2019 academic years had a total of 428 students (323 for Masters and 105 PhDs from 53 member states. PAUGHSS had 75 masters and 26 PhDs, PAULESI had 80 Masters and 30 PhDs, PAUSTI had 106 masters and 49 PhDs, PAUWES had only 62 masters. The percentage of female students for the courses was 36.7%. With regards to graduation, the total number of PAU graduates by level of study as at 31 December 2019 was for PAUGHSS, 273 masters and 33 PhDs; PAULESI, 254 Masters and 23 PhDs; PAUSTI, 248 masters and 63 PhDs; and PAUWES, 218 masters with no PhDs. The total percentage of female students who have graduated was 30 %.

Sources: AfDB (2013); Project Appraisal Report
; https://pau-au.africa/fileadmin/Annual_Report_of_the_Pan_African_University_Dec_2019-_FOR_RACA.pdf

African countries have made efforts in ensuring that they maintain high quality standards in HESTI, R&D, and entrepreneurship development. According to the 2018 innovation index that was published by the World Intellectual Property Organization (WIPO), South Africa was ranked number one in Africa, followed by Mauritius, Kenya, Botswana, Namibia, Rwanda, Senegal and Madagascar making it among the top ten in Africa[94]. Additionally, most African states have made milestones in making sure that the AU's STISA-2024 mission is achieved aimed at accelerating Africa's transition to innovation led knowledge-based economy. According to 2016/2017 Global Entrepreneurship Monitor Report, Morocco, South Africa and Egypt have been classified as stage two countries. The third stage which is innovation stage under STISA-2024 will be achieved through improvement and implementation of STI policies and programmes including infrastructure, capacity technical competence and entrepreneurial capacity (African Union Commission, 2014)[95].

Intra-Africa collaborations in STI has contributed in ensuring that research and technological innovations are generated and scaled to support sector growth and economic development on the continent. Intra-Africa collaborations in science can help in ensuring that HEIs become the best in

[94]https://www.scidev.net/global/innovation/news/african-countries-fare-poorly-in-innovation-ranking.html
[95]https://au.int/sites/default/files/newsevents/workingdocuments/37841-wd-stisa-2024_report_en.pdf

R&D in the technological sector as it promotes knowledge and technology transfer among African HEIs, R&D and the industry. This could further be achieved through scaling up existing regional research and research-based education programs that stimulate regional collaborations, such as the African Institute for Mathematical Sciences, the Africa Centers of Excellence, the Regional Initiative for Science Education, the Pan-African University, the Nelson Mandela Institutes for Science and Technology, and regional universities forums (Addaney, 2018).

To scale up collaborations in HESTI and R&D for better quality results, closer public-private partnerships among the HEIs, research and industry have been initiated across Africa. For instance, to leapfrog Rwanda into 4IR, the government launched its digitation project (The Kigali Innovation City) in 2016 which saw universities and industries collaborate closely with the government's support. This network is expected to produce a mass of scientists, engineers, and mathematicians who will be at the heart of innovation and human capital development in the country for the next era. In Kenya, the government has established Kenya National Innovation Agency (KENIA) [96] which is mandated to institutionalize linkages between the research institutions, universities, and the private sector in creating a robust innovation system (AEO, 2019). In support of the importance of collaborations, majority (44%) of the respondents in the survey conducted under this study indicated that there are collaborative ongoing activities among various institutions in Africa both governmental and non-governmental across the research, university, government and the industry. **Collaborations among the relevant institutions (government, research and the private sector) have proven to deliver better results for HESTI, R&D and Entrepreneurship development in Africa.**

3.4 CROSS-CUTTING ISSUES

3.4.1 Gender and equity in access to Higher Education Science, Technology and Innovation

Women scientists have a critical role to play in Africa's development. Despite women's clear contribution to development, they remain under-represented in STEM fields (African Academy of Sciences, 2020)[97]. The number of women who pursue science and engineering programmes in HEIs are fewer than men. Also, major gender disparities between women and men research scientists are also evident in their levels of responsibility. Whilst the gender parity enrollment in tertiary education was achieved by 2000 and it stood at 1.10 in 2013, Africa remained the only region where the Gender parity index is yet to be attained. In 2013, its gender parity index was

[96] The Kenya National Innovation Agency (KENIA) is a statutory body established under the Science, Technology and Innovation Act, No. 28 of 2013. The Agency is mandated to develop and manage the National Innovation System

[97] https://www.aasciences.africa/news/bridging-gender-gap-women-science-africa

0.85[98].In some countries, including Benin, the Central African Republic, Chad and Niger, fewer than 40 women were enrolled for every 100 men[99]. In Kenya, STEM participation shows a clear gender disparity ranging from 30% to 35%. Fewer women take and complete STEM studies[100]. The development of a critical mass of scientists in Africa is one of the pillars for the promotion of STI for development and it is important that this inequity is addressed because human resource capacity building cannot be completely successful if half of the population is faced with constraints to access higher education in STI[101]. This requires harnessing the potential of its population through education and training to create a critical mass of experts in STI and providing equal access for both men and women.

In Africa, efforts are already being made to bridge the gap of inequality between the men and women in the STEM and R&D fields. For example, the Pan-African Network for the Popularization of Science, Technology and Science Communication is one platform that aims at dealing with such inequalities. Women advancement forum was initiated in 2014 and aims at addressing the under-representation of African women in STEM. The program is conceptualized through partnerships with African universities and research institutions in planning, delivery and support systems. Countries that benefit from the program include Nigeria, Ghana, Kenya, and Benin. In Kenya, the government has tried to close the gap by putting policies that admit women to HEIs with lower cut off points compared to males. Other countries that have implemented such affirmative action aimed at increasing women enrollment in HEIs includes: Gahan, Uganda, Zimbabwe and Tanzania (Bunyi, 2003). Furthermore, gender equality and youth empowerment continue to feature under the UNESCO sponsored activities. For instance, the Gambia National Commission for UNESCO in consultation with other stakeholders and in line with their national priority areas have deemed it necessary to prioritize women and youth activities in all future activities (Box 13) (UNESCO, 2017).

[98]https://www.theelephant.info/features/2018/07/05/the-giant-challenge-of-higher-education-in-africa/
[99]https://gem-report-2016.unesco.org/en/chapter/parity/
[100]https://theconversation.com/why-fewer-kenyan-women-are-choosing-or-completing-stem-courses-91706
[101]http://www.unesco.org/new/en/natural-sciences/science-technology/sti-policy/africa/african-women-scientists-contribute-to-growth/

Box 13: STEM and Gender Advancement (SAGA)- Gambia

SAGA project is a global UNESCO project which was launched in 2015 in a bid to strengthen UNESCO's work in support of gender equality in STI in Africa. Gambia is the first SAGA pilot country in Africa. The project has had an impact in mainstreaming gender equality in Gambia's STI policies and programmes. A gender unit has been established in the Ministry of Higher Education, Research, Science and Technology with a budgetary vote to support, monitor and advice STEM and gender advancement issues in the country, strengthen existing education units in Gambia. With recommendations from the SAGA the national STI has been reviewed as well to include gender component in the STI policy. From 2015 to 2018, SAGA has been supported by Government of Sweden through the Swedish International Development Cooperation Agency (Sida).

Source: UNESCO; https://en.unesco.org/saga

Despite the efforts being carried in Africa to increase the number of women to STEM, majority (40%) of the respondents in this study indicated that there is a weak pipeline of girls and women transitioning from primary to secondary and university training. **As such, the promotion of women in science and technology requires actions at all levels using different modalities including advocacy, enactment of appropriate policies, affirmative actions and capacity building.** In scaling access for girls and Women to STEM, respondents in this study indicated that the AfDB should strategize by funding STI related projects at lower levels of learning in HESTI programmes, provide scholarships and organize targeted events (e.g. skills competition, exhibitions, etc.) and capacity building. For instance, one respondent noted that: "Female enrollment into institutions of higher learning in Cameroon is very encouraging and competitive. There is also an increase in the number of girls in the science. AFDB can only accelerate this process through scholarships for meritorious women interested in the STEM."

3.4.2 Harnessing HESTI and R&D to Leapfrog Technology Innovation and Entrepreneurship Development

HESTI systems have the potential to power the rising youth population with skills needed to leapfrog technology advancement and accelerate innovation for economic growth and creation of job opportunities. In an effort to maximize technological innovations, African countries have embraced collaborations with foreign countries in developing technological innovations and entrepreneurial skills. Nigeria, Kenya and South Africa have created innovation partnerships with the United Kingdom in a bid to stimulate economic growth through development and creation of new job opportunities. Tech experts in Nigeria and Kenya are expected to build links in the digital sectors between the UK and their respective countries. Some of the partnerships include; the roll of digital skills such as TeXchange, Global EdTech Awards, Go Global from the Founders Institute and Coders programs established in Nigeria, Kenya and South Africa[102]. For instance, Nigeria and

[102]https://www.intelligentcio.com/africa/2018/08/31/ambitious-new-innovation-partnerships-with-african-countries/

Kenya's technology sectors are rapidly growing and generating more than 10% and 11% of their economic output respectively[103]. The survey conducted under this study showed that majority (78%) of the respondents indicated that institutionalizing exchange programs in HESTI, R&D and Entrepreneurship within and outside Africa has promoted knowledge circulation and partnerships. **This is an indication that African states should promote digital skills in HE to leapfrog technological innovations and entrepreneurship development.**

3.4.3 Enhancing flexibility and responsiveness of HESTI and R&Dto meet market needs

The COVID-19 pandemic has shown how important it is to build flexible and transferable skills (especially digital and soft skills) needed for resilience/ mobility in the labor market and new era of digitalization. Around Africa, many countries are adapting educational technologies such as online teaching and use of social media in offering educational services. In Tanzania, Shure Direct which is an online learning platform is being used by teachers and students in schools and is serving about 2 million students and 23,637 teachers with telecommunication companies offering free access to this platform. Again, Eneza Education provides services to 380,000 people a month and provides a subscription service for education content to children and secondary schools via SMS or USSD in Kenya, Ghana and Ivory Coast[104]. **This again provides a good opportunity for private sector partnership with HEIs to provide the technical services as well as investment opportunities from both development partners and the private sector entities.**

3.4.4 Linking HESTI and R&D to Productive Sector

Considering the Bank's High-5 priorities which are; Light up and Power Africa; Feed Africa; Industrialize Africa; Integrate Africa; and Improve the Quality of Life for the People of Africa, several emerging best practices have been embraced aimed at promoting linkages to selected economic sectors/clusters. In an effort to support investment in energy in Africa, and grow skilled professionals, the Renewable Energy Cooperation Programme (RECP) has taken bold steps in supporting HE and TEVET in developing skills needed to meet the growing demands. RECP supports in training future engineers, entrepreneurs and policy experts[105]. In an effort to boost innovation and skills development, 682 beneficiaries have participants at events on R&D, 53 academic papers have been published, 194 energy professionals have been trained, 22 start-ups in innovation hubs have been supported, and 67 Master of Science students in energy have been trained[106]. **Therefore, Linking HESTI, R&D to economic sectors where there are sizeable**

[103]https://www.intelligentcio.com/africa/2018/08/31/ambitious-new-innovation-partnerships-with-african-countries/
[104]https://www.eib.org/attachments/country/africa_s_digital_solutions_to_tackle_covid_19_en.pdf
[105]http://www.euei-pdf.org/en/recp/innovation-and-skills-development
[106]http://www.euei-pdf.org/en/recp/innovation-and-skills-development

opportunities for economic transformation would contribute to the development of human capital through the production of skilled graduates.

3.4.5 Regional Centres of Excellence

Regional centers of excellence (CoE) are key in enhancing capacity of the institutions in delivering high quality training as well as the capacity to deliver R&D that addresses regional challenges. Since 2014, the Africa's Higher Education Centers of Excellence program has promoted quality delivery of relevant post graduate education that meets the demand for skills. Between 2014-2020, the program has supported 14,000 masters and PhD students in Agriculture, Health and other sciences. In an effort to develop regional infrastructures and Centers of Excellence for training and research, the International Development Association (IDA) has invested over $580 million towards supporting more than 70 centers in 20 countries in West, Central, East, and Southern Africa[107].About 1005 research publications have been made under the programme with over 87 partnerships with other institutions and industries, and about US$ 8.9 million external revenues generated[108].The establishment of Center of Studies for Oil and Gas Engineering and Technology (CS-OGET) based in Mozambique [Box 14] aims to assists the country and the region to fill the gap in building national skills in the field of Oil &Gas[109].Further, African Center of Excellence in Internet of Things (ACEIoT) in Rwanda [Box 15] aims to train and educate African researchers in the field of Internet of Things (IoT). This is expected to advance and install innovative IoT-enabled services, to offer solutions to growth challenges all over East and South African, in the highest precedence fields. **The AFDB should support and upscale the CoE programme across the RMCs so that they can provide high**

Regional centers of excellence (CoE) are key in enhancing capacity of the institutions in delivering high quality training as well as the capacity to deliver R&D that addresses regional challenges.

[107]https://reliefweb.int/report/world/building-centers-excellence-africa-address-regional-development-challenges
[108]https://ace.aau.org/ace-1-achievements/
[109]https://ace2.iucea.org/index.php/2018-01-22-22-04-02/aces-at-a-glance/cs-oget

Box 14: Center of Studies for Oil and Gas Engineering and Technology (CS-OGET): Universidade Eduardo Mondlane

The recent onshore discoveries of oil in Uganda and Kenya and enormous gas accumulation offshore in Tanzania and Mozambique has presented huge challenges to the local training institutions. Center of Studies for Oil and Gas Engineering and Technology (CS-OGET) based in Mozambique was established to bridge the skill gap thus assisting the region in building a local and regional capacity in oil and gas that will provide scholarships, exchange programs for student and lecturers and joint research programs throughout the Eastern and Southern Africa. University Eduardo Mondlane will host CS-OGET and implement progressively MSc and PhD programs and research in Petroleum Engineering (upstream), Hydrocarbons Processing Engineering (downstream), Safety and Environmental Engineering, related to oil and gas (O&G), and Petroleum Geology. The center strives to assist the country and the region to fill the gap in building national skills in the field of O&G. The centre intends to train 150-200 MSc in Petroleum Engineering, Hydrocarbons Processing Engineering as well as O&G related Geology, and Safety and Environmental Engineering, in 5 years. About 8-12 PhD students are expected to have been enrolled within this period in the aforementioned fields of knowledge. In parallel, 180-200 short trained professionals are to be targeted during the ACE project lifetime. For the academic degree awarded courses, efforts will be put in place to secure at least 20-30% female and 20-25% regional students. Achievements include; approval of the Center as a formal organic unit in the Universidade Eduardo Mondlane that will be in charge of supporting teaching and research in the field of engineering and technology of oil and gas for post graduate students. Eight regional students enrolled in MSc programs (Malawi 2, Uganda 3, Rwanda 2, and Zimbabwe 1.

Source: Center of Studies for Oil and Gas Engineering and Technology (CS-OGET); https://ace2.iucea.org/index.php/2018-01-22-22-04-02/aces-at-a-glance/cs-oget

Box 15: African Centre of Excellence in Internet of Things (ACEIoT -Rwanda)

African Center of Excellence in Internet of Things (ACEIoT), is one of four African Centers that were set up at University of Rwanda in 2017, under the Eastern and Southern Africa Higher Education Centers of Excellence Project (ACE II) financed by the World Bank to establish and strengthen specialization and collaboration in the region. ACEIoT aims to train and educate African researchers in the field of Internet of Things (IoT). This is expected to advance and install innovative IoT-enabled services, to offer solutions to growth challenges all over East and South African, in the highest precedence fields. ACEIoT's objectives are to (i) build a critical mass of African scientists and engineers in IoT through higher education and research, and (ii) set up an IoT living lab in Rwanda for open innovation and co-creation of IoT4D. At the end of the program, the students taking the programme are expected to be equipped with entrepreneurship skills which will enable them start their businesses. As at 2017, 2 PhD candidates had completed their studies, 18 PhD students had been enrolled and 2 masters students graduated. Some of the challenges in the program include; the center relies on using international lecturers who at times do not make it to class and gender balance is yet to be achieved at the centers.

Source: ACE 11 progress update report 2017: https://www.ace2.iucea.org/index.php/2018-01-22-22-04-02/aces-at-a-glance?limitstart=0

4.0 CONCLUSION

The analytical note on "Higher Education Science, Technology and Innovation, Research and Development (R&D) and Entrepreneurship in Africa" lays out the strategic direction for the Bank in re-skilling/upskilling Africa's workforce with demand driven science and technological skills from HESTI institutions, strengthening of the relevance of R&D to industry and building resilient enterprises that can weather economic shocks and pivot businesses to models that meet the changing demand of market. The analytical note has provided critical areas that need to be addressed. A key point to recognize is that the Bank has taken several initiatives as outlined in the analytical note in supporting the resurgence of RMCs in its development growth pathway by; enhancing linkages between the HEIs and Industry and supporting RMCs in carrying out in-depth reforms particularly in HE.

With respect to the thematic areas and cross cutting issues, key findings from the analytical note has established that most countries in Africa exhibit low skill production in STEM. Further, statistics show that skills and educational mismatches are prevalent in Africa. The failure to invest in R&D by the African governments makes it challenging for the scientists and researchers to develop homegrown, sustainable solutions for African problems leading to slow economic growth. Entrepreneurship development in HEIs has gained support due to its influence on socio-economic development. Further, HE has enhanced entrepreneurial capacities and technological transfers aimed at improving linkages between the private sector and the institutions. As such, increased collaboration between the private sector entities and the HEIs will yield more fruits in the future.

The infrastructural gaps witnessed in many African states have posed a challenge in developing skills for employability and job creation. Supporting HEIs in providing these relevant training infrastructures will boost learning, skills development and employability. The results show that the AfDB has supported several projects particularly in upgrading and rehabilitation of select higher education institutions in its RMCs as well as providing resources needed in building laboratories with a view to promote STEM education. These efforts have led to mass evolution of scientists in African. There is therefore a need for all stakeholders and development partners to build and upgrade more training infrastructure for STI development.

Despite most African states witnessing low financing for skills development, several emerging financing models for HESTI, R&D and Entrepreneurship development have been very instrumental in building skills that match industry needs. As such, countries need to undertake situational analysis to adopt some of the emerging funding models that will fit in their contexts as well as increase collaborations in education investments with the private sector. The Bank has led by example in its commitment to finance HESTI programmes in its RMC e.g. by funding Uganda's HESTI programme.

Poor governance structures and ineffective policies currently in place in most African countries do not support HESTI, R&D and entrepreneurship development in producing competent skilled human capital for employment, increased productivity and sustainable livelihoods. As such, it is important for the African states to develop friendly policy landscapes that drive HESTI, R&D and Entrepreneurship in their respective countries. Also, Africa should arise and make efforts in creating favourable conditions that will attract other external development partners to support R&D and HESTI substantially in Africa.

Women scientists have a critical role to play in Africa's development as such, the promotion of women in science and technology requires actions at all levels using different modalities including advocacy, enactment of appropriate policies and capacity building. Again, regional centers of excellence are key in enhancing the capacity of the institutions in delivering high quality training as well as the capacity to deliver R&D that addresses regional challenges, as such, more efforts to upscale the CoE in RMCs should be key so that they can provide high quality education.

The analytical note has identified several gaps that need to be filled in order to leapfrog the benefits of industrialization. Some of the gaps have been addressed by the Bank, but some require close collaboration with the Bank, development partners, private sector and the African governments. In supporting the economic growth of Africa, the analytical note emphasized the need to establish strong linkages between HEIs specially in the STEM areas, industry and the government. The African states should re-examine the role played by each stakeholder in the system to bring about strategy and reforms that are implementable and aimed at skills development at HESTI levels for increased productivity at Industry level. Institutional capacity building and strengthening at the RMCs in HESTI, R&D remains the key to success towards skills development for the industry in Africa.

5.0 OVERALL RECOMMENDATIONS

Several recommendations have been proffered above that the Bank can utilize to support Higher Education Science, Technology and Innovation, Research and Development (R&D) and Entrepreneurship in Africa. However, a few specific recommendations where the **Bank may have comparative advantage** are highlighted below:

5.1 **The Banks's track record and experience in skill development over the past 4 decades gives it a clear comparative advantage in HESTI, R&D and Entrepreneurship**. The current trends in skills production particularly in the HE landscapes which do not match with the labour market demand has posed a challenge for African economies. The Bank has been working with its RMCs since 1975 in supporting education. For instance, between 2005 and 2017, the Bank invested $2 billion in 70 education projects, with a primary focus on science and technology benefiting 7 million youths [i] . Also, from 2014 to 2018, the Bank approved a total

of 40 skills development projects amounting to UA 771.2 million that contributed to scaling up Skills and Technology in African countries. Half a million people benefited from better access to education in 2017 from the Bank's operations across the continent. The share of HE students' enrollment in STEM education rose from 30% in 2010 to 38.5% in 2017 [ii].In Ghana, the implementation of the Development of Skills for Industry Project (DSIP) between 2013 and 2019 with $95.2 million from the AfDB has achieved significant results with about 2,010 students enrolled in two technical universities and 10 technical institutes (40.7 percent of whom were women) were provided with scholarships, with the goal of increasing the participation of disadvantaged groups over the period [iii]. Also, a total of 4,510 people including 2,173 disadvantaged students benefited. **Therefore, the Banks's track record and experience in skill development puts it in a better position to invest more in upskilling Africa's workforce with demand-driven science and technological skills.**

5.2 **The Bank's strong operational focus and capacity in supporting skilled, productive and innovative workforce which is employable and entrepreneurial enough in creating decent jobs across its RMCs gives it a clear comparative advantage. Specifically, the pipeline of operations witnessed in many African Countries through the Bank's supports gives it a comparative advantage in HESTI.** Report from the 2019 implementation progress of the Uganda's HESTI Project being supported by the AfDB shows that a total of 228 (49.8%) HESTI students graduated from the programme of which 102 [44.7%] were Females). With regards to the ratio of researchers per members of the workforce, the programme had 828 researchers registered in 2018 per 1,000 members of the workforce. In the Nelson Mandela Institutes -African University of Science and Technology (AUST), the 2019 mid-term review shows that the Bank's investment in scholarships has amplified the enrolment rate and has further catalysed more female participation in STI with 35% of scholarships in AUST, 44% in Institut International de l'ingéniérie et de l'Eau (2iE), and 51% in African Institute of Science and Technology (AIST). The project has graduated 1,477 PhDs and MScs (out of which 676 are women). Further, a total of 35 partnerships have been brokered with the private sector to enhance the quality and relevance of research and development. In the Skills and Business Development Programme (SBDP) in Rwanda which is supported by the Bank there have been some policy reforms for boosting domestic production through skills development and enterprise growth for job creation. The 2019 implementation progress and results report show that 'Made in Rwanda Policy' was approved by the Cabinet in December 2017, Revised Special Economic Zone Policy was approved by the Cabinet in 2018, and the Professional Certification Programme for Financial Sector has been developed and operationalized as well. As at June 2019, the Professional Certification Programme for Financial Sector had a total of 30 graduates. Additionally, the Bank's support to the Skills, Employability and Entrepreneurship Programme II (SEEP II) in Rwanda has supported policy reforms addressing skills gap, education relevance and entrepreneurship development. Achievements as of 2015 include; increased number of TVET student/trainees by 37% overall during 2011-2014 period, about 13,610 new SMEs were registered surpassing the target of 13,500. Business development trainings have been conducted (about 7,484 start-ups and 1500 toolkits to start-ups have been provided). These confirms the Bank's strong capacity in skills development

through supports to HESTI, R&D and entrepreneurship development on the continent compared to other development partners. More of these supports are required to develop relevant skills for employment for more than 50% of African graduates that are without jobs.

5.3 **The Bank is known as "the infrastructure Bank" – with a lot of infrastructure interventions in the HESTI, R&D and Entrepreneurship**. For instance, the Bank has supported CoE in enhancing capacity of the institutions in delivering high quality training and the capacity to deliver R&D in addressing regional challenges facing development. A case in point is the Bank's approved a total of US$124.3 million for ground breaking CoE in HE in Mali, Uganda and Rwanda in 2011. The CoE receiving the funds included the Mulago Teaching Hospital in Kampala, Uganda (USD 88.8 million), the Bamako Digital Complex in Mali (USD 22.5 million) and Carnegie Mellon University in Rwanda (USD 13 million)[iv]. These projects have provided internships/on-the-job training/work-based training during the development of Bank supported infrastructure projects and have opened a big window to the development of relevant skills for industry – this massive potential needs to be harnessed. This would be another area where the Bank could flex its muscles in skills development by supporting more regional infrastructural projects not only in HESTI but in related sectors such as energy and ICT.

5.4 **The Bank has experience in IT infrastructure and ICT projects having supported several projects in RMCs.** In Rwanda, Carnegie Mellon is receiving USD 13 million from the Bank and USD 95 million over 10 years from the Rwandan government to operate the program. The Center aimed at driving Rwanda's economic growth through digital transformation. As of May 2020, the Carnegie Mellon University Africa (CMU-Africa) has 262 alumni with 83% of them working in their home countries where they impact the development and application of ICTs on the continent[v]. In Africa, a number of tech hubs have been developed, however, most of the tech hubs are privately owned. As such, they are at liberty to choose what start-up to promote. Further, there is no enough capacities and resources to promote them. The Bank is well placed to use its capacity and linkages to provide institutional and capacity supports to upgrade these tech hubs while creating partnerships with global giants such as Google and Facebook to support these tech hubs in developing skills for employment through entrepreneurship. This is necessary to enable African countries seize the opportunity presented by the 4IR, Artificial Intelligence, Robotics, Internet of Things, 3D printing, and Big Data among others to leapfrog development through skills acquisition, employment creation, technological innovations and overall sustainable livelihoods on the continent.

5.5 **The Demand-Driven Supports by the Bank to the RMCs have enabled them to achieve their development goals and visions and should be doubled**. Several clients within the RMCs in Africa have sought the Bank's interventions/supports as a priority in developing projects aimed at meeting the country's development goals and visions especially in the area of HESTI, R&D and Entrepreneurship development. For instance, in 2020, the government of Ghana embarked on deepening their efforts towards inclusive growth and has sought the support from the Bank to establish a National Development Bank. As such, the government has pledged to work with the Bank to look at global arrangements for cheaper financing of the initiative. In supporting the

private sector, the Bank has funded a $56.3 million project designed to provide incentives for private sector agribusinesses in northern Ghana in order to boost productivity in the agricultural sector. Also, the ministry of Agriculture is seeking additional US$ 150 million to implement its "Planting for Food and Jobs" policy[vi]. Other areas of demand-driven supports can include; curriculum review in HE; policy and institutional reviews to lay stronger emphases on STEM; establishment of programs such as the innovation incubation programmes, tech hubs, etc. with strong links to the private sector and venture capital; etc. The Bank should therefore double its efforts in this regard based on their decades of experience in providing demand-driven supports to RMCs.

5.6 **Several African countries do not have robust policies for HESTI, R&D and Entrepreneurship development.** Even when these policies are in place, there is limited capacity to articulate and implement them adequately to realize desired and sustainable impacts. It is important to understand the stakeholders and policy landscape that drive HESTI, R&D and Entrepreneurship in different African countries and how these stakeholders (governmental and non-governmental agencies) can be supported to develop and implement policies to enhance skills development and employability. The AfDB has a long history and institutional capacity that has kept it at the forefront in transforming the RMCs through policy support. Over the years, the Bank has played a key role in building its expertise and organizational capacity including economic governance reforms. The Bank has established the African Development Institutes (ADI) as a platform to support capacity developments across the continent in creating policy solutions in Africa. The AFDB in collaboration with RMCs should support policy reforms by allocating funds for holding policy reviews, analyses, and dialogues as well as benchmarking activities. The Bank should partner with leading Think Tanks in STI policy research, policymaking and advocacy in Africa such as the African Technology Policy Studies Network (ATPS) to review existing HESTI policies with a view to understanding the statuses and identifying what works (successes) what does not work (failures) and why (reasons for successes and or failures) and be able to advocate for change.

5.7 **The Bank is well positioned to contribute to Africa's development particularly in supporting R&D by virtue of its position and its strategic partnerships with RMC, regional economic communities and other international development partners**. For instance, despite the African Union's target of 1% investment of GDP on R&D for Member countries, available data show that few countries in sub-Sahara have been close to achieving this target. The Bank's investment power gives it a comparative advantage in supporting RMCs in attaining the 1% target of GDP on R&D which is directly proportional to innovation development, skills and employment and productivity. Attaining 1% investment of GDP on R&D in RMCs will complement the Banks's effort in strengthening scientific research particularly in re-skilling/upskilling Africa's workforce with demand driven science and technological skills, strengthen relevance of R&D to industry and building resilient enterprises that can weather economic shocks and pivot businesses to models that meet the changing demand of market. In order to enable the Bank to achieve the boosting of RMCs' investments in R&D the Bank should utilize their convening power and its strategic partnerships track records to engage the following strategic partners:

i. Strategic Partnerships with International STI Research Councils such as: BBSRC, ESRC, NERC, MRC, GCRF which are all research councils and research funds in the UK with special interest in African partnerships especially in research and innovation. Partnerships should be extended to similar initiatives in other continents. The partnership should also include the provision of technical capacity and advisory where necessary in collaboration with the Bank.

ii. Strategic Partnerships with International Donor Agencies and development partners with specific mandate for development in Africa. These include Ford Foundation; UK Aid, USAID, DFID; European Union; World Bank; Bill and Melinda Gates Foundation; Carnegie Foundation; and a lot more. A profile of these development partners and their specific mandates in promoting HESTI, R&D and entrepreneurship development in partnership with the Bank will be necessary.

5.8 **Given the Bank's comparative advantage in promoting gender equality and mainstreaming in its operations in the RMCs as well as in its own internal transformation to make it a more supportive, gender-responsive institution, there is need to adopt more beneficial strategies to scale access for girls and women in STI/STEM in the pipeline.** Women play a crucial role in the development and survival of STI in Africa enough to attract a special programme for this demographic. Achieving this mainstreaming of women in STI requires actions at different levels using different mechanisms including advocacy, appropriate policies and programmes, affirmative actions and capacity building. For instance, establishing the Women Executive Programmes (WEP), Women Graduate Programmes (WGP) and Women Community Programmes (WCP) around STEM-focused SMEs and career. While the WEP targets senior and middle management level women working in established HESTI institutions and businesses to empower them with training and loans to establish enterprises, the WGP will target female students and graduates by encouraging them to take up STEM-courses or grow in such areas by offering training, scholarships, bursaries, mentoring schemes (in partnership with WEP), internships and industrial attachments with SMEs (in partnership with the Academic-Industry Bridge Programme identified in the list of recommendations). On the other hand, the WCP will target local and rural women engaged in activities that can benefit from STEM-areas, R&D and innovation from HESTI institutions. The WCP engagements could be used to address issues and challenges of waste management, food processing, marketing and storage etc. These women are not very literate and there are challenges bordering on religion, culture and language. Therefore, programme delivery would be on-site and using different engagement platforms to bridge communication and knowledge transfer challenges.

6.0 PARTNERS FOR THE BANK

The Bank enjoys wide range of partners that can complement and play synergistical roles in the implementation of its numerous work activities across Africa. Some are mentioned below:

6.1 Development partners: UNICEF has supported educations in many African states. For instance, it has supported the government of Rwanda to implement new Competence Based

Curriculum (CBC) which puts more emphasis on quality education with requisite skills for the labour market. The Bank should partner with this organization in developing more employability skills particularly STEM skills. Other development organizations include; IMF and UNESCO that are supporting education in Africa.

6.2 Private partners. The private sector has played a bigger role in promoting economic development. Tech Giants such as Google and Facebook have supported development of employability skills. The Bank should work with these organizations since they align with the aspirations of the Bank in developing employability skills.

6.3 Philanthropy: Tony Elumelu Foundation is one of the leading champions of entrepreneurship in Africa. It aims to empower women and men across Africa, catalyzing economic growth, and ensuring job creation. The Bank should partner with this and other similar Foundations in empowering more women and men in creating more jobs.

6.4 Universities: Leading world class universities such as the Massachusetts Institute of Technology (MIT) innovation centers for entrepreneurship have raised billions of dollars and created jobs through offering sponsorships. The Bank should partner with MIT and the likes in supporting African students to acquire entrepreneurship skills which will lead to creation of startups.

6.5 **STI Institutions in Africa**: Considering the leading roles and contributions that some STI institutions have made in STI capacity building/strengthening; skills development and entrepreneurship; STI policy analysis, policymaking, advocacy and policy implementation among others, it becomes necessary for the Bank to provide supports to these institutions to enable them deliver their mandates fully and sustainably in this regard. One such institution is the African Technology Policy Studies Network (ATPS) that has been rated for the last eight years by the Global Go Think Tank Index Report as the Top Best STI Policy Think Tank in Africa (10^{th} globally)[110]. ATPS also rates as the Top Best Policy Advocacy Think Tank; Top Best Think Tank with Innovative Policy Ideas; Top Best Networked Think Tank; and Top Best Think Tank with Institutional Collaboration among others.

6.6 Foundations: African Capacity Building Foundation (ACBF) has strengthened financial systems through capacity building in the banking and finance in Southern and West Africa through and has Promoted critical skills in science and technology in Burkina Faso, Nigeria and Tanzania. It has promoted knowledge and learning by supporting the African Union in identifying capacities needed in implementing Agenda 2063. ACBF has funded African University of Science and Technology in Abuja-Nigeria, International Water and Environmental Engineering in Ouagadougou- Burkina Faso, African Institute of Science and Technology in Arusha-Tanzania. The AfDB should continue to support the ACBF to enable it upscale its mandate in capacity building in more regions within Africa.

[110]https://repository.upenn.edu/cgi/viewcontent.cgi?article=1018&context=think_tanks

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Annexes

Annex 1: List of Science and Technology Universities and Higher Education Institutions in Africa

S/N	country	name of university	year of establishment	Type of ownership
1	Algeria	University of Science and Technology–Houari Boumediene	1974	Public
		Oran University of Science and Technology	1975	
2	Angola	Universidade Técnica de Angola		

3	Benin	University of Science and Technology of Benin	1996	Private
		InstitutSupérieur des Sciences et Techniques		Private
4	Botswana	Botswana International University of Science and Technology	2005	Public
		Botswana Institute of Technology Research and Innovation	2012	Public
5	Burkina Faso	University of Ouaga I–Pr Joseph Ki-Zerbo	1974	Public
		Polytechnic University of Bobo-Dioulasso	1996	Public
		Institute for Science	2004	Public
		Polytechnic center of FadaN'Gourma	2009	Public
		Polytechnic center of Ouahigouya	2010	Public
		Polytechnic center of Dédougou	2012	Public
		Higher Institute for Informatics	1996	Private
		St. Thomas d'Aquin University	1995	Private
		Catholic University of West Africa	–	Private
		University Aube Nouvelle	1989	Private
		Higher school of applied sciences	–	Private
		Other small R&D schools (4)		Public
		Other small R&D schools (10)		Private
6	Cameroon	Bamenda University Institute of Science and Technology		Private
		Bernice University of Science and		Private
		Catholic University Institute of Buéa–School of Engineering	2010	Private
		Catholic University Institute of Buea–School of Information Technology		Private
		Institute of Science Technology Cameroon–Bamenda		Private
		University College of Technology Buea		Private
		InstitutSupérieur des Technologies et de l'Innovation		Private
		The ICT University		Private
		Christian University Institute–Higher Institute ofSciences, Engineering and		Private

7	Congo, Dem. Rep.	University of Technology of the Congo	2010	Private
8	Congo, Rep.	Higher Institute of Technology of Central	2002	
9	Côte d'Ivoire	Institut National Polytechnique Félix HouphouëtBoigny		
		The University of Science and Technology of Ivory Coast	2009	Private
		Ecole SuperieureAfricaine des Techniques de la Communication		
		The Higher Institute of Technology of Ivory	2007	Private
		InstitutSupérieur de TechnologieDubass		
10	Egypt	University of Science and Technology at Zewail City	2011	Public
		Egypt–Japan University of Science and	2010	Public
		Institute of Aviation Engineering and	1997	Private
		Alexandria Higher Institute of Engineering and Technology	1996	Private
		Arab Academy for Science, Technology, and Maritime Transport	1972	Private
		Cairo Higher Institute for Engineering, Computer Science & Management	1995	Private
		Higher Institute for Engineering and Technology in Kafr Elsheikh	2011	Private
		International Academy for Engineering and Media Sciences	2002	Private
		Misr University for Science and Technology	1996	Private
		Modern University for Technology and	2004	Private
11	Eritrea	Eritrea Institute of Technology	2003	
12	Ethiopia	Addis Ababa Science and Technology		
		Graduate School of Telecommunications and Information Technology		
		HiLCoE School of Computer Science and Technology college		
		Eprom Technology College		
		Kombolcha Institute of Technology		
		Mekelle Institute of Technology	2002	
		Ethiopia Institute of Technology		
		Adama Science and Technology University		

		Universal Technology College		
13	Gabon	Université des Sciences et Techniques de		
14	Ghana	Kwame Nkrumah University of Science and Technology	1952	Public
		University of Mines and Technology	2001	Public
		Accra Institute of Technology	2005	Private
		Anglican University College of Technology	2008	Private
		Osei Tutu II Institute for Advanced ICT		
		Accra Polytechnic		
		Ghana Telecom University College		
		Kumasi Polytechnic		
		Koforidua Polytechnic		
		University of Energy and Natural Resources		
		Takoradi Polytechnic		
		Ho Polytechnic		
		Cape Coast Polytechnic		
		Tamale Polytechnic		
		Sunyani Polytechnic		
		Bolgatanga Polytechnic		
15	Kenya	Masinde Muliro University of Science and Technology	1972	Public
		Dedan Kimathi University of Technology Kimathi University of Technology	1972	Public
		Jomo Kenyatta University of Agriculture and Technology	1981	Public
		Jaramogi Oginga Odinga University of Science and Technology	2009	Public
		Meru University of Science and	2008	Public
		International Center of Technology (ICT-Thika)–Thika		Private
		The Kenya College of Science and		Private
		Kenya Institute of Biomedical Sciences and Technology– Nakuru		Private
		Kiriri Women's University of Science & Technology		
		Nyandarua Institute of Science &		
		Sang'aloInsitute of Science & Technology		

16	Libya	College of Electronic Technology–Tripoli		
		College of Electrical and Electronic Technology–Benghazi		
		College of Engineering Technology–Houn		
		College of Engineering Technology–Janzur		
		College of Engineering Technology–		
		College of Mechanical Engineering Technology–Benghazi		
		College of Computer Technology–Zawiya		
		College of Medical Technology–Derna		
		College of Medical Technology–Misurata		
17	Madagascar	InstitutSupérieur de		
		InstitutSuperieur Polytechnique de Madagascar		
18	Malawi	Malawi university of Science and	2012	public
19	Mali	École Nationaled'IngénieursAbderhame Baba Toure'		
20	Mauritania	Université des Sciences, de Technologie et de Médecine		
21	Mauritius	University of Mauritius (Faculty of Science)	1965	public
		University of Technology, Mauritius	2000	public
22	Morocco	The Scientific Institute	1920	
		École Nationale de l'IndustrieMinerale		
		École Marocaine des Sciences de		
		High Technology School in Morocco		
		Institut de Formation enTechnologieAlimentaire		
		InstitutSupérieur du Génie Appliqué		
		École Supérieure d'Ingénierieen Sciences Appliquées		
		Institut Polytechnique Privé de Casablanca		
		École Polyvalente Supérieure d'Informatique et d'Electronique		
		École Marocained'Ingénierie		
		École d'IngénierieenGénie des SystèmesIndustriels Casablanca		

		École Supérieure Vinci d'Informatique et des Telecoms de Rabat/Maroc		
		École Polytechnique Privéed'Agadir		
23	Mozambique	Academy of Police Sciences		
		Alberto Chipande Higher Institute of		
		Higher Institute of Sciences and		
24	Namibia	Namibia University of Science and		
25	Nigeria	Our Saviour Institute of Science, Agriculture and Technology	1989	Private
		Akwa Ibom State University (formerly Akwa Ibom State University of Science and	2010	Public
		Bells University of Technology	2004	Private
		Cross River University of Technology	2002	Public
		Enugu State University of Science and Technology	1979	Public
		Kano State University of Science and		
		Kebbi State University of Technology		
		Ladoke Akintola University of Technology	1990	Public
		ModibboAdama University of Technology Yola		
		Ondo State University of Science and Technology		
		ModibboAdama University of Technology Yola		
		Ondo State University of Science and Technology 2010 Public	2010	Public
		Rivers State University of Science and Technology	1980	Public
26	Rwanda	Tumba College of Technology		Private
27	Senegal	Institut de TechnologieAlimentaire		
28	Somalia	Juba University of Science and Technology		
		Modern University for Science and Technology		
29	South Africa	Tshwane University of Technology	2004	Public
		Central University of Technology	1981	Public
		Durban University of Technology	2002	Public
		Vaal University of Technology	2004	Public
		Walter Sisulu University for Technology and Science	2005	Public

		Cape Peninsula University of Technology	2005	Public
		Mangosuthu University of Technology	1979	Public
		University of Mpumalanga	2014	Public
		The Sol Plaatje University	2014	Public
30	South Sudan	John Garang University of Science and Technology	2006	Public
31	Sudan	Sudan University of Science and Technology	1932	Public
		Bayan College for Science & Technology	1997	Private
		Garden City College for Science and Technology		Private
		The Future University of Sudan	1991	Private
		University of Medical Sciences and Technology	1995	Private
		University of Science and Technology– Omdurman	1995	Private
32	Tanzania	Nelson Mandela African Institution of Science and Technology	2010	Public
		Mbeya University of Science and Technology	2012/13	Public
		International Medical and Technological University	1997	Private
33	Togo	Togo The University of Science and Technology of Togo	2012	Private
34	Tunisia	Tunisia Higher Institutes of Technological Studies		
35	Uganda	Uganda Mbarara University of Science and Technology	1989	Public
		University of Military Science and Technology		
36	Zambia	Zambia Information and Communications University	1998	Private
		Victoria Falls University of Technology Livingstone Zambia		Private
	Zimbabwe	Chinhoyi University of Technology	2001	Public
		Harare Institute of Technology	1988	Public
37		Manicaland University of Science and Technology		

		National University of Science and Technology	1991	Public
		National University of Technology Public		Public

Source: African Capacity Report (2017)

Annex 2: Publications from African Countries 1996-2019

Rank	Country	Publications	Citable Publications	Citations	Self-citations	Citations per Publications	H index
1	South Africa	303863	275974	4434473	921646	14.59	468
2	Egypt	230156	221423	2410995	473454	10.48	288
3	Nigeria	102154	96260	812185	168289	7.95	208
4	Tunisia	94962	90118	840209	168596	8.85	193
5	Algeria	74802	72646	569227	120385	7.61	178
6	Morocco	71536	67432	623082	118851	8.71	196
7	Kenya	39051	35034	788048	107724	20.18	261
8	Ethiopia	27461	25830	331025	70700	12.05	155
9	Ghana	23715	21770	307727	40293	12.98	160
10	Tanzania	19678	18052	363861	50452	18.49	175
11	Uganda	19550	17730	379857	54167	19.43	184
12	Cameroon	18273	17084	246363	42795	13.48	138
13	Zimbabwe	11740	10493	183155	19031	15.6	140
14	Senegal	11275	10501	143880	15855	12.76	129
15	Sudan	10141	9558	122578	10632	12.09	100
16	Botswana	8417	7461	113911	10369	13.53	109
17	Malawi	8347	7546	166150	19464	19.91	147
18	Burkina Faso	7419	7034	114145	15438	15.39	111
19	Côte d'Ivoire	7115	6731	108869	8977	15.3	119
20	Zambia	6876	6106	135558	12477	19.71	131
21	Libya	6291	6036	57402	2614	9.12	76
22	Benin	6127	5814	97478	11473	15.91	98
23	Congo	5305	4883	87752	6927	16.54	109
24	Madagascar	4830	4548	74058	10947	15.33	98
25	Mozambique	4428	4014	99706	7652	22.52	108

26	Namibia	4197	3701	62515	5477	14.9	101
27	Mali	3925	3661	74881	6322	19.08	104
28	Mauritius	3910	3516	44345	4231	11.34	81
29	Rwanda	3698	3263	62159	4534	16.81	88
30	Gabon	2925	2750	64269	6009	21.97	106
31	Gambia	2793	2583	114400	7251	40.96	131
32	Niger	2444	2293	40662	3248	16.64	81
33	Togo	2311	2139	23636	1534	10.23	55
34	Swaziland	1652	1520	19880	902	12.03	62
35	Angola	1313	1219	15791	1220	12.03	49
36	Sierra Leone	1309	1144	22570	1988	17.24	57
37	Democratic Republic Congo	1308	1204	23354	669	17.85	66
38	Guinea	1127	1039	21431	1212	19.02	63
39	Central African Republic	828	766	13505	730	16.31	55
40	Reunion	811	751	13139	211	16.2	54
41	Lesotho	770	703	8308	349	10.79	40
42	Mauritania	763	715	8846	622	11.59	45
43	Burundi	742	684	11118	444	14.98	45
44	Seychelles	717	664	22675	1193	31.62	65
45	Guinea-Bissau	710	647	15904	3201	22.4	61
46	Liberia	699	579	10205	747	14.6	46
47	Eritrea	685	644	9799	630	14.31	46
48	Chad	621	589	10112	761	16.28	45
49	Cape Verde	378	364	3914	288	10.35	30
50	Somalia	292	251	2817	108	9.65	23
51	Djibouti	287	272	2641	202	9.2	26
52	Equatorial Guinea	237	223	4498	325	18.98	28
53	Comoros	173	159	1912	122	11.05	18
54	Mayotte	97	93	747	28	7.7	13
55	Sao Tome and Principe	82	78	1254	73	15.29	21
56	South Sudan	67	54	388	9	5.79	11
57	Saint Helena	47	44	340	4	7.23	10

58	British Indian Ocean Territory	29	26	378	0	13.03	7
59	Western Sahara	10	7	51	0	5.1	4

Source: SCImago Journal Rank (SJR), 2020.

End Notes

[i]https://blogs.afdb.org/investing-gender/international-day-women-and-girls-science-calls-africa-address-gender-gap-stem

[ii]UNESCO Institute for Statistics. Percentage of students in tertiary education enrolled in STEM programmed 2017

[iii]https://www.afdb.org/en/news-and-events/press-releases/ghana-african-development-bank-funded-training-builds-skills-economy-future-report-36946

[iv]https://www.afdb.org/en/news-and-events/afdb-approves-usd-124-million-for-centers-of-excellence-in-mali-uganda-and-rwanda-8459

[v]https://www.africa.engineering.cmu.edu/alumni-impact/index.html

[vi]https://www.afdb.org/en/news-and-events/ghana-seeks-african-development-bank-support-domestic-development-bank-34688