SOUTHERN VOICE

Southern perspectives. Global debates.

10 years

OCCASIONAL PAPER SERIES N°

88

Ed-Tech landscape and challenges in Sub-Saharan Africa

Adedeji Adediran
Abdulfatai Adedeji
Emmanuel Nwosu
Emmanuel Nwugo
Great Nnamani

OCCASIONAL
PAPER
SERIES
N°
88

Ed-Tech landscape and challenges in Sub-Saharan Africa

Adedeji Adeniran
Abdulfatai Adedeji
Emmanuel Nwosu
Emmanuel Nwugo
Great Nnamani

Publisher

Southern Voice Website: www.southernvoice.org

E-mail: info@southernvoice.org

First Published November 2023 © Southern Voice

This work was carried out with the aid of a grant from the International Development Research Centre (IDRC, Ottawa, Canada).

Cite this content as: Adeniran, A., Adedeji, A., Nwosu, E., Nwugo, E., & Nnamani, G. (2023). Ed-Tech Landscape and Challenges in Sub-Saharan Africa (Occasional Paper No. 88). Southern Voice.

ISSN 2307-9827 (Online)

ISSN 2307-681X (Print)

Acknowledgement

This study received scientific and technical support from the Group for the Analysis of Development (GRADE) and Southern Voice. The authors, GRADE, and the Southern Voice team engaged in a collaborative and continuous feedback process throughout the writing and development of this document. The study also benefited from internal and external review processes and editorial support.

We extend our sincere appreciation to the participants of the 2023 workshop organised by GRADE and Southern Voice in Mexico. Their valuable and constructive comments have greatly enriched this work. Our gratitude also goes to the anonymous internal and external reviewers for their insightful contributions, which have significantly strengthened the content of this paper. Additionally, we would like to express our deep thanks to the editorial team of Southern Voice for their rigorous evaluation and feedback, all of which have played a pivotal role in enhancing the overall quality of this study.

Abstract

This study examines the adoption of education technology (ed-tech) in primary and secondary education in 10 sub-Saharan African countries: Nigeria, South Africa, Sierra Leone, Uganda, Kenya, Tanzania, Cameroon, Benin, Malawi, and Senegal. The study assesses the development and implementation of ed-tech policies and programmes in the region, exploring how far ed-tech has advanced learning outcomes, improved access, and reduced education inequalities within and between countries in sub-Saharan Africa.

Overall, the study reveals that insufficient budgetary allocation, a lack of supportive infrastructure, and inadequate teacher training outweigh the limited progress in ed-tech adoption rates observed in the countries surveyed. It was also found that the heavy burden placed on households to provide digital devices and infrastructure limited the possibility of achieving higher adoption rates. There were high levels of inequality in ed-tech adoption in most countries, both in terms of gender and geography (rural and urban), with much lower access to, and use of ed-tech tools and resources in rural areas. The study also finds that insufficient government funding significantly affects ed-tech adoption in nearly all countries, with most initiatives being led and financed by non-governmental organisations (NGOs) and startups in these countries. Additionally, political shifts and transitions, which capture the role of political economy, are other factors that shape ed-tech implementation and adoption in the countries, with transitions from one government to another often undermining the sustainability of ed-tech policies. Overall, the study highlights the need for comprehensive and sustained government support to address access inequalities and ensure long-term sustainability. Governments should also encourage private sector participation by providing an enabling environment for it to support ed-tech adoption in schools.

Authors

Adedeji Adeniran is the director of research at the Center for the Study of the Economies of Africa (CSEA), Abuja, Nigeria. Dr. Adeniran has been working in the area of international development for more than a decade with specific expertise in sustainable development, education and digital economy.

Abdulfatai Adedeji is a research associate at the Centre for the Study of the Economies of Africa (CSEA). His research focuses on pivotal areas such as human capital development, domestic resource mobilisation, armed conflict, and macroeconomic management. He is a holder of a PhD in Economics from the University of Ibadan.

Emmanuel O. Nwosu is a non-resident senior research fellow at the Centre for the Study of the Economies of Africa Abuja and a Professor at the Department of Economics, University of Nigeria, Nsukka. He obtained his degrees from the University of Nigeria, Nsukka, Nigeria and University of Tsukuba, Japan.

Emmanuel Nwugo is a researcher at the Centre for the Study of the Economies of Africa (CSEA). He holds a Bachelor of Science in Economics from the University of Nigeria and is currently pursuing a Master of Development Economics at Dalhousie University, Canada. Emmanuel has experience in macroeconomic research and policy analysis, and has contributed to development projects in education, climate, gender, and food security.

Great Nnamani is a research and communications assistant at the Centre for the Study of the Economies of Africa (CSEA). He holds a Bachelors degree in Economics (First class Honours) from the University of Nigeria. His research interests include development economics, macroeconomics, public policy, and international development.

Content

List of figures

List of tables

List of boxes

Acronyms and abbreviations

ICT	Information Communication and Technology
KIIs	Key Informant Interviews
NGOs	Non-Governmental Organisations
OECD	Organization for Economic Co-operation and Development
TCPD	Teacher Continuous Professional Development
TLCs	Teacher Learning Circles
TSC	Teaching Service Commission
UN	United Nations
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization

Key concepts

Key concepts	Definition
Ed-tech	Education technology (ed-tech) refers to the application of information and communication technologies to improve instruction and learning processes (Rodriguez-Segura, 2022; Khan et al., 2012). It is a combination of hardware (such as radios, televisions, phones, smartphones, tablets, and laptops), software, infrastructure (such as the internet, local connectivity, and electricity), and other digital methods (such as crowdsourcing, open innovation, and open licensing) used for teaching/learning, administrative tasks, monitoring, and evaluation (Haßler et al., 2020).
Learning poverty	The World Bank (2019) defines "learning poverty" as a child's inability to read and comprehend a simple text by the age of ten. A child is considered to be in learning poverty if he or she cannot read and comprehend a simple story by this age. Learning poverty emphasises the importance of measuring not only access to education, but also education quality and learning outcomes. Its goal is to draw attention to the critical need to improve educational quality so that all children can develop the foundational literacy and numeracy skills required for lifelong learning and success.
Learning deprivation	Proportion of children who read below the minimum proficiency level at the end of primary school (World Bank).
Schooling deprivation	Proportion of primary-aged children who are not in school (World Bank).
Political economy	Political economic theory in relation to ed-tech explores how political and economic factors influence ed-tech adoption and implementation. It examines power dynamics, government policies, funding allocation, and the role of the private sector in shaping ed-tech initiatives. It also emphasises the impact of socio-political context and access to technology on educational outcomes (Regan & Khwaja, 2019).
Basic education	This captures the foundational level of education given to children in their early years of schooling. It provides basic skills and knowledge that form the fundamental blocks for further education and lifelong learning. In sub-Saharan Africa, basic education comprises primary education, which captures the first six years of formal schooling, and lower secondary education, which includes the first three years of secondary schooling. In some countries, it may also include three years of upper secondary education. Its length varies across countries: Nigeria (9 years), Senegal (13 years), Kenya (16 years), Sierra Leone (12 years), Malawi (12 years), South Africa (9 years), etc.
Low technology in education	These are traditional devices such as radio and television which are used in teaching with limited physical interaction or non-physical interaction.
High technology in education	These are advanced devices which include computers, smartphones, tablets, and interactive boards, and which are used in teaching and learning with little physical or non-physical interaction.

Ed-Tech landscape and challenges in Sub-Saharan Africa

Adedeji Adeniran
Abdulfatai Adedeji
Emmanuel Nwosu
Emmanuel Nwugo
Great Nnamani

Introduction

Education challenges are mounting in sub-Saharan Africa. These include limited access to quality education, language barriers, skills gaps, gender disparities, a lack of investment, political instability, brain drain, and global economic disparities (World Bank, 2018; United Nations Educational, Scientific and Cultural Organization [UNESCO], 2019; Winthrop, 2022; United Nations Development Programme [UNDP], 2020; World Economic Forum, 2017). Furthermore, the region has the highest rate of out-of-school children in basic education in the world (Roser & Ortiz-Ospina, 2023; World Bank et al., 2022; United Nations International Children's Emergency Fund [UNICEF], 2021). While there have been considerable improvements in primary and secondary school enrolment, learning performance remains low and, in some cases, is deteriorating. For example, the World Bank's Learning Poverty (LP) index[1] shows that 86.3% of sub-Saharan Africa's school-aged children lacked minimum proficiency in literacy at the end of primary school in 2019. This number increased to 90% in 2022.

In recent years, both the public and private sectors have been exploring the deployment of technologies in education in order to improve the accessibility and quality of education in the region. However, the COVID-19 pandemic exposed low levels of technological readiness and an absence of resilience in the educational system in countries across sub-Saharan Africa. The absence of a vibrant ed-tech[2] sector is reflected in the

1 The World Bank (2022) defines learning poverty as the inability of children to read an age-appropriate text. The figure for 2022 was based on a simulation reported by Azevedo et al. (2021).

2 Ed-tech refers to the use of information and communication technologies to improve the delivery of instruction and learning processes (Rodriguez-Segura, 2022; Khan et al., 2012). More specifically, it can be defined as a combination of hardware (such as radios, televisions, phones, smartphones, tablets, and laptops), software, infrastructure (including, for instance, the internet, local connectivity, and electricity) and other digital methods (such as crowdsourcing, open innovation, and open licensing) for teaching and learning, school administration, and monitoring and evaluation of learning and teaching (Haßler et al., 2020).

heavy reliance on low-technologies such as radio and television during school closures. During the pandemic, many schools were unable to effectively transition to alternative learning approaches due to the absence of an enabling environment (Ayega, 2020). At the same time, the COVID-19 pandemic appears to have led to increased policy interest in the need for technology deployment in the education system. This has motivated over 90% of education ministries worldwide to adopt some type of remote learning policy, with stakeholders seeking actions to "reimagine education" by leveraging technology (UNICEF & International Telecommunication Union, 2020).

Ed-tech was already part of the educational system in sub-Saharan Africa before COVID-19. However, it was focused on providing teachers with teaching aids, and teaching digital literacy to students. The recent global trend of digitalisation has triggered a new phase of ed-tech focused on student-centred and personalised learning. The promise of ed-tech to improve learning outcomes and address other challenges in the education sector has fuelled its incorporation into the educational systems in developing countries (Rodriguez-Segura, 2022). At the classroom level, technology can support teaching with interactive learning aids, automation of grading, report preparation, student auto-learning, and professional development (Gondwe, 2021; Matthews et al., 2012; Mize, 2011). Ed-tech can also play a significant role in teacher development programmes. For instance, Hennessy et al. (2022) find that ed-tech benefits teachers in terms of improvement in teaching quality, although evidence on its sustainability, cost effectiveness and influence on classroom practice and student outcomes remains thin.

The progress in network coverage implies that students in rural areas of the Sub-Saharan countries can increasingly gain access to mobile phone services, which opens up opportunities for them to leverage ed-tech tools and resources.

Ed-tech can also support the automation of school management and administrative tasks, allowing for data-driven decision making and education planning (McBurnie, 2021; de Barros et al., 2019; de Hoyos Navarro et al., 2017; Meckes & Carrasco, 2010). Other stakeholders, such as parents, can also benefit from technological adoption through more effective and timely communication channels with schools. However, the ed-tech adoption can also worsen education inequalities among vulnerable and marginalised groups, associated with technology's high cost and limited access (Chama & Subaveerapandiyan, 2023). Haleem et al. (2022) note that despite several

benefits associated with education technology, challenges include high inequality, difficulties for teachers to operate digital tools, and excessive screen time.

In sub-Saharan African countries, there has been only limited adoption of technology in the education sector (French Development Agency and UNESCO, 2015). For example, Krönke (2020) reports a digital non-readiness[3] score of 56.6% for the region and a digital literacy rate[4] of 31%. The limited deployment of ed-tech initiatives in the region is also characterised by the exclusion of some population groups. For instance, ed-tech initiatives deployed by the Kenyan government largely exclude marginalised and vulnerable groups (Ngware & Ochieng, 2020). This is a common experience in several countries in sub-Saharan Africa, that could be attributed to the high number of learners residing in rural areas without electricity or internet connection. The effectiveness of ed-tech in improving learning largely depends on supporting infrastructure, political commitment, digital literacy, and teacher training.

In this context, it is important to evaluate how the ed-tech landscape has continued to evolve since the COVID-19 pandemic, and the implications of this for addressing the education challenges facing the region. A political economy analysis is also crucial to understanding how politics affect ed-tech programmes' sustainability. Such an analysis provides insights in terms of how policy funding and design influence adoption of ed-tech at the basic levels of education. By considering the power relationships that exist between ed-tech stakeholders, a better understanding of the factors that promote or act as barriers to the implementation of ed-tech programmes can be gained.

In this way, this study seeks to examine the efforts, challenges, and prospects of ed-tech policies and interventions in enhancing accessibility and quality of primary and secondary education in 10 selected countries in sub-Saharan Africa.[5] Our overall research question is: how can the adoption of digital technologies in 10 sub-Saharan African countries assist in improving learning outcomes and reducing inequalities across different groups in primary and secondary education? Specifically, the study aims to answer the following questions:

---

3 Digital non-readiness captures people who are not digitally literate and do not have access to at least a smartphone or a computer in their household.

4 The digital literacy rate is the percentage of people who are familiar with the devices (smartphones and computers) and frequently use the internet.

5 Benin, Cameroon, Kenya, Malawi, Nigeria, Senegal, Sierra Leone, South Africa, Tanzania, and Uganda.

1. How important have ed-tech policies and programmes been in the region?
2. What are the priorities of ed-tech policies within the region, and in what ways has ed-tech been used?
3. What factors have facilitated the development and implementation of ed-tech policy within the region?
4. What factors have acted as barriers to the development and implementation of ed-tech policy within the region?
5. How far is ed-tech advancing learning outcomes, improving access, and reducing education inequalities, including support for connectivity between rural and urban areas as well as regional integration between countries in sub-Saharan Africa?
6. What are the political economic issues driving ed-tech adoption and deployment, including the role of the public and private sectors?

To address these questions, this study employs a mixed-methods approach that combines literature reviews, descriptive analysis, key informant interviews (KIIs), and field observations. Ultimately, this study provides an evidence-based analysis of ed-tech policies and programmes in the region, their influence on learning outcomes along gender and geographical divides, and the political economic issues facing the deployment of ed-tech in sub-Saharan Africa.

The study is organised as follows: Sections 1.1, 1.2., and 1.3., provide background information on the state of education and ed-tech in the region. Section 2 describes the methodological framework, including the research design, data collection methods, and analytical framework. Section 3 presents the descriptive findings from the literature, while section 4 focuses on analysis and discusses policy recommendations. The study ends with concluding remarks and limitations of the study in Section 5.

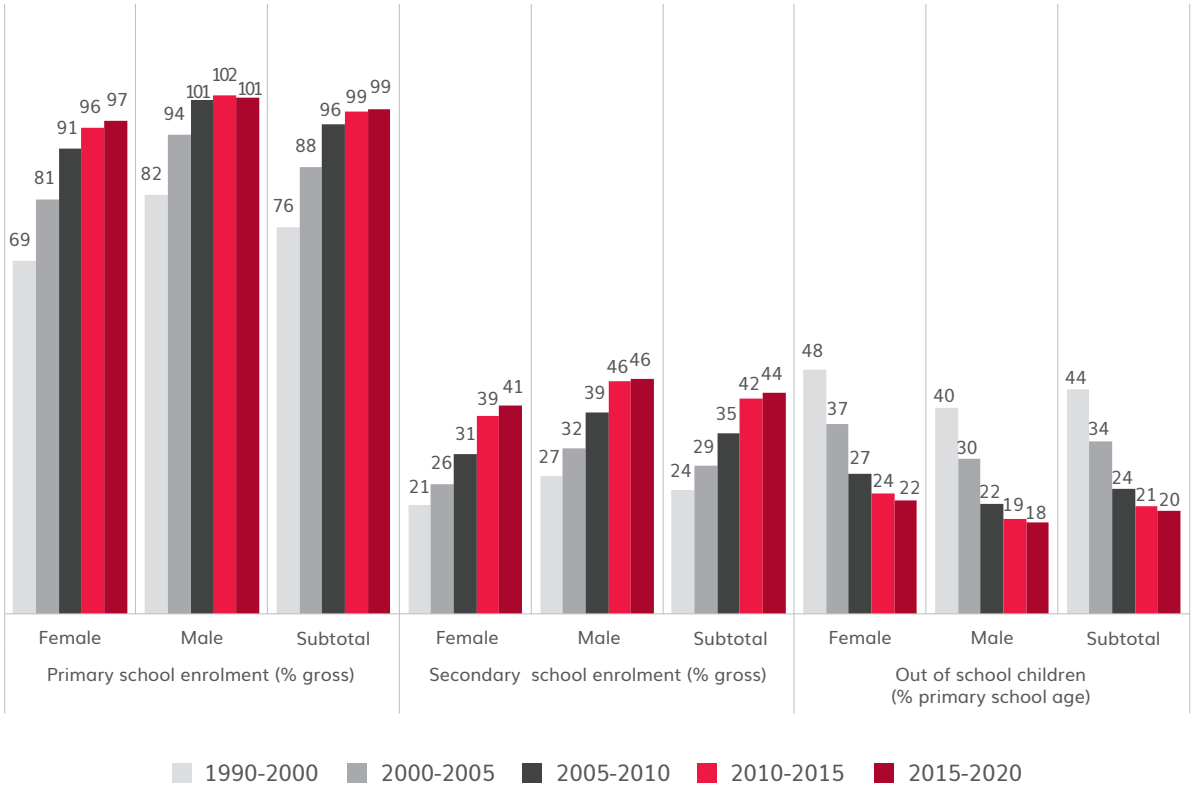
The state of basic education in sub-Saharan Africa

School enrolment and out-of school children

Basic school enrolment has improved significantly over the past three decades in most sub-Saharan African countries, largely due to the introduction of free public education programs. As shown in Figure 1, between 1990 and 2020 primary school enrolment in the region increased from 75.9% to 99.2%. Secondary school enrolment climbed from 24.2% to 43.5% over the same period (World Bank, 2022a). The proportion of out-of-school children decreased from 44.1% in 1990 to 20.1% in 2020 (World Development Indicators, 2022). Net enrolment rates in primary schools also improved, although enrolment rates are higher among male than female students (see Figure 1). Conversely, secondary school net enrolment rates remain notably low, with a majority of

the secondary school age population not enrolled. Net enrolment rates are higher for male than female students.

Figure 1. Schooling indicators in sub-Saharan Africa, 1990-2020



Note. Authors' own elaboration based on data from *World Development Indicators* by the World Bank (2022a).

Benin, Cameroon, Sierra Leone, Malawi, and Uganda have achieved a net enrolment rate of over 90% in primary schools, while Nigeria (68.3%) falls short in this regard (Upadhyay & Taddese, 2020). Among the countries with a high net enrolment rate, only Malawi has achieved a high female net enrolment rate (more than 90%) relative to other countries. In terms of secondary school net enrolment, only South Africa has achieved a net enrolment rate of more than 50%, with a higher female net enrolment rate in comparison to males (World Development Indicators, 2022).

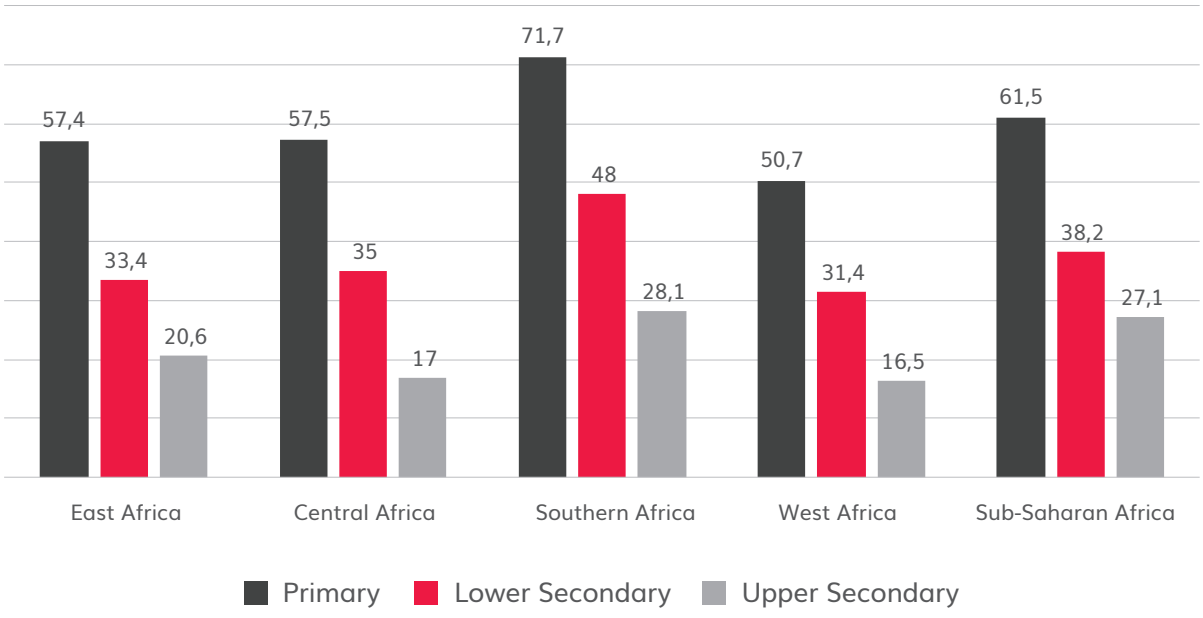
These results reflect concerted efforts made by some governments in sub-Saharan Africa to ensure that school-aged students have access to education. The decline in the number of out-of-school children is a positive development, and is accompanied by an increase in enrolment, mainly at the primary school level. However, education in the

region still faces numerous challenges such as inadequate infrastructure, social norms, conflict, unqualified teachers, language barriers, and poor health, which continue to impede progress in this sector, such that more than 90 million children between the ages of 6 and 17 are still not attending school (UNESCO, 2019).

School completion and pupil-teacher ratios

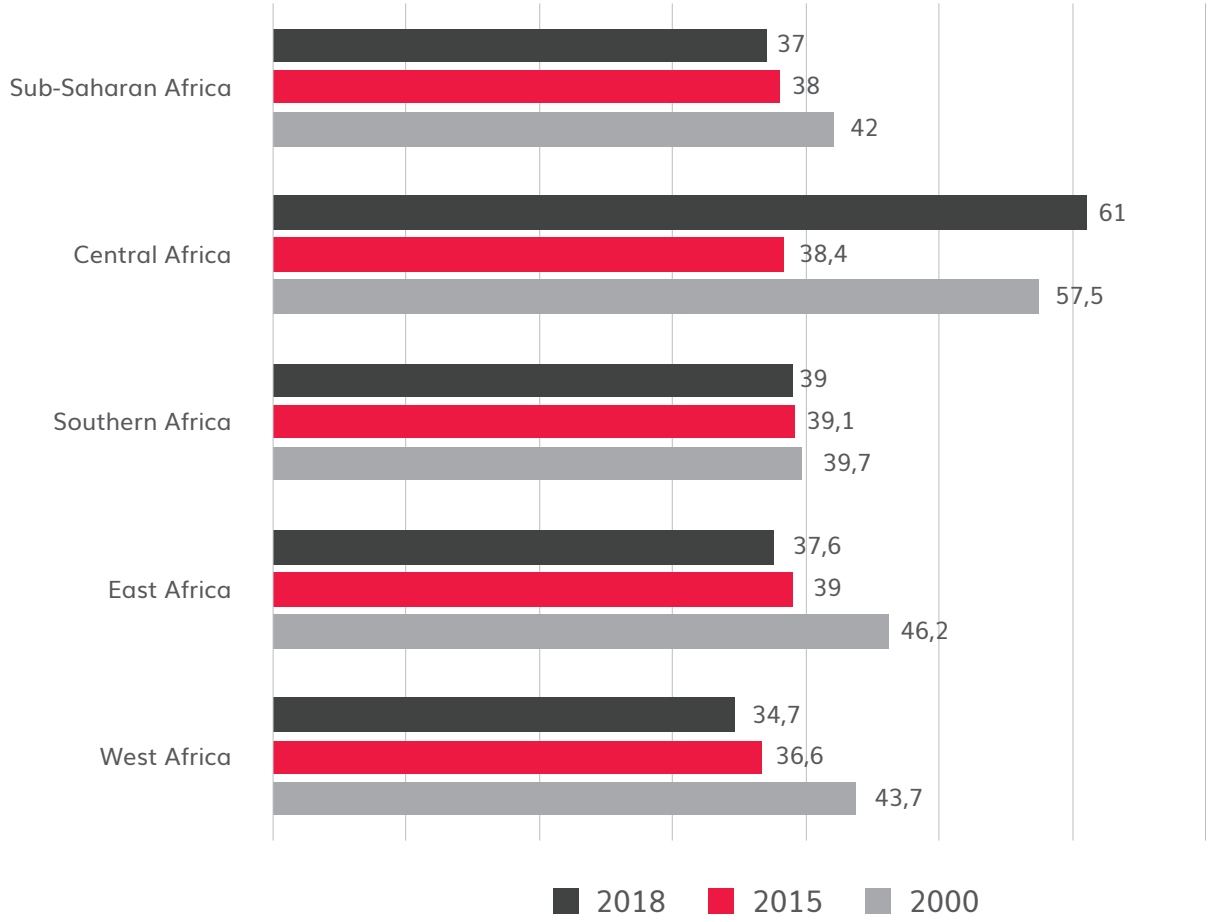
School completion and pupil-teacher ratios are another key measure of education outcomes. Figures 2 and 3 present data on school completion rates for primary and secondary education and pupil-teacher ratios in sub-Saharan Africa, disaggregated at the sub-regional level according to available data, respectively. The region overall has witnessed a significant improvement in primary school completion rates, illustrating the effectiveness of introducing mandatory and free primary education programmes. However, completion rates at the lower and upper levels of secondary education remain low, at 38% and 27% respectively. The pattern is the same at sub-regional levels, as primary school completion rates significantly exceed the rates in both lower and upper secondary levels in all sub-regions. The pupil-teacher ratio (PTR) in primary education, on the other hand, has marginally improved in sub-Saharan Africa, from 42 pupils per teacher in 2000 to 37 pupils per teacher in 2018. However, the PTR remains high across all sub-regions, especially when compared to the global average of 23, showing a persistent lack of teachers despite increasing enrolment.

Figure 2. School completion rates in sub-Saharan Africa, by sub-region, 2022



Note. Authors' elaboration using data from UNICEF (2022).

Figure 3. Primary education pupil-teacher ratio in sub-Saharan Africa, by sub-region 2000-2018



Note. Authors' own elaboration based on data from *World Development Indicators* (2000-2018) by the World Bank (2023).

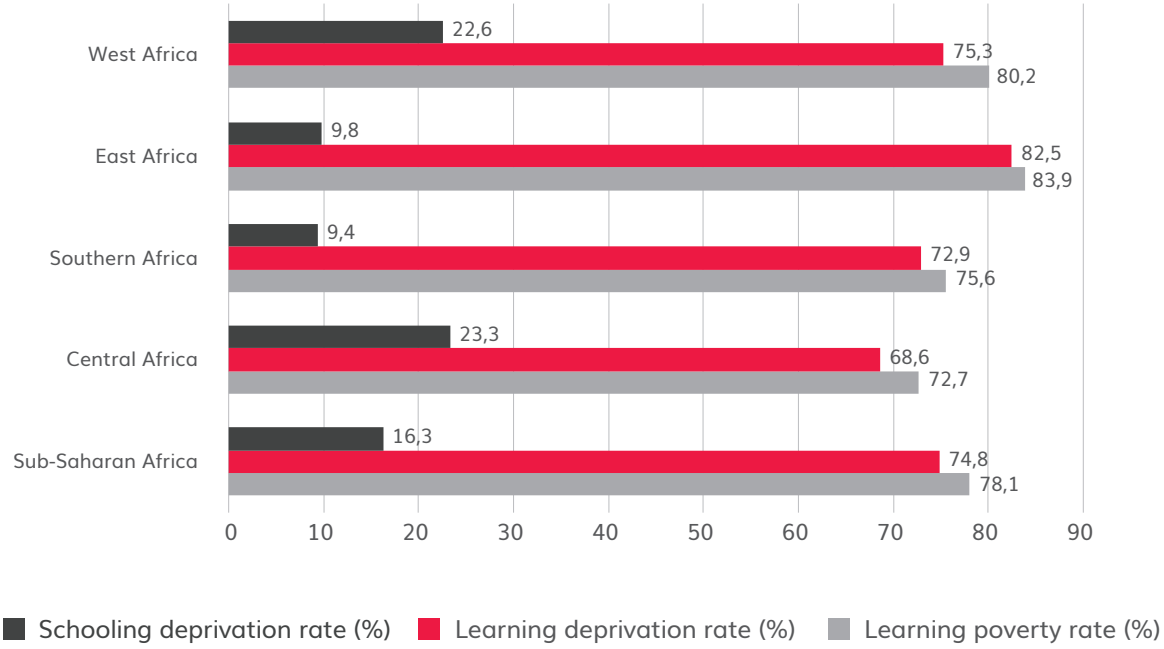
The learning crisis in sub-Saharan Africa

There is an undeniable learning crisis in the region. Children enrolled in basic education find it difficult to read and understand text; such shortcomings in foundational learning have implications for the skills needed to pursue further education (World Bank, 2020). The World Bank introduced learning poverty as a metric to measure the learning crisis, defined as the inability of a 10-year-old to read, comprehend a basic sentence, or solve fundamental numeracy problems (World Bank, 2021a).

While school deprivation captures the share of primary school-aged children who are out of school, learning deprivation represents the share of children who, at the end of primary education, read below the minimum proficiency level. As shown in

Figure 4, school deprivation in sub-Saharan Africa is relatively low, while learning deprivation rates are alarmingly high, standing at 74.8% in 2019. At 78.1%, the overall learning poverty rate in the region is high compared to the Middle East and North Africa (63%), South Asia (60%), and Latin America and the Caribbean (52%) (World Bank et al., 2022). Overall, despite improvements in enrolment, there is a worrying lack of the kind of quality education needed to strengthen the skills and capacity of future human capital. Mitigation approaches implemented during the COVID-19 pandemic (especially remote learning) did not have a significant positive impact on the learning crisis, due to a lack of availability of remote learning solutions, and the incompatibility of remote learning approaches (World Bank et al., 2022).

Figure 4. Learning crisis in sub-Saharan Africa, by region, 2019



Note. Authors' elaboration using data by the World Bank et al., (2022).

Ed-tech infrastructure

Ed-tech adoption is facilitated by the presence of key infrastructure, such as electricity and internet coverage. While there has been progress in electricity coverage over the last two decades, less than half of the population in sub-Saharan Africa is connected to an electricity supply, with lower rates in rural areas. For instance, only 47.7% of the population in sub-Saharan Africa were connected to the electricity grid in 2018 (Mo Ibrahim Foundation, 2021). Additionally, access to the internet and digital devices is also low in the region (World Development Indicators, 2022; UNICEF, 2022).

Specifically, about 89% of learners in sub-Saharan Africa do not have access to computers in their households, while 82% lack internet access, and around 20 million live in areas without mobile network coverage (Mo Ibrahim Foundation, 2021). Consequently, innovation in ed-tech is likely to have limited impact, especially among vulnerable groups (poor households and rural dwellers), since a greater fraction of these groups lack electricity and internet access.

Methodology

This section outlines the research design and methods used here to explore the trajectory of ed-tech development and its deployment in improving learning outcomes in selected sub-Saharan African countries. Specifically, it explains the process for selecting the sample of countries included, and the approaches taken to data collection and analysis.

Subregional scope and country-case selection

The study focuses on sub-Saharan Africa, which covers four subregions: West Africa (17 countries), East Africa (20 countries), Southern Africa (11 countries), and Central Africa (11 countries). Several selection criteria were used to define the countries of focus, as summarised in Table 1.

First, GDP per capita and income measures were used to classify countries based on their income level and level of development. This is important as it measures the financial capacity of countries to support ed-tech policies and interventions; wealthier countries with stronger economies may have greater resources to invest in and implement ed-tech solutions relative to poor countries. Wealth and development were determined using GDP and the IMF income classification (IMF, 2018), which classifies countries by income level.

Second, language and culture were considered, as these are essential to the implementation of ed-tech policies and initiatives in basic education in the region. Sub-Saharan African countries are characterised by differences in language, which any successful government policy must take into account. Moreover, the realities in anglophone and francophone countries are heterogeneous, including along lines of culture and colonial affiliation. Different cultures may influence attitudes towards the adoption of ed-tech. The perceived relevance of education varies across ethnic groups, which plays a significant role in the inclusion and exclusion of children from ed-tech

benefits. While some ethnic groups may see ed-tech as a tool to facilitate education quality, others may see it as a threat to their cultural values.

Third, factors including the human development index (HDI), government expenditure in public education, and ed-tech enablers (infrastructure, internet penetration and access, and electricity) were considered, since these significantly influence the effectiveness of ed-tech policies and interventions in education.

Based on these indicators, a total of 10 countries were selected for the study: Benin, Cameroon, Kenya, Malawi, Nigeria, Senegal, Sierra Leone, South Africa, Tanzania, and Uganda.

Table 1. Country selection criteria

Country	Official Language	GDP	Income Level Classification[6]	Human Development Index	Government expenditure on education (% of total)	Infrastructure (on a scale of 100)	Internet Penetration (%)	Electricity (% of pop.)	Internet Access (% of pop.)
Benin	French	15.77	Low-income	0.525	17.70	17.40	30.0	41.4	28.2
Cameroon	English, French	38.97	Middle-income	0.576	14.89	21.85	33.1	64.7	45.5
Kenya	English, Swahili	90.37	Middle-income	0.575	18.52	27.52	85.2	71.4	25.5
Malawi	English, Chichewa	7.74	Low-income		11.49	22.84	13.8	14.9	18.9
Nigeria	English, Yoruba, Hausa, Igbo	518.47	Middle-income	0.535	5.14	24.53	73.0	55.4	51.5
Senegal	French	24.24	Middle-income	0.511	21.08	31.30	56.7	70.4	47.2
Sierra Leone	English	5.18	Low-income	0.477	33.83	12.70	12.8	26.2	18.0
South Africa	English, Afrikaans, isiNdebele, isiXhosa, isiZulu, Sesotho, Setswana, siSwati, Tshivenda, Xitsonga, Sepedi	353.25	Middle-income	0.713	18.41	81.67	57.5	84.4	70.3
Tanzania	Swahili, English	75.7	Low-income	0.534	14.33	16.22	31.6	42.7	23.8
Uganda	English, Swahili	42.21	Low-income	0.525	8.21	22.64	39.3	42.1	6.1

Note. Adapted from *data* by the World Development Indicators (2022), UNDP (2022) and UNESCO (2022).

6 According to the IMF (2018), low-income countries are classified as countries with income per capita that is equal or less than USD 1005 while middle-income countries are countries with income per capita of more than USD 1005.

Literature review

The literature review consisted of three strands. The first strand focuses on ed-tech policies, interventions, and usage priorities. The second strand examines the factors that have aided the formulation and implementation of ed-tech policies in the sub-Saharan African region, as well as those that have hampered them. The last strand explores the state of ed-tech post-COVID-19, including lessons learned and the importance of inclusive and high-quality education provision for primary and secondary school students. The following search engines were used for the literature search: the African Education Research Database, ed-tech Hub, Google Scholar, Springer Link, ResearchGate, and ScienceDirect. Online searches for relevant reports and policy documents were also carried out. Searches were conducted using the following keyword phrases: education technology (ed-tech) in primary and secondary schools; education technology (ed-tech) in Africa; information communication and technology (ICT) in primary and secondary schools; ICT in education; education interventions; video and mobile phone for education; and education technologies for poor and marginalised learners. Additional inclusion criteria included publication year (2007–2023) and the 10 countries. Publications that did not meet these search parameters were not considered.

Quantitative data collection and analysis

The quantitative analysis relies on three survey rounds conducted by Afrobarometer (2022) in different years: 2016/2018 (pre-COVID-19), 2019/2021 (during COVID-19), and 2022 (post-COVID-19). Round 7 surveys were conducted from October 2016 to 2018, round 8 surveys were conducted from October 2020 to August 2021, and round 9 surveys were carried out between October 2021 and December 2022. These surveys were instrumental in gathering data pertaining to technology infrastructure, and the accessibility and use of digital devices, thereby enabling us to quantitatively assess the presence of the digital infrastructure needed for ed-tech in the selected sub-Saharan African countries. The surveys involve face-to-face interviews with a randomly selected, nationally representative sample comprising 1,200 to 2,400 adult citizens from diverse households in each country (Afrobarometer, 2022).

We opted for this survey method due to its capacity to provide comprehensive insights into various facets of ed-tech across the countries included. Specifically, the survey provided insights into computer access, mobile phone ownership, network connectivity, internet accessibility, electricity availability, and ed-tech readiness. This readiness assessment involved comparing the availability of digital devices with internet connectivity, electricity access, and poverty levels. Moreover, the survey data was disaggregated by income levels (rich and poor), gender (male and female), and geographic location

(urban and rural). To analyse the findings, we employed a descriptive approach, using graphical representations to facilitate comprehension and interpretation of the data.

Qualitative data collection and analysis

Qualitative data were gathered in this study through key informant interviews and field observations, in order to strengthen and supplement the findings from the quantitative analysis and fill in knowledge gaps. It was also used to investigate the political economy of ed-tech interventions, to consider how relationships of power between ed-tech stakeholders impact the adoption of digital learning technologies.

Key informant interviews

Key informant interviews (KIIs) were carried out with members of governmental and non-governmental organisations, ed-tech providers, public primary and secondary school administrations, and parents. For each selected country, 10 education stakeholders were interviewed. The distribution of respondents for KIIs includes two teachers/school administrators, two ed-tech providers, two government officials, two education experts, and two parents for each country. This gives a total of 100 respondents. At the policy level, senior government officials who were familiar with the operation of agencies and the educational system were prioritised. At the operational level, the heads of public schools and other stakeholders, such as the presidents of parent-teacher associations (PTAs), are included to get a balanced perspective among these groups. Overall, the stakeholders interviewed assisted us in developing a comprehensive understanding of the role of ed-tech in improving learning outcomes and reducing education inequality.

Case studies

The research team selected two examples of e-learning programmes as case studies to understand how ed-tech is deployed, and to explore its priorities and barriers. EdoBest, Nigeria, and ConnectEd, Botswana were selected. The EdoBest programmes. was selected as an example of a successful initiative in Nigeria, which was about to enter a second phase and be scaled-up by the government in collaboration with its development partner (the World Bank). The research team conducted a site visit to EdoBest between 20 and 25 April 2023. The case study relies on a reportorial approach –a description of what is observed in the field. In the case of Botswana, ConnectEd was chosen, as it has been found to be cost-effective and efficient in reducing levels of innumeracy. The case was analysed using existing reports and evaluations of the programmes.

State of ed-tech in sub-Saharan Africa: An overview

This section explores the literature on the ways ed-tech has been used, the importance of ed-tech policies, and their priorities in the selected sub-Saharan African countries, using the three-strand approach as explained above.

All countries in our sample have one or more ICT policies at the national level specifically for education, compiled in Table 2. These are aimed at providing a conducive environment for the deployment of digital technology in education. Most of these countries are gradually prioritising digital devices for administrative purposes in schools, pedagogical activities, and learning inclusion. However, progress in using ed-tech to improve learning outcomes is slow, and faces several constraints including a lack of funding, political economy factors, low capacity for development and training, and poor supportive infrastructure. There are also notable differences in the extent of their implementation and impact per country. This section explores similarities and differences in ed-tech adoption between the countries studied.

Table 2. Overview of ed-tech policies in the selected sub-Saharan African countries

Countries	Policies
Nigeria	National Policy on Information and Communication Technology (ICT) in Education; Universal Basic Education Commission (UBEC) ICT Policy; National Information Technology Development Agency (NITDA) Guidelines; Nigerian Research and Education Network (NgREN); National Teachers' Institute (NTI) e-Learning Programme; and State-level Initiatives.
South Africa	National Integrated ICT Policy White Paper for South Africa; National e-Learning Strategy; South Africa Institute for Distance Education; and Provincial-level initiatives
Sierra Leone	Education Sector Plan 2018-2020; National ICT Policy 2017-2022; Computer for Schools Sierra Leone; Smart Classroom Initiative; Sierra Leone Library Board
Uganda	National ICT Policy; National ICT in Education Policy; National Teacher Policy; SchoolNet Uganda; and Universal Secondary Education ICT project
Kenya	Kenya National ICT policy; Kenya Education Sector on ICT; Digital Literacy Programme; Kenya Education Cloud; Kenya Institute of Curriculum Development; and e-Learning Centers and Digital Villages
Tanzania	Tanzania Education and Research Network; Open Education Resources, e-School Initiative; Basic Education Development Plan; and National ICT Policy for Education and Training
Cameroon	National ICT Policy; National Digital Economy Strategy; ICT for Education Programme; and Schoolnet Cameroon
Benin	National Education and Training Policy; National ICT Policy; and E-Benin Project; Kenya Education Cloud; Kenya Institute of Curriculum Development

Malawi	National ICT Policy; Malawi ICT in Education Policy; Malawi National Education Plan; National Digital Transformation; National Digital Transformation Strategy; Partnership for Education; and Teacher training Programmes
Senegal	National Digital Strategy; Programme de Développemen't de l'Education Numérique; Ecole Numérique pour Tous (ENT); and Plan Sénégal Émergent (PSE)

Note. Adapted from *data* by the United Republic of Tanzania, Planning Commission (2010); Karsenti et al. (2012); Dele-Ajayi & Taddese (2020); Federal Ministry of Education [FME] (2019a); Otieno & Taddese (2020); Republic of South Africa (2018); Kumasewera (2021); UNESCO (2019); Ministry of Basic and Senior Secondary Education (2020).

The literature shows that Nigeria, Kenya, Rwanda, and South Africa have all demonstrated a strong commitment to ed-tech integration in their education systems, but also reveals several important challenges to implementation. Nigeria introduced the National ICT Policy in 2010 and the National Policy on ICT in Education in 2019 (FME, 2019b). Prompted by advances in education technology to improve the quality of learning, the policy was aimed at improving human capital development, infrastructure, research and development, awareness and communication, governance, financing, and monitoring and evaluation. It was expected to guide development partners and transform education infrastructure, teaching, learning, research, and administration in the country. The policy design reflects consultation and collaboration with education departments at the national level, state ministries of education, the private sector, NGOs, and development partners during its development process. Additionally, the National Implementation Guidelines for ICTs in Education were introduced in 2019 to provide a clear direction to education stakeholders (Dele-Ajayi & Taddese, 2020; FME, 2019a).

Availability of electricity is another crucial factor that facilitates the adoption of ed-tech in primary and secondary schools, yet access to electricity in many African countries is poor.

Yet, according to Dele-Ajayi and Taddese (2020), the policy has faced several setbacks. First, it has not achieved its stated objectives due to poor implementation. Second, the state ministries of education—the stakeholders responsible for implementation of the policy, especially regarding teacher training—do not have knowledge of the required training. Third, the deliverables and key performance indicators highlighted in the guidelines for implementation are not effectively measurable, meaning

it is not possible to evaluate their contribution to education quality in the country. Adequate funding for the implementation of ICT policies in education also remains a major challenge in Nigeria (UNICEF, 2022). Furthermore, while the policy stated the government's commitment to allocate 5% of the annual education budget to ICT, there is no evidence to show if this allocation took place. Other infrastructural factors, such as a lack of electricity, internet facilities, and computers in many public schools, hinder the effective integration of ed-tech (Lawal, 2017). Evidence in Nigeria suggests, therefore, that there remain several challenges in the adoption of ed-tech.

Kenya also started implementing a policy for integrating ICT into the education system before the pandemic. The country partnered with various agencies and invested in ICT integration programmes, such as the Digital Literacy Program. They also introduced the 2019 National ICT Policy and the Vision 2030 Social Pillar which prioritised education and training. The Ministry of Education partnered with several agencies, such as the Kenya Institute of Curriculum Development, the Teacher Service Commission, and the Kenya National Examination Council, to help harness the benefits of ICT in education. For example, the Kenya Institute of Curriculum Development controls the Kenya Education Cloud which provides interactive digital and on-demand radio content, textbooks for teachers and students, and training on curriculum implementation and ICT in learning. According to Otieno and Taddese (2020), the Kenyan government is also investing in, and implementing ICT integration programmes under the administration's Digital Learning Program.

Despite progress, Manyasa (2022) identified shortcomings in ICT policy for education in Kenya. First, the introduction of ICTs into education policy was marked by instability due to frequent changes in ICT implementation. This makes the effectiveness of interventions and the general evaluation of policy achievements challenging. Second, there is a wide disparity between policy implementation and enactment. Third, frequent changes in policy objectives and implementation structures were driven more by political interests than improving education quality in the state. Finally, policy inconsistency exacerbates existing geographical and socioeconomic inequities in Kenya's education system. As with the implementation of ed-tech initiatives in Nigeria, it appears that these measures in Kenya are also held back by political instability and challenges in monitoring and evaluating the effectiveness of policies.

South Africa introduced the National Integrated ICT Policy White Paper in 2016, with initiatives such as the South African School Information System and e-Schools Network, resulting in improved administrative processes and access to learner data (Republic of South Africa, 2018). The first initiative focused on the integration of ICT in schools in the country. The second, led by the Department of Basic Education

(DBE), involved managing student information, schedules, and exam results online. The system has benefited administrative processes, accuracy, and access to learner data in schools (DBE, n.d.). The e-Schools Network provides schools with access to a range of digital resources such as online platforms, digital textbooks, and educational content. However, South Africa is also battling infrastructure challenges for ed-tech deployment, including access to electricity, internet, and digital devices, as well as poor enforcement of e-education, and a lack of skills among teaching staff (Padayachee, 2017). Challenges in funding for ICT infrastructure in education also hinder ed-tech adoption in South Africa (Parliamentary Monitoring Group, 2016). Like other countries surveyed, the literature thus indicates that infrastructure and training challenges in South Africa represent significant barriers to the successful adoption of ed-tech.

Although ed-tech adoption is still in its infancy in Malawi, the literature shows increasing government commitment to its use. Working with development partners, the country is providing computers and tablets to schools, as well as ICT training for teachers (Abubakar & Saka, 2021). It also launched the Malawi Education Cloud, a digital platform that offers online access to digital textbooks, instructional videos, and other teaching and learning resources for teachers and students (Kumasewera, 2021; UNESCO, 2019). Additionally, the British Council is working with the Ministry of Education to provide tablets and laptops with educational materials for schools in rural areas. The devices work with solar power and are equipped with the Digital Library app. Student grades, records, fees, and payments, among other data, are also managed on tablets and laptops.

The World Bank is also supporting the development of ed-tech through the Malawi Education Sector Improvement Project (World Bank, 2021b). There is also ongoing collaboration between Onebillion (working with the Ministry of Education) and Voluntary Service Overseas (VSO) Malawi on an intervention which explores the use of *onetab* programme for students moved from the classroom to a learning centre within the school campus, and a home-based *onetab* to enhance learning for children at home (Schmitt, 2021). While it is anticipated that *onetab* for schools will face funding challenges in building learning centres on campus, the home-based *onetab* saw significant engagement among children at home (Schmitt, 2021). Additionally, Building Education Foundations through Innovation Technology (BEFIT)[7] was launched by Ulalo in the country. This was in partnership with the Malawi government to improve education quality at the foundational level (standards 1-4) by exploring the benefit of technology. This programme placed much emphasis on personalised learning, and there

7 For more details see: https://www.ulalo.org/blog/transforming-education-in-malawi-befit-pilot-program-takes-flight

is an ongoing effort[8] to massively scale it up to serve 5,800 public schools per year to reach a cumulative of 15,210,000 learners by September 2029.

Despite increased funding for primary education, government funding for ed-tech remains a major challenge (UNICEF, 2022). Poor infrastructure is also an important barrier to the implementation of ed-tech in the country, particularly a lack of access to reliable electricity, internet connectivity, and computers (World Bank, 2019). Thus, while there have been some prominent efforts in Malawi to introduce ed-tech initiatives and significant cooperation between different stakeholders, funding issues still represent a significant constraint.

Sierra Leone has also made efforts to integrate ed-tech into their education system, although the efficacy of these programmes has yet to be evaluated. ICT policies in Sierra Leone include the National Telecommunication Act, the National ICT Policy, and the Broadband Policy. Although there is no specific ed-tech policy in Sierra Leone, the Ministry of Basic and Senior Secondary Education (MBSSE) introduced the "One Tablet Per School" programme to enhance management and administration in public schools. The programme was initially a collaboration between MBSSE and international consultants, and the ed-tech Hub, a global research partnership, later began to assist in the implementation of the programme through technical support involving several co-working sessions (such as problem scoping, mapping users' applications, and stakeholder analyses) (McBurnie, 2021). The programme was expected to review data collection processes, monitor teacher and student attendance, and facilitate the development of an integrated teacher management information system. Moreover, McBurnie (2021) noted that the long-term objectives include the digitalisation of school financing and planning, payroll management, pre-service training and recruitment, and staff deployment. In this way, it also has the dual purpose of increasing the number of specialised teachers in the classrooms and ensuring that district offices collaborate with schools to prioritise hiring full-time qualified teachers. However, a major shortcoming of the program is its emphasis on teacher management over teaching and learning itself.

Another notable initiative is the attempt to develop a tech-supported continuous professional development programme for teachers, implemented through the Teaching Service Commission (TSC), and aimed at enhancing foundational literacy and numeracy teaching (Beoku-Betts et al., 2022). There have also been efforts towards collaboration between the Ed-tech Hub, TSC, and the World Bank to support primary school teachers

8 For more details see: https://www.imagineworldwide.org/wp-content/uploads/Malawi-Project-Overview-General-2-27-23.pdf

to effectively deploy ed-tech tools in their teaching activities (Beoku-Betts et al., 2022). Specifically, the Ed-tech Hub is currently working with TSC and the World bank to introduce tech-supported teacher continuous professional development (TCPD) programme. As in other contexts, however, funding is a significant barrier to the implementation of ed-tech policies (Tetang, 2007), together with limited access to reliable electricity, internet connectivity, and computers (World Bank, 2019). It remains to be seen whether infrastructural and funding issues will continue to operate as barriers to adopting ed-tech in Sierra Leone.

In Benin, there is no specific mention of ed-tech in the Education Sector Plan for 2018-2030, despite its objective to promote education accessibility and quality. However, there is some evidence that schools have started implementing technology in the classroom (Banuelos, 2021), indicating a gradual shift towards ed-tech adoption. Banuelos (2021) indicates that improving education in Benin requires more government funding, programmes, and teacher training in ed-tech.

Cameroon has a number of initiatives targeting ICT in education. In 2001, the country developed an ICT curriculum (Karsenti et al., 2012), and in 2003 established official ICT programmes for secondary schools through the Educational Research Network for West and Central Africa. Partnerships with private contractors and the MTN Foundation have led to the provision of computer equipment, improved teaching approaches, and improved quality in both public and private secondary schools (Nsolly & Charlotte, 2016). A number of schools also receive presidential grants via online multimedia resource centres (Mbangwana, 2008). In 2008, ICT syllabi were published and made available. The National Book Commission has also written and validated textbooks to aid in the teaching of ICTs (République, 2007a, cited in Mbangwana, 2008). République (2007) also notes a draft strategy for implementing the national ICT policy in basic education, which was developed in 2007. The strategy aimed to educate teachers and principals about the value of using ICT in teaching and learning, as well as in school administration. To achieve the training objectives, national guidelines for ICT teaching in preschool and primary schools were implemented, with six modules for each level. These guidelines addressed skills such as discovery and presentation applications, knowledge construction, and ethical and equity issues (République, 2007).

To address challenges facing ICT integration in primary and secondary schools in Cameroon, Fouda et al. (2013) note that the government partners with private contractors and parent-teacher associations to provide computer equipment and funds. The Ministry of Secondary Education also collaborates with the MTN Foundation to introduce a competition for teachers to demonstrate ICT integration into teaching and learning (Camerpost, 2013). The competition aims to improve innovative teaching

approaches and quality among public and private secondary teachers (Twaong, 2015). Insufficient budgetary allocation is a major barrier to ed-tech implementation in Cameroon (Tetang, 2007), and there is a strong reliance on external funding which hampers sustainability (Nsolly & Charlotte, 2016). Therefore despite progress towards integrating ed-tech in Cameroon, funding issues remain a significant challenge.

In Tanzania, there have also been efforts to strengthen ed-tech in schools. National ICT policy holds that the integration of ICT in education is necessary to ensure effective education delivery (Tanzanian Ministry of Communications and Transport, 2003), by facilitating the teaching and learning process (Ngeze, 2017). Additionally, the country's Development Vision 2025 policy aims to integrate ICT into education delivery, and the government has allocated substantial funding to ICT programmes, including the supply of equipment and training to selected schools, the provision of ICT training in secondary schools, and the introduction of Tanzania Beyond Tomorrow and e-Schools project (Ngeze, 2017). Focusing especially on capacity building, the Ministry emphasises that the integration of ICT in teaching and learning will improve the capacity of school managers, educators, teachers, and leaders to effectively deploy ICT in day-to-day activities, resulting in higher education quality (Ministry of Education, Science, Technology, and Vocational, 2007). Mwalongo (2011) notes that access to ICT resources encourages teachers to frequently use these devices.

Nevertheless, Tanzania has limited teacher capacity, with some teachers lacking the necessary skills to use educational technology effectively (Padayachee, 2017). A notable government programme aimed at promoting capacity building among teachers is MEWAKA[9], which includes a technology component involving collaboration between the Tanzania Institute of Education and the University of Dares Salaam College of Information and Communication Technologies. This initiative provides semi-structured communities of learning modules, self-learning modules, peer facilitator guides, and manuals (Koomar et al., 2023). While the scaling of these programmes remains a challenge, increased collaboration between different education stakeholders in sub-Saharan Africa is a promising tool to address the challenge of building capacity among teachers for the deployment of ed-tech in schools. However, as in other contexts, poor access to electricity, a lack of computers and devices, and limited internet connectivity impede ICT integration more broadly (Abubakar & Saka, 2021). Thus, while the government of Tanzania has recognised the importance of ed-tech, infrastructural, knowledge, and funding constraints are still prominent barriers to further implementation.

9 Mafunzo Endelevu kwa Walimu Kazini or, Teachers' Continuous Professional Development.

Senegal has a robust national ICT policy, but there is no specific ICT policy for education. The absence of a specific ICT policy for the education sector hampers the adoption and implementation of ICT in education (Upadhyay & Taddese, 2020). Only some primary schools have access to electricity and computers, hindering the integration of ed-tech (Upadhyay & Taddese, 2020). However, there is a national digital learning platform—POMET (Plateforme d'Enseignement et d'Apprentissage à Distance)—which offers students and teachers a range of educational resources and tools. Additionally, there is encouraging evidence that a high number of teachers have access to the basic infrastructure required to take advantage of ed-tech. CyberSmart Africa (2020) found that 89% of the 300 teachers sampled in a 2019 survey own a personal smartphone with monthly internet connection. While the lack of a specific and central government ed-tech policy continues to impact the success of related initiatives in Senegal, there is evidence that a high number of teachers have access to basic ICT devices, such as smartphones, to support the gradual integration of ed-tech initiatives in the country. Senegal is also currently collaborating with UNICEF and Ed-tech Hub to develop a national digital learning strategy for the education sector (Upadhyay & Taddese, 2020).

This review of the literature has shown that efforts to integrate ed-tech into the education systems of the sampled sub-Saharan African countries vary widely in terms of policy implementation, funding, and impact. Nigeria, Kenya, Rwanda, and South Africa have made substantial progress in implementing ed-tech initiatives, while countries like Malawi, Sierra Leone, Benin, Cameroon, and Tanzania are at different stages of adoption, with varying degrees of success. Notably, Benin and Senegal lack specific ed-tech policies. The countries studied shared common challenges in terms of ed-tech implementation, including limited budget allocations, poor infrastructure, and gaps in teacher capacity. These challenges pose barriers to the effective integration of ed-tech in primary and secondary schools in the Sub-Saharan Africa region, hindering the realisation of the potential benefits of ed-tech.

Analysis of ed-tech interventions in the region

This section undertakes an in-depth analysis of ed-tech interventions in sub-Saharan Africa, based on data from Afrobarometer surveys, interviews and field observations. It identifies factors that have acted as barriers or enablers in its development and implementation at different levels and provides insights into how the ed-tech landscape has changed since the COVID-19 pandemic. Inequalities are incorporated into the analysis along lines of gender, socioeconomic status and geographical location. Finally, it analyses the implementation of ed-tech policies and programmes in the region

from a political economy perspective, observing how the interactions and power relations between different public and private sector stakeholders have affected the success or failure of ed-tech initiatives.

Ed-tech barriers and enablers at the household level

Computer ownership

Limited computer ownership among households in the region hampers the widespread adoption of ed-tech initiatives. The Afrobarometer surveys (2016/2018, 2019/2021 and 2022) reveal that with the exception of Cameroon and South Africa, there is a consistently low prevalence of computer ownership across the countries studied. On average, just 21% of households owned a computer in the 10 countries in 2016/2018, which increased only marginally to 25% by 2022. Specifically, Uganda, Tanzania, and Malawi have seen a slight increase from 2016/2018 to 2022, but they remain below the region's already low average. Despite modest growth in Nigeria, Senegal, Kenya, and Benin, more than 60% of households in these countries do not own computers. Sierra Leone, on the other hand, has experienced an ongoing decline in computer ownership from 2016. Only in Cameroon and South Africa do nearly 50% of households own a computer. Therefore, leveraging this scarce digital resource for educational purposes may not substantially influence learning outcomes.

> **Mobile operators are realising the power of ed-tech and are offering solutions to improve digital literacy.**

As shown in Table 3, gender disparities in computer ownership in the region are also evident. On average, males have greater access to computers compared to their female counterparts, resulting in a gender gap of 4 to 5%. However, significant improvements in computer ownership are observed for both genders in Cameroon (see also Bediang et al., 2013). In South Africa, there is a slight increase in female computer ownership between 2016/2018 and 2022, while male ownership remains unchanged.

Table 3. Ed-tech readiness by gender

	Household ownership of Ed-tech device (Computer)						Digital literacy level (degree of mobile phone usage)						Level of internet accessibility					
	2016/2018		2019/2021		2022		2016/2018		2019/2021		2022		2016/2018		2019/2021		2022	
Country	Male (%)	Female (%)	Male (%)	Female (%)	Male (%)	Female (%)	Male (%)	Female (%)	Male (%)	Female (%)	Male (%)	Female (%)	Male (%)	Female (%)	Male (%)	Female (%)	Male (%)	Female (%)
Benin	20	12	17	15	29	21	95	78	94	86	91	81	41	19	52	38	55	41
Cameroon	44	40	46	42	57	55	95	93	95	95	96	92	54	55	69	62	77	69
Kenya	11	11	24	16	33	24	93	75	97	85	96	95	55	46	61	47	61	52
Malawi	6	6	5	4	13	9	71	55	76	60	81	67	57	34	40	27	41	33
Nigeria	26	13	21	8	29	31	97	90	96	91	94	85	54	48	50	40	57	47
Senegal	38	30	38	32	43	33	98	92	99	95	97	92	52	44	69	67	63	60
Sierra Leone	17	14	16	15	17	11	86	72	89	77	83	72	44	44	40	42	53	45
South Africa	51	41	51	45			96	94	94	95			68	69	76	71		
Tanzania	7	6	9	6			93	87	90	82			31	23	34	25		
Uganda	9	8	12	6	19	13	88	75	91	82	89	84	37	33	41	26	33	25
Total	**23**	**19**	**23**	**19**	**28**	**23**	**92**	**84**	**93**	**87**	**91**	**85**	**48**	**40**	**53**	**46**	**53**	**46**

Note. Elaborated by the authors based on data by Afrobarometer surveys (2023a; 2023b). The shading in the table shows variation over time. Darker shading indicates higher values, while pale shading indicates lower values. South Africa and Tanzania are excluded in 2022 due to data unavailability.

Patterns of computer ownership also vary significantly according to residential area, as presented in Table 4. Overall, households in urban areas had greater access to computers, with ownership rates increasing slightly from 36% in 2016/2018 to 39% in 2022. While rural areas experienced a rise from 9% ownership in 2016/2018 to 17% in 2022, this still meant a staggering 83% of rural households lacked access to computers in 2022.

Mobile phone usage

In contrast to computer ownership, there is evidence of high levels of mobile phone usage in the sub-Saharan African countries considered in this study. Afrobarometer surveys (2019/2021 and 2022) show significant mobile phone usage across all countries. The average values for frequent usage in the 10 countries were above 80% in the two periods surveyed, but declined slightly in 2022. Unlike computer ownership, access to and use of mobile phones consistently remains high. Six of the ten selected countries had over 80% usage rates in 2019/2021, while Nigeria, Cameroon, Kenya, South Africa, and

Senegal surpassed a 90% frequent usage rate. Malawi had the lowest mobile phone usage rates, with 61% of individuals frequently using mobile phones and over 20% of individuals never using them in 2019/2021. Little progress was recorded in 2022, and while most countries have the potential for adoption of ed-tech through mobile phones, it may be more challenging in Malawi. However, mobile phones are relatively affordable, and increasingly so as prices continue to drop (Dahir, 2016). The widespread availability of mobile devices suggests that students could effectively use them at home to access ed-tech learning resources. This suggests that mobile devices could usefully be prioritised when considering ed-tech deployment in schools.

Furthermore, there are relatively low gender divides in mobile phone usage in most countries, with the exception of Malawi, Sierra Leone, and Uganda (see Table 3). In South Africa, more females than males used mobile phones in 2019/2021. The rural-urban gaps, however, are substantial in most countries, except for Senegal and South Africa (see Table 4). During the period 2019/2021, which coincided with the COVID-19 pandemic, six countries—Benin, Cameroon, Kenya, Malawi, Senegal, and Uganda—recorded improvements in mobile phone usage in rural areas, while only Kenya and Malawi experienced further improvements in 2022. On average, 93% of urban households use mobile phones frequently, compared to 87% in rural areas in 2019/2021. In 2022, however, this figure declined to 91% and 85% in urban and rural areas, respectively.

Table 4. Ed-tech readiness by area

	Household ownership of Ed-tech device (computer)						Digital literacy level (degree of mobile phone usage)					
	2016/2018		2019/2021		2022		2016/2018		2019/2021		2022	
Country	Urban (%)	Rural (%)	Urban (%)	Rural (%)	Urban (%)	Rural (%)	Urban (%)	Rural (%)	Urban (%)	Rural (%)	Urban (%)	Rural (%)
Benin	26	7	27	6	37	15	92	82	96	85	91	82
Cameroon	55	28	56	32	65	46	97	90	97	92	98	89
Kenya	21	5	32	14	39	22	95	82	98	83	97	94
Malawi	22	3	20	2	23	8	90	57	91	62	87	72
Nigeria	40	7	33	5	37	25	97	91	99	90	96	85
Senegal	49	19	52	18	53	24	98	91	98	96	96	93
Sierra Leone	24	9	32	2	26	5	84	75	97	72	88	70
South Africa	52	32	54	36			95	94	95	93		
Tanzania	17	1	18	2			97	87	95	82		

Uganda	26	3	22	5	28	11	95	77	95	85	92	85
Total	**36**	**9**	**37**	**11**	**19**	**17**	**95**	**83**	**97**	**85**	**94**	**85**
	Level of mobile phone network accessibility						Level of internet accessibility					
Benin	92	82	96	85	91	82	98.9	89.9	100	76.8	94.8	86.2
Cameroon	97	90	97	92	98	89	100	93.6	96.1	97.8	100	91.8
Kenya	95	82	98	83	97	94	100	98.8	100	97.2	100	97.9
Malawi	90	57	91	62	87	72	100	90.3	100	94.7	100	96.9
Nigeria	97	91	99	90	96	85	96.9	87.8	100	89.3	100	96.4
Senegal	98	91	98	96	96	93	100	96.4	100	92.6	100	98
Sierra Leone	84	75	97	72	88	70	93.4	79.9	100	52.7	100	76.3
South Africa	95	94	95	93			83.3	56.3	85.2	73.3		
Tanzania	97	87	95	82			97.5	89.3	92.5	76.2		
Uganda	95	77	95	85	92	85	97.8	98.5	97.6	81.8	93.3	87.5
Total	**95**	**83**	**97**	**85**	**94**	**85**	**95.1**	**89.2**	**95.9**	**84.5**	**98.2**	**91.6**

Note. Elaborated by the authors based on data by Afrobarometer surveys (2023a; 2023b).
Note: The shading in the table shows variation over time. Darker shading indicates higher values, while pale shading indicates lower values. South Africa and Tanzania are excluded in 2022 due to data unavailability.

Network accessibility

The availability of mobile phone network service is a fundamental driver of ed-tech adoption. Afrobarometer survey data (2022) indicates that network coverage across the 10 countries examined was above 90% in 2022, with the exception of Sierra Leone (87%) and Uganda (89%).[10] Individuals in urban areas enjoyed stable and efficient mobile network service (see Table 4), and there is substantial progress in network coverage in rural areas in nearly all the countries included in this study. This progress in network coverage implies that students in rural areas can increasingly gain access to mobile phone services, which opens up opportunities for them to leverage some ed-tech tools and resources.

Internet accessibility

On average, the majority of individuals (54% in 2016/2018) still lack internet access. Yet there are important differences between countries. Three of the countries studied

10 No data available for South Africa and Tanzania

had notably higher rates of internet access in 2016/2018: Cameroon (55%), Nigeria (51%) and South Africa(68%). There have also been important changes over time. For example, Benin Republic and Tanzania witnessed some improvement, with Kenya (54%), Cameroon (66%), Senegal (68%), and South Africa (73%) showing significant progress in 2019/2021. Moreover, many countries continue to experience an expansion in internet connectivity, with Cameroon (74%) and Uganda (80%) demonstrating a remarkable increase in 2022.

However, gender disparities in internet access persist across countries (see Table 3). Significant gender disparities were observed in six countries in 2022 (Benin [male-55%, female-41%], Kenya [male-61%, female-52%], Malawi [male-41%, female-33%], Nigeria-[male-57%, female-47%], Senegal [male-63%, female-60%], and Uganda [male-33%, female-25%],). However, South Africa (male-76%, female-71%), and Cameroon male-77%, female-69%]), with their high levels of internet penetration, have made more progress towards improving gender balance in 2022.

A prominent effort to increase internet accessibility in the region is the World Bank Group's Digital Economy for Africa (DE4A) initiative, introduced in 2019. This initiative covers 37 countries, including the 10 countries sampled here, and was implemented in collaboration with national governments and the private sector. The aim of the initiative is to provide a vibrant, safe, and inclusive digital economy, with individuals, businesses, and governments in Africa being digitally enabled by 2030. The initiative has been responsible for a 10% improvement in access to broadband internet between 2019 and 2022 (World Bank, 2023). However, there are still issues with inclusivity as wide digital gaps relating to gender and geography remain (World Bank, 2023).

Access to electricity

Availability of electricity is another crucial factor that facilitates the adoption of ed-tech in primary and secondary schools, yet access to electricity in many African countries is poor (Krönke, 2020). The use of computers and mobile phones/smartphones relies on a functioning electricity grid. While Cameroon, Senegal, and South Africa have made significant improvements in electricity availability over the years—reaching 91, 81, and 96% of electricity accessibility[11] for the latest data available—Kenya and Nigeria stand at 74 and 71%, respectively, and the remaining countries under study have an electricity accessibility of 66% or lower, with Tanzania at 66%, Benin 63%, Uganda 50%, Malawi 45%, and Sierra Leone 35% (Afrobarometer surveys 2016/2018, 2019/2021 and 2022).

11 Survey respondents were asked: are there electricity grids that most houses can access in your area?

There is also a significant disparity between rural and urban areas (Table 4). While urban households enjoy near-universal coverage of this essential service, rural households suffer from a serious lack of coverage, with the exception of South Africa. Rural areas continue to be marginalised in access to these (and other) basic services, which likely contributes to poorer education outcomes.

Some countries are working to improve access to electricity. For instance, Nigeria recently signed the Electricity Act 2023 into law, which is aimed at decentralising the power sector and electricity market, facilitating the Integrated National Electricity Policy, and the Strategic Implementation Plan, and disaggregating licence distribution (Adu & Olawepo, 2023). Also, the Senegalese government is implementing a plan (Emerging Senegal Plan) to improve access to electricity, especially in rural areas.[12] Malawi also introduced the Malawi Compact (2013–2018)[13] to improve access to electricity in the country, but the tariff is very high, making it unaffordable for most of the population. Overall, although there have been legislative efforts to improve access to electricity in several of the surveyed countries, cost barriers continue to prevent widespread access, and with it, an environment which is conducive to the implementation of ed-tech initiatives. In addition, the substantial urban-rural disparity in electricity availability further exacerbates the educational disadvantages faced by rural communities. Addressing these issues and ensuring widespread electricity access is essential for the effective integration of ed-tech and fostering equitable education outcomes.

Ed-tech readiness

The availability of computers, mobile phones, and internet services among different income groups across the region, as well as the availability of electricity, represent infrastructural constraints which continue to act as a barrier to the adoption of ed-tech initiatives. Table 5 summarises the current state of ed-tech readiness across countries, showing variation in the indicators between countries. For example, the proportion of individuals with computers is relatively low overall, except for Cameroon which had 60% computer ownership in 2022. Moreover, the share of mobile phone ownership is very high overall (with rates above 90% in seven countries) with the lowest rate in Malawi (79%). Internet connectivity rates are over 50% in six countries, while Uganda (33%) and Malawi (34%) have the lowest proportion of individuals with internet connectivity. Only a few countries, such as Cameroon, Kenya, Nigeria and Senegal have more than

12 For more details see: https://www.usaid.gov/powerafrica/senegal and https://www.presidence.sn/en/pse/emerging-senegal

13 For more details see: https://www.mcc.gov/resources/doc/star-report-malawi

70% individuals with access to electricity. In sum, only Cameroon has a high level of ed-tech readiness, given its high performance across the indicators, while other countries' readiness is still relatively weak. It is important to note that Malawi and Uganda perform especially poorly relative to other countries.

Table 5. Ed-tech readiness in 2022

Country	Percentage of individuals that own a computer	Percentage of individuals that own a mobile phone	Percentage of individuals that have internet connectivity	Percentage of individuals with access to electricity
Benin	35	97	60	59
Cameroon	60	95	71	91
Kenya	31	98	61	74
Malawi	13	79	34	45
Nigeria	32	91	57	71
Senegal	43	99	65	81
Sierra Leone	17	88	51	35
South Africa				
Tanzania				
Uganda	18	92	33	50
Total	29	94	53	62

Note. Authors' own based on data by Afrobarometer surveys (2022). The shading in the table assists cross-country comparison by variable. Darker shading indicates higher values, while pale shading indicates lower values. South Africa and Tanzania are excluded due to data unavailability.

Ed-tech barriers and enablers in schools

Discrepancies are evident in the experiences of school administrators relative to the integration of ed-tech in schools (see Box1). Certain administrators in the surveyed countries highlighted a deficiency in computer availability for both administrative and instructional activities. Moreover, the challenges extend beyond a mere scarcity of computers to encompass other devices and smart classrooms. This underscores the persistent inadequacy of ed-tech adoption in certain educational institutions, which impacts teaching and learning dynamics. School administrators consistently reported

issues stemming from the absence of computers or restricted usage even when a limited number were accessible. Insights from interviews underscore that some schools encounter challenges in fully embracing ed-tech. Conversely, there is also evidence suggesting there have been positive strides in the deployment of ed-tech in certain educational settings. Notably, a subset of 19 school administrators emphasised the integration of advanced technology in their schools' teaching and learning methodologies.

Box 1. Excerpts from interviews on ed-tech adoption in schools

"No, we don't have any at all, there is nothing, no computer centre, nor library" (School administrator Benin Republic, May 10, 2023).

"Yes, multifunctional. Admin-centred or teacher-centred or student-centred. More so, the learners have TVs in the classrooms; projectors in some of the classrooms for the smaller children the foundation phase; internet for the higher-grade learners; the teachers play YouTube videos, or any educational videos etc" (School administrator South Africa, June 13, 2023).

Resources and infrastructure for implementing ed-tech are also not readily available in schools in the region, as indicated in Box 2. Insights gained from interviews with school administrators shed light on several critical challenges affecting the effective integration of ed-tech across countries, underscoring the multifaceted nature of the barriers schools face in embracing digital advancements.

For instance, one school administrator highlighted poor infrastructure in rural schools, limiting teacher-student engagement. Additionally, there is a concern about inadequate resource allocation to these schools, pointing to a systemic problem that extends beyond the availability of technology. In another context, an administrator draws attention to infrastructural limitations, emphasising the lack of reliable, high-speed internet connections. The scarcity of personal devices among students further compounds the challenge, alongside struggles with continuous internet availability, limited understanding of device usage, and a dearth of digital literacy skills. In a different perspective, an administrator underscores the overarching challenge of inadequate power supplies, exacerbated during the rainy season and worse in remote areas. This power deficiency affects electronic device usage and contributes to limited internet access. The administrator also pointed out the dual problem of network issues when the internet is available and a shortage of professional teachers, indicating a gap in trained and qualified educators nationwide. Overall, it can be surmised from the interviews that impediments to ed-tech adoption are complex and interconnected.

Box 2. Excerpts from interviews with school managers on ed-tech challenges

> "Poor infrastructure in rural schools, limited teacher-student engagement, poor resource allocation to rural schools, use of mostly Swahili which poses a difficulty to translate to English, limited capacity building for both teachers and students" (School administrator Tanzania, August 5 2023).
>
> "Lack of reliable, high-speed connection, limited ownership of personal devices, lack of continuous internet availability, lack of knowledge of usage of devices, limited access to digital literacy skills" (School administrator Kenya, August 5 2023).
>
> "Lack of adequate power supply across the country and it even gets worse during the rainy season and in remote areas, limited access to the internet. Here there is the internet, there are often network problems; lack of professional teachers, here are not many trained and qualified teachers across the country" (School administrator South Africa, June 13 2023).

Challenges reported include the lack of connectivity, mobile phones, computer equipment, and reliable electricity. Insufficient funding and limited maintenance of resources contribute to the unavailability of computer equipment and other technological resources, with schools in rural areas particularly affected. There is also a lack of external assistance, such as trainers to guide students in their learning, limited digital skills among teaching staff, and a level of resistance among teachers to adopting new technologies and approaches. Broader challenges reported include poverty, language barriers, poor awareness, and an overall lack of government support (see Box 3).

Box 3. Excerpts from interviews on government commitment to ed-tech deployment

> "...There are a few initiatives driven by individuals or some school administrators, usually in private schools, who are trying to make the introduction of educational technologies a reality by equipping their institutions with computers. There are some primary and especially secondary schools that have computer labs accessible to students. In these labs, students have the opportunity to work with texts or conduct research when the computer labs are connected to the internet. Even at the secondary level, which we are discussing, the training of future teachers includes the integration of educational technologies. As I speak to you, I am responsible for a course here at the École Normale Supérieure titled "ICT and School Learning". At the governmental level, it remains a policy; it has not yet been fully implemented due to the lack of equipment. We are still unable to equip schools to make it possible. There are some NGOs, individuals, and benefactors who believe that the middle school or high school in their village or district should be connected and equipped with educational technologies to ensure better success for our students. And they make

efforts to provide equipment and connectivity, but in terms of percentage, it may be only 2 or 3% of the institutions that are affected. This is especially true in some well-stocked private schools in Cotonou, Porto-Novo, and other major cities, where students have access to computers and the internet. But in the public sector, it is still very much in its early stages due to equipment limitations, not to mention the issue of access to electricity, which is also challenging in many institutions" (Academic expert, Benin Republic, May 10 2023).

However, governments and development partners are making collaborative efforts to provide ed-tech tools. Expansion and sustainability remain critical issues when it comes to ed-tech interventions across countries, as this may largely determine the success of ed-tech in improving learning (see Box 4).

Box 4. Excerpts from interviews on collaboration between government and development partners

"When I consider for example MTN, UNESCO or UNICEF, that support us, they provide equipment or finance various training" (Government official, Benin Republic, May 10 2023).

"If there is to be collaboration, it should be sincere. Collaboration between the government and the educational technology industry should focus on facilitating the acquisition of digital equipment for teachers and providing them with training. This should promote technology-enabled learning among students. Collaboration between the government and donors should aim to enhance capacity-building in terms of digital skills development" (Government official, Benin Republic, May 10 2023).

"There is a lot of private-public partnership but these are based on individual capacity. Can be more efficient if the government hosts and allows others to coordinate with support from the Ministry" (Government official, Sierra Leone, June 5 2023).

Ed-tech adoption during the COVID-19 pandemic

Experiences of the use of ed-tech during the COVID-19 pandemic revealed several barriers which constrained the rollout of digital learning technologies. Specifically, it is apparent that the countries surveyed had limited time to plan ed-tech interventions during the pandemic, that existing socioeconomic and geographical inequalities made it harder to deliver ed-tech initiatives in remote and poorer areas, and that it was challenging to train educators to make effective use of ed-tech devices and programmes. Yet, the challenges faced during the implementation of ed-tech in African countries

during COVID-19 also opened up significant opportunities. Despite initial difficulties, a newfound awareness of ed-tech's potential emerged, accompanied by a heightened appreciation for technology in education. This period showcased evidence that ed-tech can complement traditional learning systems, marking a transformative shift in perception. Experiences during the pandemic highlighted the potential for technology to improve education access across the continent, pointing to a future where ed-tech and traditional methods coalesce for enriched learning outcomes.

One notable intervention introduced during the COVID-19 pandemic to sustain learning was ConnectEd, developed by Youth Impact in Botswana, provides an example of low-tech solutions like using SMS messages and phone calls to provide numeracy tutorials (see Box 5).

Box 5. Case study: ConnectEd, Bostwana

Following the educational disruptions caused by the COVID-19 pandemic, Youth Impact, a non-profit organisation, developed a low-tech education solution to the distance learning challenges faced by many groups of students. About 70 – 90% of low- and middle-income households have at least one mobile phone, and ConnectEd was developed to leverage this resource. In contrast to other low-tech solutions that involve use of radio (Damani & Mitchell, 2020) and television (Watson, 2020), ConnectEd is a numeracy intervention in which one-way SMS messages and simple phone calls are deployed to reach students at home, and deliver impactful tutorials with targeted content to improve learning (Youth Impact, n.d.).

Youth Impact partnered with the University of Oxford, Columbia University, and the Jameel Poverty Action Lab (J-PAL) to run a randomised trial that produced some of the first experimental evidence on how the impact of the pandemic on learning could be minimised (Youth Impact, n.d.). The pilot implementation and base experiment was carried out in Botswana, in which a sample of 4,500 households with children of primary school age across nearly all regions of the country were assigned to either an intervention arm or a control arm. In one treatment arm, SMS text messages provided some basic numeracy problems for the week, while a second treatment arm was the use of phone calls from instructors to supplement the SMS messages (Angrist et al., 2020). These calls lasted 15 – 20 minutes and provided a direct walk-through of the learning activities stated in the SMS messages. High-frequency data collected at week four of the experiment were used to cross-randomise a targeted instruction intervention, where customised SMS and phone instructions were sent based on students' numeracy levels (Angrist et al., 2020).

The results from this experiment in Botswana show some statistically significant learning gains, which, among other things, include a demonstration that certain ed-tech instructions through low-tech mobile phones can provide an effective and scalable delivery of educational contents beyond the conventional schooling system, and can allow for personalised instruction through

flexible implementation that can target students who need special or extra support (Vota, 2022). Specifically, it showed that remote instruction through a combination of phone calls and simple SMS texts can reduce innumeracy by up to 31% at a cost of USD 14 per child or less (Angrist et al., 2023). This intervention has so far been implemented in six different countries, including Botswana, Kenya, Nepal, India, Uganda, and Philippines, and evidence indicates that ConnectEd has had positive impacts in all six countries. As particularly observed by Evans and Yuan (2022), phone calls in combination with text messages improved learning by 0.33 standard deviations, which is higher, by more than a third, than the median effectiveness of education interventions.

Other identified strengths of the framework (ConnectEd) include that it is highly cost-effective; in fact, it produced 3.4 Learning Adjusted Years of Schooling (LAYS) per USD 100, making it one of the top three most cost-effective interventions of its type (Angrist et al., 2023). The challenge with this intervention, however, is that learning is undertaken without the advantage of visual illustration of, and interaction with problem solutions, as well as the command of attention that the physical presence of teachers/instructors compels. Nevertheless, available evidence has shown that it effectively aided the teaching of basic numeracy skills when schools were closed due to COVID-19. Moreover, in the post-lockdown period, where millions of children in Africa are still faced with unexpected closures of schools as a result of natural disasters, conflicts, and other circumstances such as teacher absence, ConnectEd is able to sustain schooling and accelerate learning, as long as households have access to phones and children are healthy and safe to learn.

See full details here: http://www.nber.org/papers/w31208

The availability of, and access to digital facilities are a precondition for efficient and effective remote learning where in-person learning arrangements would not be possible (Basar et al., 2021). However, this was largely lacking in most sub-Saharan Africa countries ahead of the COVID-19 pandemic. While there were no universally applicable strategies (eLearning Africa, 2020), the use of radio and television for broadcasting lessons and internet-based applications were widely adopted learning alternatives across sub-Saharan African countries during the pandemic (Upadhyay & Taddese, 2020; Dele-Ajayi & Taddese, 2020; Mullan & Taddese, 2020), especially since it was the method that best matched pre-existing levels of technology application in basic schools, and access to technology among most of the population (eLearning Africa, 2020). The adoption of ed-tech in the region to support learning during the pandemic was limited by three main factors:

1. Limited time to plan: Governments had little time to make adequate plans before the pandemic hit. Countries like South Africa, Senegal, Nigeria, and Kenya responded quickly by imposing curfews or total lockdowns across sectors (including education), and rapidly dispensing fiscal stimulus packages

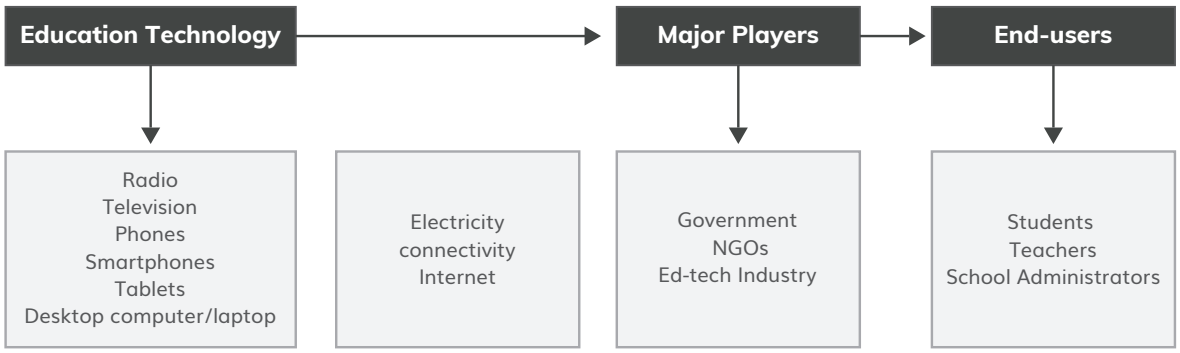
(Organization for Economic Co-operation and Development [OECD], 2020), and designing distance learning options that were mostly low-cost, but which created challenges for learners due to exposure to a new approach to learning (Human Rights Watch, 2020). Moreover, there was a problem with inclusion, as governments found it challenging to determine which learning approach and technological tool would be most appropriate for which learning group, as well as problems with ICT uptake, and television and radio coverage (ADEA, 2020). Other areas affected by limited time to plan responses include inadequate funding, poor quality assurance in assessments, and a lack of an effective monitoring and evaluation framework (ADEA, 2020).

2. Structural problems: Structural issues that manifested in the form of digital, socioeconomic, and rural-urban divides created complex and divergent education needs that ed-tech alone could not address. Socioeconomic inequalities affected the quality of remote learning and access to digital facilities between different groups (rich and poor; rural and urban), thus limiting the possibility of ed-tech to ensure learning for all during the pandemic. It is not surprising, therefore, that most countries (Cameroon, Kenya, Nigeria, South Africa, Kenya, Uganda, Senegal, Malawi and Tanzania) identified a lack of access to technology as the most significant challenge they faced in using ed-tech facilities to learn during the lockdown (eLearning Africa, 2020).
3. Inadequate training for educators: Many teachers and other education practitioners lacked the ICT skills needed to navigate the available resources and adopt ed-tech for learning and teaching (Ngware & Ochieng, 2020). Of the 18 countries studied by Ochieng, Asego, and Gyasi (2023), the percentage of teachers trained in ICT and ed-tech was low across the countries. Specifically, the proportion of teachers trained to support and address the remote learning needs of excluded and vulnerable learners during the pandemic were in Congo (16%), DR Congo (15%), Liberia (10.7%), and Kenya (10.6%).

Political economic issues driving ed-tech deployment and adoption in sub-Saharan Africa

This section analyses the role of the political landscape and the relevant stakeholders in the development and implementation of ed-tech policies in sub-Saharan Africa. Figure 5 shows the intersection between ed-tech, key players, and end users. Specifically, ed-tech policies and initiatives are driven by key stakeholders, which include the government, NGOs, and ed-tech service providers.

Figure 5. The ed-tech ecosystem



Note. Elaborated by the authors adapted from *Ed-tech and COVID-19 response* by Haßler et al. (2020)

The success of ed-tech implementation also depends on the political landscape of the countries. Findings from the case studies (see Boxes 5 and 6) show that the government and private sector have a crucial role to play in maximising the potential of ed-tech to improve learning outcomes in primary and secondary education in the sub-Saharan Africa region. The political economy of ed-tech implementation refers to the system of political, economic, and social factors that underlie the adoption, implementation, and outcomes of ed-tech initiatives in the region. In our analysis, we define these issues as: (i) funding, priorities, and policy clarity; (ii) governance structure and transition of political power; and (iii) procurement issues.

Funding, prioritisation, and policy clarity

Funding and prioritisation represent the most critical aspects of ed-tech implementation. Technological interventions cannot thrive without adequate funding and investment relating to infrastructure, the design and implementation of appropriate policy and regulatory frameworks, basic digital skills, and the creation of locally relevant content (United Nations & Inter-agency Task Force on Financing for Development, 2021). In education, governments, private investors, and NGOs play vital roles in mobilising funding for programme implementation (OECD, 2017). Appropriate funding requires an understanding that ed-tech is not an end in itself, but rather a means to establish innovative teaching and learning that can improve educational access and learning (Vegas et al., 2019). Designing such initiatives and innovations will require clearly defined sources of funds and funding arrangements, either as an integral part of the overall education fiscal commitments or as a separate investment framework specifically for ed-tech initiatives.

The most common indicators for assessing education funding levels are public education expenditure as a percentage of total government expenditure, and as a percentage of total budget. Generally, fiscal commitments to education have been lower than the 15–20% recommended by the Education for All (EFA) High-Level Group of UNESCO (French Development Agency & UNESCO, 2015), or about 3.4% of the country's GDP, which is lower than the 6% recommended in the Incheon Declaration. Efforts to expand these commitments have proved unsuccessful (UNICEF, 2022). Half of the countries selected for this study have a public education budget of less than 15% of their total national budget. Sierra Leone has the highest level of education spending (9.1% in 2021) while Uganda has the lowest (2.7%). Spending is also relatively low in countries such as Kenya (4.8%), Rwanda (3.8%), and Tanzania (3.3%), while in South Africa, spending was around 6.6% in 2021.

While a few countries, such as Sierra Leone and South Africa, have improved spending compared to other countries, it is difficult, owing to the unavailability of disaggregated education spending data, to determine how much ed-tech benefits from this spending in terms of capacity building for teachers, the provision of ed-tech tools, and supporting infrastructure. A lack of overall spending on education has knock-on effects for ed-tech investment. In Nigeria for example, there is limited government funding for ed-tech, and nearly every ed-tech initiative is led by startups, NGOs, and international organisations (Dele-Ajayi & Taddese, 2020).

Many ed-tech startups operate at very limited capacity due to inadequate investment and low capital outlays for expansion. Funding has been a major challenge for both private investors and public-private partnerships. Only 29 ed-tech startups in sub-Saharan Africa received funding in 2021, and the total funding attracted between 2019 and 2021 stood at USD 20 million, which is only a fraction of the global investment of USD 18.6 billion (UVU Africa, 2022). In 2022, funds raised by ed-tech startups in the region (mainly in Nigeria, Rwanda, Kenya, South Africa, and Ghana) declined by nearly 70% from their peak in 2021 (Augustine, 2023). But some private investors are still making efforts to boost finance for ed-tech startups, as shown by the USD 15 million ed-tech accelerator programme set up by Co-Creation Hub (CCHub) to support 72 ed-tech startups in Nigeria and Kenya (TechCrunch, 2023). Given that the realities of the ed-tech system are complex (Burns, 2020), a clear and specifically focused ed-tech policy, distinct from conventional ICT policies, is imperative for all countries.

Governance structure and transition of political powers

The structure of governments and political transition can also shape the development and sustainability of ed-tech initiatives. French Development Agency & UNESCO (2015) noted that insofar as the policies and regulations established by

governments lead to the integration of technology in education systems, governance structure will determine the processes of decision-making and accountability mechanisms, as well as the coordination of efforts among the various actors associated with ed-tech initiatives. Whether governance is centralised or decentralised, together with changes in who wields political power, have largely been deciding factors for policy priorities, funding allocations, and the continuity of ed-tech initiatives (Harrison, 2018). Specifically, political transitions can lead to policy shifts and disruptions to in-progress projects. Changes in governments can also bring about resource reallocation or reprioritisation of educational goals, which can impact the implementation of ed-tech (Neuman & Powers, 2021).

The Nigerian government, for example, has recognised the potential of ed-tech to address challenges within the education sector, and the National Information Technology Development Agency (NITDA) is a vital player in coordinating and supporting the implementation of digital projects in education (NITDA, n.d.). However, the federal system—in which responsibilities are shared between the federal, state, and local governments—can create discrepancies and gaps in ed-tech adoption across regions (Adebayo et al., 2020). In fact, it has led to an ed-tech system that allows for different ed-tech policies and programmes at the federal and state levels. The simultaneous operation of the Nigerian Learning Passport (a federal government project) and the EdoBEST programme (by the Edo state government; see Box 6) exemplify this. The success recorded in the first of EdoBest held to its recent expansion in 2023, termed EdoBest 2.0 (New Globe, n. d.). More so, the Nigerian Learning Passport continues to foster digital learning and teaching in schools. For instance, tablets loaded with offline learning resources distributed to teachers and few students continue to improve learning at primary schools (UNICEF, 2023).

Box 6. Case study: EdoBEST, Nigeria

EdoBEST (Edo Basic Education Sector Transformation) is an initiative of the Edo State government in Nigeria, through its Universal Basic Education Board in partnership with Bridge International Academics. The programme was launched in April 2018, with the aim of achieving a holistic transformation of the state's basic education sector, by leveraging a technology-based approach to education to better support teachers, enhance teaching and learning outcomes, and boost public confidence in public schools. The project is targeted at facilitating teaching for teachers, enhancing learning for the pupils, and promoting a more efficient and effective school administration and management (Edo State Universal Basic Education Board (SUBEB), n.d.). As noted by Cantrell et al. (2019), the programme started with an extensive pedagogical training of 1,500 teachers and headteachers from 2,639 schools across 18 local government areas of the state.

The teachers were trained on (i) teacher and pupil perspectives on the EdoBEST programme, (ii) classroom management practices to motivate and encourage participation among pupils, (iii) use of tablets as lesson guides and tool to keep track of pupil attendance and learning, (iv) techniques to deliver tangible and actionable feedback to all pupils, and (v) how to generate a positive, nurturing, and safe classroom environment. By 2022, at least 16,000 teachers had been trained, and learning outcomes transformed for over 300,000 children across 1,029 primary schools and 232 junior secondary schools in the state (Edo SUBEB, n.d.). The implementation involved Bridge specifically providing:
(a) Learning resources and materials like lesson guides for teachers through tablets, independent study books, individual homework books, and standardised daily timetable for each grade;
(b) training and ongoing support for effective classroom management by teachers; and
(c) tech-supported management and quality assurance services for school heads, among others.

The deployment of tablets to teachers in selected public primary schools in the state became the most striking component of the programme. These devices are preloaded with interactive learning materials (detailed scripts) that are aligned with the state's curriculum and guide the delivery of each lesson. The scripts tell teachers what to say, what to write on the board, and even when to walk around the classroom. The tablets can also register when teachers arrive, if a teacher has scrolled through a lesson faster than appropriate, or if they abandon a lesson midway through. There is also a team of officials (about one for every 10 schools) who observe lessons and coach teachers, based on data from the tablets (The Economist, 2023).

Although faulted on some counts, including criticism of scripted lessons as undermining teaching and encouraging rote learning and exam drilling, given the challenges of teacher shortage, inadequate classrooms, and poor network coverage and connectivity, EdoBEST has been lauded for several reasons as a successful tech-based initiative in education. Through its five pillars (systems strengthening and organisational development, teachers' professional development and quality assurance, curriculum development and learning outcomes, community engagement and partnerships, and school infrastructure and facilities), significant progress has been made in the state's education system, as documented in the 3rd year results report on the programme (Edo SUBEB, 2022).

For instance, lesson plans have been digitised; professional development has been provided to thousands of school staff including education managers; teachers have been upskilled to employ a child-centred pedagogical approach, positive classroom management techniques, and to leverage technology; school infrastructure has been significantly improved; and the practice of using data to drive decision making has been embedded in the system. Among other achievements, these, together with the state's ability to track teachers' attendance and performance of duties, have brought about gains in learning, such that the EdoBEST initiative is largely considered a success story amongst ed-tech interventions.

Another success point of the programme was its quick response to COVID-19. EdoBEST was about two years old when the pandemic hit, but it provided the Edo state government a platform to

quickly transition to online learning through EdoBEST @Home. About 7,000 virtual classrooms were created, and more than 11,000 teachers who had already been through rigorous training under the EdoBEST initiative were able to conduct e-classes for their students via WhatsApp. Meanwhile, the state government, in partnership with telecommunication providers, facilitated data subscription for participating students (World Bank, 2021b). The state government is currently making efforts to launch the second phase of the initiative.

In Kenya, a centralised government structure exists, with the Ministry of Education leading the formulation and coordination of policies, and the Institute of Curriculum Development overseeing the incorporation of digital content into the curriculum. This has facilitated the implementation and expansion of ed-tech initiatives in the country, like the Digital Literacy Program (Digischool, n.d.). Conversely, South Africa has a decentralised governance structure, which allows provincial education departments to take charge of decision-making and implementation, but which can also lead to differences in ed-tech progress between provinces (Heystek et al., 2018). While some regions, like the Gauteng province, have been able to implement enhanced learning through technology in schools, others have been unable to, owing to challenges like financial resources and capacity constraints (Makgato, 2014; Aruleba & Jere, 2022).

Another important issue is a lack of continuity and policy reversals linked to party political interest and power transitions. For example, rapid turnover of education ministers with varying interests has resulted in inconsistent education policies in Nigeria (Olayinka, 2016). Factors such as the drive to gain political power have resulted in over-ambitious ed-tech projects popularised through campaigns to win majority votes, but which eventually fail due to bogus funding arrangements and poor sustainability plans, as was the case in Kenya's OLPC programme (Muhamad, 2014). Also, key among the major concerns raised by stakeholders engaged in the EdoBEST field observation is uncertainty around programme continuity if a new government is formed by another political party, particularly due to the possibility of conflicting interests and priorities between the previous and current ruling parties. This suggests that improving the education system requires not just reforms but also coherent, long-term political planning tailored toward achieving the set goal.

Procurement issues

Procurement in ed-tech is a systematic process that involves careful planning, thorough evaluation, supplier selection, and effective contract management to meet specific needs and objectives. However this is often limited by issues such as insufficient procurement capacity and unclear guidelines, budget constraints, as well as

transparency and accountability issues, which together impact the acquisition, deployment, and long-term viability of ed-tech solutions.

Limited procurement capacity and technical expertise, for example, can result in the emergence and acquisition of substandard solutions, and a lack of clear guidelines for procurement can lead to bogus practices that compromise ed-tech quality. This has been evidenced in some cases, such as the Learning TV programme COVID-19 in Ghana (Ghana Education Service [GES], 2020). The absence of clear guidelines could also impede the implementation of ed-tech programmes, as was the case with Kenya's OLPC (Gutschmidt, 2013). Rather than working with stakeholders to address specific concerns, the Kenyan government, through its OLPC programme, pursued an intensive, top-down approach that excluded the participation of a wide range of stakeholders. They focused on providing materials without accounting for differences in the level of infrastructure available in different regions, the capacity of the teachers to integrate ICT into their learning processes, the school environment and social norms dictating technology use, teachers' pain points, and the ability of this solution to solve them (Pallaruelo et al., 2022; Mutua, 2013; Oduor, 2021). These examples indicate that poor procurement practices can have considerable impact on the success or failure of ed-tech initiatives.

The unavailability of supportive infrastructure, including internet connectivity and electricity, remains a significant challenge that hampers students' ability to embrace ed-tech in their learning experiences.

Some ed-tech initiatives have faced significant setbacks caused by bureaucratic procedures and ineffective methods. Due to delays in purchasing ed-tech solutions, the integration of technology in classrooms in Tanzania has been sluggish ((Ndume et al., 2021). Issues of corporate influence, transparency, accountability in supplier selection, programme funding, and overall management of the ed-tech programme contract are also at play in the ed-tech ecosystem of sub-Saharan Africa countries. Where transparency and accountability systems are weak, quality is often compromised. In Nigeria, favouritism, unclear guidelines, and a lack of transparency have resulted in the selection of substandard suppliers, affecting the quality of ed-tech solutions (Iji et al., 2020). On the other hand, South Africa has developed specific policies on procurement for ed-tech, which outline procedures for fair bidding and supplier selection (Brunette et al., 2019). Rwanda also has a history of a fairly transparent process of evidence uptake in education; annual data on education are published

by the country's National Institute for Statistics, long-standing partners involved in the development of the Rwandan ed-tech ecosystem (Pellini et al., 2021), and clear guidelines existed for education and technology workers on how to use ed-tech during COVID-19 (eLearning Africa, 2020). These cases demonstrate that robust procurement management processes are critical in ensuring the success of ed-tech initiatives through effective oversight and scrutiny of purchasing decisions.

The role of stakeholders in ed-tech development and implementation

1. The government: The advancement of education and effective integration of technology in learning are direct consequences of the intentionality of the government, driven by the introduction of policies and the means to implement them. Ed-tech solutions require clear guidelines, quality standards, and data privacy that the government must provide to ensure that ed-tech platforms are safe and aligned with educational objectives. It is also the responsibility of the government to provide access to reliable internet connectivity and adequate infrastructure, especially in rural and underserved areas, if the advantages of ed-tech solutions are to be maximised. Other key roles played by the government include providing professional development opportunities for teachers and administrators, monitoring and evaluating ed-tech initiatives, allocating funding for research and development (R&D), protecting the privacy of students and teachers through data ownership policies, and ensuring that ed-tech initiatives promote equity and inclusivity.

   Evidence from the selected countries reveals that governments in sub-Saharan Africa have taken steps to introduce policies and programmes that facilitate the adoption of ed-tech tools in the classroom. For example, the National Education Information and Management System and the School Radio and Television Broadcasting Division (DRTS) are two Ministry of National Education (MEN) entities in Senegal that play critical roles in ed-tech. MEN's ed-tech projects are focused on providing online tools for remote study, as well as supporting radio and television education programmes. It has identified ed-tech as a key strategic feature in its PAQUE 2018–2030, with plans to build the capacity of education personnel in the use of ICT resources and to improve the learning environment of schools through ICT (Upadhyay & Taddese, 2020). In Nigeria, the government has launched a National Implementation Guideline for ICT in education to clearly direct stakeholders on how to effectively deploy ed-tech at all levels (Dele-Ajayi & Taddese, 2020). State ministries have capitalised on these guidelines and the ICT in Education policy to set up state-based ed-tech programmes. Despite these efforts, a significant gap persists in the deployment of ICT in education, and limited government funding for ed-tech is common in

nearly all countries (Dele-Ajayi & Taddese, 2020). Most ed-tech initiatives are led and funded by startups, NGOs, and donor agencies (Dele-Ajayi & Taddese, 2020). The quality of ed-tech professional development for teachers is also of paramount importance as a crucial aspect of the modernisation of education. In South Africa, the "Teacher-Laptop" initiative was launched to offer teachers training on the effective use of technology in the classroom (South African Government, 2010).

2. Donor agencies: The increased adoption and implementation of ed-tech programmes sub-Saharan African countries has been strongly influenced by the influx of funding from donor agencies. Funding can help bridge the government expenditure gap and is instrumental in procuring the necessary hardware, software, and infrastructure for end users. Donor agencies can also contribute significantly to capacity building through their large base of technical expertise, thereby improving the digital literacy of teachers, and integrating technology effectively into the classroom. Through donor technical support, teachers gain the skills and knowledge needed to adapt to the changing educational landscape, ensuring that students receive a well-rounded and technologically enhanced learning experience.

   Evidence shows that funding of ed-tech programmes by donor agencies is common in the selected countries. In Sierra Leone for example, the Tony Blair Institute for Global Change, in collaboration with EducAid, and Save the Children, is funding the Sierra Leone Education Innovation Challenge (Education Outcomes Fund [EOF], n. d.). World Reader (n. d.) funds an initiative that provides children with e-readers loaded with content. Other donor agencies include the 60 million Girls Foundation and CAUSE Canada (Mullan & Tadesse, 2020). There are limitations to the impacts of these funds, however. Findings from this study reveal that they offer the platform for donor agencies to impose ed-tech solutions that may not correctly align with the local context, resulting in limited effectiveness and sustainability. Additionally, the focus of donor agencies is usually on software and content development. This coverage is insufficient given that fundamental infrastructure, such as electricity, is a major challenge for the region. Neglecting to target unreliable internet connectivity and the insufficiency of hardware can hinder the successful implementation of ed-tech initiatives.

3. Private sector actors: Private actors, including ed-tech startups, are leading the way in introducing innovative ed-tech solutions in the countries surveyed. Their activities significantly influence the ecosystem, and they have attracted the attention of international investors. According to Disrupt Africa (2022), African ed-tech startups raised over USD 24 million in 2022. Their experience in technology, instructional design, and business strategies contributes to their unique development of ed-

tech products and services (Disrupt Africa, 2022). However, they are often driven by profit, and most prioritise financial gain over educational impact. For instance, the needs of marginalised communities may be overlooked, thereby hindering widespread adoption and use of ed-tech tools, as reported by Languille (2016). The author argues that Spark Schools, a South African low-cost private school that has embraced ed-tech solutions as part of its teaching and learning resources, does not cater for poor children because they are unable to afford these resources.

In sub-Saharan Africa, ed-tech startup activities (i.e., private initiatives) are divided into two categories: primary value chain and support activities. The primary value chain covers the use of ed-tech to directly support learning and teaching activities, while support activities include the use of ed-tech to facilitate key school activities such as administration, communication, procurement, teacher development, and student support (The Baobab Network, 2019).

A cursory examination of sub-Saharan Africa shows astounding uptake of private ed-tech initiatives in some countries. In Cape Verde, the Huawei-led WeLab programme, overseen by the Ministry of Education and Sports, runs in 43 of 44 secondary schools (Burns, 2020). InstantSchools, funded by the Vodacom network, provides a free digital learning platform in local languages to over 750,000 learners in DR Congo, Tanzania, Ghana, and South Africa, with the goal of reaching 5 million learners by 2025. Kenya also made strides in ed-tech with the introduction of KioKits, eLimu, and eKitabu. Yet, ed-tech private startups are concentrated in a small number of countries, with South Africa (39%), Nigeria (28%), and Tanzania (4%) accounting for 67% of all African ed-tech startups (Rumble & Nyakio, 2019). This strong concentration means improvements in education quality in the region are not guaranteed, and indeed could further underscore inequality in access to educational opportunities.

Funding remains one of the major impediments to the region's ed-tech progress. Africa's ed-tech sector received only USD 20 million between 2019 and 2021, compared to global financing of USD 18.6 billion in 2019 (Oneyibo, 2021). Table 6 also shows that startups focus more on providing services for learning, which accounts for 31.3% of aggregate activities, while the deployment of ed-tech for teacher development and the procurement of teaching resources account for the lowest share.

4. Mobile operators: With low internet connectivity in the selected countries and the wider region, the role of mobile operators in facilitating the use and adoption of ed-tech has become increasingly important. Mobile operators are realising the power of ed-tech and are offering solutions to improve digital literacy. In

South Africa, Vodacom has partnered with UNCHR to create an online platform that offers individualised learning to primary and secondary school students. Currently, over one million students can access the platform with any device (Vodacom, 2017). In 2018, Airtel's Internet for Schools Program partnered with Computer for Schools Kenya and Longhorn Publishers to provide free internet access services to 30 schools in Kenya. The partnership aimed to enhance digital learning in Africa. MTN has been active in offering digital solutions and helping set up educational centres for underserved students in Africa. Through its African branches, the MTN Foundation and MTN Business, the group has had a positive impact on education across the continent. Specifically, MTN Benin has created digital classes for 50 schools and digital literacy training for educators (GSMA, 2020). The initiative has enabled access to learning resources for 15,000 students and 100 teachers in the country.

5. Teachers: Like students and parents, teachers are end-users of ed-tech programmes and solutions. Ed-tech solutions can help teachers achieve better results in classrooms. Collaboration among teachers is also needed, as they can provide feedback on the usability, functionality, and relevance of ed-tech programmes and tools. In Uganda, teachers were able to provide real-time assistance to students through the chat-based Q&A set up by Teach for Uganda. Eneza Education of Kenya also provided an SMS-based ed-tech solution with an "Ask-A-Teacher" feature that allows students to ask teachers questions in real time. Teachers assisted the programme by developing lessons and quizzes that can be accessed by any mobile phone (Tembey et al., 2021). However, the success of these programmes depends on the proficiency level of teachers using ed-tech tools and gadgets. Degbedzui (2018) argues that teachers have limited digital literacy and knowledge about how ed-tech can support their teaching, and are not motivated to use the new solutions (Kweku, 2018). Hence, there is a need for continuous training to upskill. Instant Network Schools, an ed-tech programme launched by UNHCR and Vodafone in Kenya, engaged teachers in training on digital learning resources. In Nigeria, OTIS[14] for educators provides both free and paid services, with high quality online professional development courses for educators and school leaders to assist them in implementing distance learning. In addition, Universal Basic Education,[15] through its Digital Resource Centre, recently trained teachers for 13 UBE Model Smart Schools[16] in 13 states.

14 For more details see: https://www.teq.com/otis-deployment/

15 This is the body responsible for quality basic education, which includes early child care, primary, junior secondary and nomadic education. https://fctubeb.gov.ng/about-ubeb-abuja-nigeria

16 For more details see: http://www.drc.org.ng/newsandevents/news-info.php?id=41

The schools will begin operations in September 2023. Specifically, the training involves capacity building for teachers in the use of technology for pedagogy practice. This training also involves a combination of facilitator-led, hands-on practical and interactive sessions. This is expected to assist the teacher in applying the skills in an actual classroom setting.

Furthermore, the Teaching Service Commission (TSC) in Sierra Leone is collaborating with the Ed-tech Hub to implement a tech-supported teacher continuous professional development (TCPD) programme to enhance foundational literacy and numeracy teaching (Beoku-Betts et al., 2022). The programme aims to establish teacher learning circles (TLCs) in schools, providing teachers with Android tablets containing pedagogical resources. Sprint 2 of the TCPD sandbox project focused on component testing, including tablet dissemination, TCPD content, and learning management system (LMS) testing, and roles for supporting communities of learning. Key findings include positive tablet usage by teachers, a preference for audio/video content, and the need for training and resources for TLC facilitators and teachers (Beoku-Betts et al., 2022). Sprint 3 will involve holistic testing of the combined components. The implementation and scaling of personalised learning technology in Malawi also focused on teacher-related aspects of the programme (Schmitt, 2021). It emphasises the importance of considering teachers' roles in adapting implementation models for effective use of educational technology.

6. Parents: The involvement and support of parents can significantly impact the success and sustainability of ed-tech programmes and policies. By raising awareness about the benefits of ed-tech, parents can encourage policymakers to invest in technology infrastructure and support the development of effective ed-tech solutions. Moreover, parents can contribute to fundraising efforts aimed at acquiring the necessary technological resources for schools. The role of parents also extends to assisting their children in effectively using ed-tech tools and encouraging them to have a positive attitude towards technology. In addition, feedback from parents on ed-tech solutions is important in modifying them to suit the needs of students. However, in the selected countries, parents have faced several challenges in relation to the adoption of ed-tech learning tools by their children. Degbedzui (2018) argues that engaging and equipping parents to be able to support their children's education is something that has not received enough attention (Kweku, 2018). Technological literacy limits the involvement and ability of parents to guide and monitor their children's technological use, and in cases where an ed-tech solution is not culturally relevant and is perceived as not aligning with cultural values, parents may resist its implementation.

7. Students/pupils: Students are the primary beneficiaries of ed-tech programmes and policies, interacting directly with ed-tech tools and platforms. As the primary beneficiaries, their attributes, experiences, needs, and feedback are essential in shaping the successful integration of ed-tech in the selected countries. Students in areas with limited access to reliable electricity and internet connectivity face challenges accessing and using ed-tech tools. Also, differences in context and linguistic diversity, if not accounted for in the design and adoption of ed-tech solutions, impair the success of the programme. The willingness of students to embrace and experiment with ed-tech solutions equally influences their broader adoption by their peers and institutions. Generally, access to ed-tech resources offers opportunities for students to access high-quality educational content that may not otherwise be readily available in their schools. Additionally, students experience more engaging and interactive learning through gamification and interactive content, which capture their attention and increase their motivation to learn. Oshodi (2022) highlights that ed-tech has a positive impact on the learning outcomes of pupils in Nigeria. This includes improved academic performance, increased engagement, enhanced understanding of subject matter, and overall better retention of knowledge. The use of technology can make learning more interactive, personalised, and dynamic, catering to different learning styles and paces. The study also shows that pupils prefer the ed-tech method of learning, despite the challenges they face while using it, such as poor digital infrastructure and limited internet connectivity (Oshodi, 2022).

The involvement of different stakeholders in the development and implementation of ed-tech policies in the region is summarised in Table 6.

Table 6. Summary of stakeholder involvement in ed-tech policies in sub-Saharan Africa

Stakeholders	Low	Medium	High	Comments
Government initiatives				Governmental involvement is low due to competing priorities, limited funding and challenges in policymaking and implementation. There is also limited coverage and sustainability when compared to other stakeholders.
Level of donor funding				Donor agencies have shown significant involvement in and support for Ed-tech interventions in sub-Saharan Africa. They provide funding, technical expertise and guidance to implement and scale up Ed-tech initiatives.
Involvement of mobile operators				Mobile operators have taken advantage of the opportunities presented by Ed-tech, expanding internet connectivity and mobile technology access. Their involvement, however, varies across countries.

Number of private actors				Private actors have been very proactive in developing and implementing innovative and versatile Ed-tech solutions to improve learning conditions for profit.
Students' usage				While some students have access to devices like tablets and smartphones, others are limited by a lack of devices, reliable internet and familiarity with technology.
Parental support				Some parents recognise the potential benefits of technology, while others face challenges relating to awareness, affordability, and digital literacy.
Teachers training inclusion				The coverage and depth of training that teachers receive vary. Whilst they receive training in the use of specific tools, support is not sustainable, which can limit their capacity.

Note. Elaborated by the authors.

Concluding remarks and limitations

Our analysis of ed-tech adoption in primary and secondary education in sub-Saharan Africa focused on a country-by-country examination of 10 countries. The findings shed light on the significant challenges limiting the widespread adoption of ed-tech in the region's education systems. This study presents five key findings and limitations.

First, the literature review revealed that the challenges facing ed-tech adoption in education, such as insufficient budgetary allocation, a lack of supportive infrastructure, and inadequate teacher training, outweigh the limited progress observed in terms of adoption rates in the countries. Second, analysis of ed-tech adoption, drivers, and readiness highlights the heavy burden placed on households in terms of providing digital devices and infrastructure. This acts as a major barrier to achieving higher adoption rates in these countries. While Cameroon and South Africa have made notable progress in computer and mobile phone ownership, other countries have performed poorly or moderately. Additionally, the availability of supportive infrastructure, including internet connectivity and electricity, remains a significant challenge that hampers students' ability to embrace ed-tech in their learning experiences.

Second, our analysis reveals a high level of inequality in ed-tech adoption within countries. Gender disparities are particularly prominent, with substantial gaps observed in most countries between male and female ownership of computers and mobile phones, as well as access to internet connectivity. Also, a significant disparity between urban and

rural areas is observed regarding the ownership of computers and mobile phones, as well as access to supportive infrastructure within households. This discrepancy highlights the existing digital divide, with rural areas and low-income households facing greater difficulties in accessing and using ed-tech tools and resources compared to their urban and higher-income counterparts. Specifically, households in rural areas are disproportionately affected due to the significant investment required for accessing computers, mobile phones (particularly smartphones), internet connectivity, and electricity. When comparing the ownership of computers between rich and poor households, high levels of inequality are evident, whereas the disparities in mobile phone ownership (mostly non-smartphones) are much smaller by comparison. Additionally, there is a significant discrepancy in access to the internet and electricity between the two groups. Poor households, already struggling to meet basic needs such as water, healthcare, food, clothing, and housing, face further challenges in providing digital devices and supportive infrastructure for their children's education. As a result, marginalised students are often excluded from the benefits of ed-tech adoption in education.

Third, the analysis highlights persistent funding gaps and overall lack of sufficient government funding as key factors influencing the adoption of ed-tech in nearly all countries. Unfortunately, the burden of ed-tech provision primarily falls on households, startups and NGOs, rather than the state. This underscores the need for more comprehensive and sustainable support from governments. Moreover, in terms of data, there is a need to disentangle budgetary allocation to ed-tech development from overall education spending, in order to be able to clearly analyse the extent of funding provided specifically for ed-tech initiatives.

Fourth, political economic factors, particularly policy shifts and political transitions, have a significant impact on ed-tech adoption in these countries. Policies and their implementation are often driven by political objectives, particularly during election periods. This could be observed in the case of the EdoBest initiative in Nigeria. Finally, the enormous support for ed-tech adoption during the COVID-19 pandemic, with increased investments from investors, NGOs, and governments, has been beneficial. However, the sustainability of these initiatives and funding remains a concern, as the existing challenges, such as structural problems and inadequate teacher training, persist in many countries. Despite these challenges, some countries are making attempts to develop the capacity of teachers through teacher development programmes. These efforts are still limited, and many countries still need to explore such initiatives if they are to have a skilled workforce for effective ed-tech deployment.

While ed-tech implementation during COVID-19 faced challenges, it also introduced a new wave of ed-tech awareness, increased appreciation of technology in the learning

system, and evidence that ed-tech has the potential to complement traditional learning systems to improve outcomes. In particular, ed-tech offers opportunities to reach both unserved and underserved populations in the education system without in-person contact and at a reduced cost. From Nigeria to Kenya, South Africa, and Rwanda, ed-tech companies are using the opportunity to innovate around existing products to serve customers they could not reach prior to COVID-19. More ed-tech initiatives are also emerging to serve identified educational needs. While not a substitute, this can go some way to filling the existing gaps in ed-tech funding from the government across different countries in the region.

In conclusion, low levels of ed-tech adoption, coupled with the challenges faced by marginalised households, underscore the need for comprehensive support from governments, addressing inequalities in access, and ensuring long-term sustainability. Moreover, policy should be driven by interests in education quality, rather than politics, by sustaining ed-tech initiatives, promoting stakeholder collaboration, and increasing funding commitments for ed-tech adoption. This will allow governments to overcome structural obstacles and improve teacher training for successful implementation in primary and secondary education. It is also crucial for ensuring a more equitable and effective integration of ed-tech in primary and secondary education across the region. Specifically, the provision of supportive infrastructure such as electricity, internet connectivity, and digital devices is vital for ed-tech to be able to drive improvements in education quality.

It is important to acknowledge that this study has limitations in providing comprehensive evidence for all countries. Consequently, there are gaps warranting in-depth investigation at the country-specific level. To address these gaps effectively, building on the findings presented here, it is imperative to conduct a detailed mapping of national digital learning platforms in each sub-Saharan African country, enabling a better understanding of disparities in ed-tech deployment. Moreover, particular attention should be paid to gathering information regarding investments in digital education and ed-tech from governmental sources, private sectors, and international donors. Additionally, there is a need to further explore the impact of ed-tech on the learning outcomes of vulnerable demographic groups, recognising its potential role in both pre-service and in-service teacher training. The study has highlighted the importance of a political economy lens for assessing the sustainability of ed-tech policy. Lastly, it has flagged that decentralisation can also create inequality in terms of the allocation of funds for ed-tech. Moving forward, it will be important to unravel the drivers of such inequality.

References

Abubakar, L., & Saka, K. A. (2021). Relationships among ICT Training, Skills Acquisition: Use and Job Performance of Library Personnel in Universities in North-West Nigeria. *Library Philosophy and Practice (e-journal 4917).* http://repository.futminna.edu.ng:8080/jspui/handle/123456789/3034

ADEA. (2020). Delivering education at home amid the Covid-19 pandemic: Country status report. https://www.adeanet.org/en/publications/delivering-education-home-african-member-states-amid-covid-19-pandemic-country-status

ADEA, AU/CIEFFA, & APHRC (2021). School Reopening in Africa during the COVID-19 Pandemic. Abidjan, Ouagadougou, Nairobi: ADEA, AU/CIEFFA, APHRC. https://www.afrobarometer.org/wp-content/uploads/migrated/files/publications/Policy%20papers/pp66-africas_digital_divide_and_the_promise_of_e-learning-afrobarometer_policy_paper-14june20.pdf

Adebayo, S. A., Olusegun, S., Iyamu, E. O. S., & Ogunleye, O. A. (2020). E-learning governance model: The Nigerian perspective. In D. G. Sampson, & P. Isaías (Eds.), *Proceedings of the 18th International Conference on Cognition and Exploratory Learning in the Digital Age (CELDA 2020)* (pp. 303-310). IADIS Press.

Adu, D. & Olawepo, S. (2023). Nigeria: Unveiling the Electricity Act, 2023: Changes in the Power Sector, Opportunities And The Next Steps. *Famsville Solicitors*. https://www.mondaq.com/nigeria/renewables/1336450/unveiling-the-electricity-act-2023-changes-in-the-power-sector-opportunities-and-the-next-steps

Afrobarometer. (2022). *Round 9 survey manual*. https://www.afrobarometer.org/wp-content/uploads/2022/07/AB_R9.-Survey-Manual_eng_FINAL_20jul22.pdf

Afrobarometer. (2023a). *Data from Survey 2016/2018*. https://www.afrobarometer.org/data/data-sets/

Afrobarometer. (2023b). *Data from Survey 2019/2021*. https://www.afrobarometer.org/data/data-sets/

Angrist, N., Beatty A., & Croslley C. (2023, May 8). 20 for 20: The Tutor Is Calling -Targeted instruction by phone boosts learning across six countries. J-Pal. https://www.povertyactionlab.org/blog/5-8-23/20-20-tutor-calling-targeted-instruction-phone-boosts-learning-across-six-countries

Angrist, N., Bergman, P., & Matsheng, M. (2020). School's out: Experimental evidence on limiting learning loss using "low-tech" in a pandemic (Working Paper No. 28205). National Bureau of Economic Research.

Aruleba, K. & Jere, N. (2022). Exploring the digital transformation challenges in rural areas of South Africa through systematic review of empirical studies. *Scientific African, 16*, e01190. https://doi.org/10.1016/j.sciaf.2022.e01190

Augustine, A. (2023). Africa's edtech startups remain bullish despite funding decline. TechCabal. https://techcabal.com/2023/03/04/edtech-startups-africa/

Ayega, D. (2020). Pandemics and education in Sub-Saharan Africa: Invest in education technology. *American Journal of Educational Research, 8*(8), 581-586. https://doi.org/10.12691/education-8-8-10

Azevedo, J. P., Wagner, D., Rogers, F. H., Cloutier, M.-H., Chakroun, B., Chang, G.-C., & Mizunoya, S. (2021). The State of the Global Education Crisis : A Path to Recovery. UNESCO, UNICEF, World Bank. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/416991638768297704/The-State-of-the-Global-Education-Crisis-A-Path-to-Recovery

Banuelos. (2021). Investments Show Hope that Technology Increases Literacy Rates in Benin. *BORGEN Magazine.* https://www.borgenmagazine.com/technology-increases-literacy-rates-in-benin/

Basar, Z. M., Mansor, A. N., Jamaludin, K. A. & Alisa, B. S. (2021). The Effectiveness and Challenges of Online Learning for Secondary School Students – A Case Study. *Asian Journal of University Education, 17*(3), 119-129. https://doi.org/10.24191/ajue.v17i3.14514

Bediang, G., Stoll, B., Geissbuhler, A., Klohn, A. M., Stuckelberger, A., Nko'o, S., & Chastonay, P. (2013). Computer literacy and E-learning perception in Cameroon: the case of Yaounde Faculty of Medicine and Biomedical Sciences. *BMC medical education, 13*(57), 1-8. https://doi.org/10.1186/1472-6920-13-57

Beoku-Betts, I., Plaut, D., & Tanweer, R. (2022, August 18). Using technology to support teacher continuous professional development in Sierra Leone. *EdTech Hub.* https://ed-techhub.org/2022/08/18/using-technology-to-support-teacher-continuous-professional-development-in-sierra-leone/

Brunette, R., Klaaren, J. & Nqaba, P. (2019). Reform in the contract state: Embedded directions in public procurement regulation in South Africa. Development Southern Africa, 36(4), 537-554. https://doi.org/10.1080/0376835X.2019.1599712

Burns, M. (2020). Educational Technology Trends in African Secondary Education Policy. *ICTworks.* https://www.ictworks.org/edutech-trends-african-secondary-education-policy/#.Y-YAQXbMLIU

Cantrell, S., Oviawe, J., Chen, L., Buttweiler, M. & Nash, S. (2019). *The EdoBEST Effect.* https://issuu.com/newglobe/docs/1._the_edobest_effect_-_study_of_gains_in_edo_nig?fr=sNjc5YzQwNTIxMDg

Chama, A., & Subaveerapandiyan, A. (2023). Digital Literacy Skills of Teachers: A Study on ICT Use and Purposes. *SSRN.* http://dx.doi.org/10.2139/ssrn.4492414

CyberSmart Africa. (2020). The Digital Life of African Teachers - Top Ten Takeaways for Telecoms. https://www.slideshare.net/newsbunny/the-digital-life-of-african-teachers-top-ten-takeaways-for-telecoms

Dahir, A.L. (2016). Smartphone use has doubled in Africa in two years. *QUARTZ.* https://qz.com/africa/748354/smartphone-use-has-more-than-doubled-in-africa-in-two-years

Damani, K. & Mitchell, J. (2020). *Radio: Rapid Evidence Review.* Ed-techHub. https://edtechhub.org/wp-content/uploads/2020/09/Rapid-Evidence-Review_-Radio-1.pdf

De Barros, R. P., de Carvalho, M., Franco, S., Garcia, B., Henriques, R., & Machado, L. (2019). Assessment of the Impact of the Jovem de Futuro Program on Learning. *World Bank*. http://documents1.worldbank.org/curated/en/825101561723584640/pdf/Assessment-of-the-Impact-of-the-Jovem-de-Futuro-Program-on-Learning.pdf

Degbedzui. (2018). Doing EdTech right in Africa. *Machine Intelligence Institute of Africa.* https://miiafrica.org/2018/10/08/doing-edtech-right-in-africa/

Dele-Ajayi, O., & Taddese, A. (2020). *Ed-tech in Nigeria: A Rapid Scan*. (Country Scan No. 08). Ed-tech Hub. https://doi.org/10.53832/edtechhub.0034

De Hoyos Navarro, R. E., Ganimian, A. J., & Holland, P. (2017). T*eaching with the test: experimental evidence on diagnostic feedback and capacity building for public schools in Argentina* (World Bank Policy Research Working Paper, No. 8261). https://hdl.handle.net/20.500.12799/5732

Digischool (n.d.). The Laptop Project: Executive Summary. Digischool Management System. https://www.digischool.go.ke/Home/executivesummary

Disrupt Africa. (2022). *The African Tech Startups Funding Report*. https://disrupt-africa.com/wp-content/uploads/2023/02/The-African-Tech-Startups-Funding-Report-2022.pdf

Edo State Universal Basic Education Board. (2022). *EdoBEST 3rd Year Results Report*. https://issuu.com/newglobe/docs/edobest_3rd_year_results_report_13_view_only?fr=sY2FmMDU1ODQxNDk

Edo State Universal Basic Education Board. (n.d.). Edo Basic Education Sector Transformation. https://edobest.org.ng/about-us/

Education Outcomes Fund. (n.d.) *The Sierra Leone Education Innovation Challenge.* https://www.educationoutcomesfund.org/post/the-sierra-leone-education-innovation-challenge

eLearning Africa. (2020). The Effect of Covid-19 on Education in Africa and its Implications for the Use of Technology: A Survey of the Experience and Opinions of Educators and Technology Specialists. *EdTech Hub*. https://www.elearning-africa.com/reports_surveys_COVID19.php

Evans, D. K., & Yuan, F. (2022). How Big Are Effect Sizes in International Education Studies? *Educational Evaluation and Policy Analysis, 44*(3), 532–540. https://doi.org/10.3102/01623737221079646

Federal Ministry of Education of Nigeria. (2019a). *National Implementation Guidelines for ICT in Education*. https://education.gov.ng/wp-content/uploads/2019/07/NATIONAL-IMPLEMENTATION-GUIDELINES-FOR-ICT-IN-EDUCATION-2019.pdf

Federal Ministry of Education of Nigeria. (2019b). *National Policy on ICT in Education.* https://education.gov.ng/wp-content/uploads/2019/08/NATIONAL-POLICY-ON-ICT-IN-EDUCATION-2019.pdf

French Development Agency & UNESCO. (2015). *Digital Services for Education in Africa.* https://unesdoc.unesco.org/ark:/48223/pf0000231867

Ghana Education Service. (2020). Ghana Learning TV: Lessons Learnt, Challenges, and the Way Forward. Government of Ghana.

Gondwe, F. (2021). Technology professional development for teacher educators: A literature review and proposal for further research. *SN Social Sciences, 1(8),* 200. https://doi.org/10.1007/s43545-021-00184-9

GSMA. (2020). Education For All in the Time of COVID-19: How ed-tech can be Part of the Solution. *GSMA*. https://www.gsma.com/mobilefordevelopment/resources/education-for-all-in-the-time-of-covid-19-how-edtech-can-be-part-of-the-solution/

Gutschmidt, B. P. (2013). *One Laptop Per Child in Rural Kenya: Student Perceptions about Computers, School and Self-Efficacy after One Year with XO Laptops and Constructionist Learning.* [Master's thesis, University of Washingtom]. https://digital.lib.washington.edu/researchworks/handle/1773/22901

Haleem, A., Javaid, M., Qadri, M. A., & Suman, R. (2022). Understanding the role of digital technologies in education: A review. *Sustainable Operations and Computers, 3,* 275-285. https://doi.org/10.1016/j.susoc.2022.05.004

Harrison, D. (2018). The political economy of educational technology in Africa. *Information Technologies & International Development, 14*(1), 61-74.

Haßler, B., Nicolai, S., McBurnie, C., Jordan, K., Wilson, S., Kreimeia, A., & Bortsie, E. (2020). *Ed-tech and COVID-19 response [Save Our Future]* (Background Paper No. 3; #SaveOurFuture). https://docs.edtechhub.org/lib/SXDQAPB6

Hennessy, S., D'Angelo, S., McIntyre, N., Koomar, S., Kreimeia, A., Cao, L., Brugha, M., & Zubairi, A. (2022). Technology use for teacher professional development in low-and middle-income countries: A systematic review. *Computers and Education Open, 3,* 100080. https://doi.org/10.1016/j.caeo.2022.100080

Heystek, J., Prinsloo, P., & Gachago, D. (2018). Ed-tech in South Africa: A landscape report. University of Cape Town.

Human Rights Watch. (2020, August 26). Impact of Covid-19 on Children's Education in Africa. 35th Ordinary Session of the African Committee of Experts on the Rights and Welfare of the Child. https://www.hrw.org/news/2020/08/26/impact-covid-19-childrens-education-africa

Iji, O., Uwazie, I., & Alaka, H. (2020). An analysis of procurement challenges in the Nigerian educational sector. *Journal of Information Technology Education: Research, 19,* 389-406.

International Monetary Fund. (2018). Sub-Saharan Africa: The Regional Economic Outlook. Domestic Revenue Mobilization and Private Investment. https://www.imf.org/en/Publications/REO/SSA/Issues/2018/04/30/sreo0518

Karsenti, T., Collin, S., & Harper-Merrett, T. (2011). *Pedagogical Integration of ICT: Successes and Challenges from 100+ African Schools January 2011.* IRDC.

https://www.researchgate.net/publication/267544398_Pedagogical_Integration_of_ICT_Successes_and_Challenges_from_100_African_Schools

Kweku, D. (2018). Doing EdTech right in Africa. *Machine Intelligence Institute Africa.* https://miiafrica.org/2018/10/08/doing-edtech-right-in-africa/

Khan, M. S. H., Hasan, M., & Clement, C. K. (2012). Barriers to the introduction of ICT into education in developing countries: The example of Bangladesh. *International Journal of instruction, 5*(2), 61-80. https://www.e-iji.net/dosyalar/iji_2012_2_4.pdf

Kimenyi, E., Chuang, R., & Taddese, A. (2020). *Ed-tech in Rwanda: A Rapid Scan* (No. 11). Ed-tech Hub. DOI: 10.5281/zenodo.3910001.

Koomar, S., Massam, W., Anthony, G., Mrope, W., Adam, T., Hennessy, S., Mtenzi, F., Proctor, J., Komba, A., Mwakabungu, F., and Barretto, J. (2023, March 3). MEWAKA in Tanzania: Emerging findings on tech-supported teacher professional development. *EdTech Hub.* https://ed-techhub.org/2023/03/03/mewaka-in-tanzania-emerging-findings-on-tech-supported-teacher-professional-development/

Krönke, M. (2020). *Africa's digital divide and the promise of e-learning.* (Afrobarometer Policy Paper No. 66). https://africaportal.org/publication/africas-digital-divide-and-promise-e-learning/

Kumasewera. P. (2021). A new system for digital education in Malawi. *Global Partnership for Education.* https://www.globalpartnership.org/blog/new-system-digital-education-malawi

Languille, S. (2016). 'Affordable' private schools in South Africa. Affordable for whom? *Oxford Review of Education, 42*(5), 528-542. https://doi.org/10.1080/03054985.2016.1220086

Lawal, I. (2017, July 20). 65 % of Nigerian schools lack electricity, says UN chief. *The Guardian.* https://guardian.ng/features/65-of-nigerian-schools-lack-electricity-says-un-chief/

Makgato, M. (2014). The Challenges of Teaching and Learning Technology Subject at Schools in South Africa: A Case of INSET Teachers in Mpumalanga Province. Procedia - Social and Behavioral Sciences, 116, 3688–3692. https://doi.org/10.1016/j.sbspro.2014.01.824

Manyasa, E. (2022). *Assessing the impact of ICT integration policy on the equitable access to quality education in African contexts: the case of Kenya.* Global Education Monitoring Group, UNESCO. https://gem-report-2021.unesco.org/wp-content/uploads/2022/06/EM_.pdf

Matthews, K., Janicki, T., He, L., & Patterson, L. (2012). Implementation of an automated grading system with an adaptive learning component to affect student feedback and response time. *Journal of Information Systems Education, 23*(1), 71-84. https://aisel.aisnet.org/jise/vol23/iss1/7

McBurnie, C. (2021). *Navigating the 'Data Revolution': A Case Study on the One Tablet Per School Programme in Sierra Leone* (Working Paper). Edtech Hub.

https://docs.ed-techhub.org/lib/FEXGB4IJ/download/XPYQTXMG/Navigating%20the%20%E2%80%98Data%20Revolution%E2%80%99_%20A%20Case%20Study%20on%20the%20One%20Tablet%20Per%20School%20Programme%20in%20Sierra%20Leone.pdf

Meckes, L., & Carrasco, R. (2010). Two decades of SIMCE: an overview of the National Assessment System in Chile. *Assessment in education: Principles, policy & practice, 17*(2), 233-248. https://doi.org/10.1080/09695941003696214

Ministry of Basic and Senior Secondary Education. (2020). *National Curriculum Framework & Guidelines for Basic Education*. Sierra Leone. https://mbsse.gov.sl/wp-content/uploads/2021/07/Basic-Education-Curriculum-Framework.pdf

Ministry of Education and Vocational Training. (2007). *Information & Communication Technology (ICT) Policy for Basic education* (Policy Document) (pp. 1–30). Ministry of Education and Vocational Training (MoEVT). http://www.moe.go.tz/index.php?option=com_docman&task=doc_download&gid=226&Itemid=619

Mize, B. (2011). *Teachers' perceptions of the impact of online grading systems.* [Electronic Theses and Dissertations Paper 1321, East Tennessee State University]. https://dc.etsu.edu/etd/1321

Mo Ibrahim Foundation. (2021). COVID-19 in Africa, on one year on: impacts and prospects. https://mo.ibrahim.foundation/sites/default/files/2021-06/2021-forum-report.pdf

Muhamad, K. F. (2014). *Kenya's One Laptop per Child Policy; a Critique.* https://www.academia.edu/21810609/Kenyas_One_Laptop_per_Child_Policy_a_Critique

Mullan, J., & Taddese, A. (2020). *Ed-tech in Sierra Leone: A Rapid Scan. (Country Scan No. 3).* EdTech Hub. https://doi.org/10.53832/edtechhub.0038

Mutua, W. (2013). Kenya's Laptops for Children Initiative: A comprehensive opinion on the Kenya government laptop project.

Mwalongo, A. (2011). Teachers' perceptions about ICTs for teaching, professional development, administration and personal use. *International Journal of Education and Development using ICT, 7*(3), 36-49. https://www.learntechlib.org/p/42357/.

Neuman, M. J., & Powers, S. (2021). Political prioritisation of early childhood education in low-and middle-income countries. International Journal of Educational Development, 86, 102458. https://doi.org/10.1016/j.ijedudev.2021.102458

New Globe. (n. d.). *EdoBEST 2.0 reform: A new chapter for Edo State Universal Basic Education*. New Globe. https://newglobe.education/edobest-2-0-reform-a-new-chapter-for-edo-state-universal-basic-education/

Ngeze, L. V. (2017). ICT integration in teaching and learning in secondary schools in Tanzania: Readiness and way forward. *International Journal of Information and Education Technology, 7*(6), 424-427. https://www.researchgate.net/profile/Lucian-Ngeze/publication/305876096_ICT_Integration_in_Teaching_and_Learning_in_Secondary_Schools_in_Tanzania_Readiness_and_Way_Forward/

links/5a12c6410f7e9bd1b2c12335/ICT-Integration-in-Teaching-and-Learning-in-Secondary-Schools-in-Tanzania-Readiness-and-Way-Forward.pdf

Ngware M., & Ochieng, V. (2020). *Ed-tech and the COVID-19 response in Kenya* (Case Study). Ed-tech Hub. https://docs.edtechhub.org/lib/SMLIMS2X

National Information Technology Development Agency. (n.d.). National Information Technology Development Agency. https://nitda.gov.ng/

Nsolly, N. B., & Charlotte, N. M. (2016). Integration of ICTs into the curriculum of Cameroon primary and secondary schools: a review of current status, barriers and proposed strategies for effective Integration. *International Journal of Education and Development using ICT, 12*(1), 89-106. https://files.eric.ed.gov/fulltext/EJ1099586.pdf

Ochieng, V. O., Asego, C. S., & Gyasi, R. M. (2023). The place of academia and industry in the adoption and adaptation of educational technologies for a post-COVID-19 recovery in Africa. *Scientific African, 20,* e01658. https://doi.org/10.1016/j.sciaf.2023.e01658

Oduor, A. (2021). Jubilee laptops project that failed Kenyan child. *The Standard.* https://www.standardmedia.co.ke/the-standard-insider/article/2001369323/jubilee-laptops-project-that-failed-kenyan-child

Organisation for Economic Co-operation and Development. (2017). *The Funding of School Education: Connecting Resources and Learning.* OECD Publishing. http://dx.doi.org/10.1787/9789264276147-en

Organisation for Economic Co-operation and Development. (2020). *COVID-19 in Africa: Regional socioeconomic implications and policy priorities.* OECD Publishing. https://www.oecd.org/coronavirus/policy-responses/covid-19-and-africa-socioeconomic-implications-and-policy-responses-96e1b282/

Olayinka. A. R. B. (2016). Effects of Instructional Materials on Secondary Schools Students' Academic Achievement in Social Studies in Ekiti State, Nigeria. *World Journal of Education, 6*(1), 32-39. https://eric.ed.gov/?id=EJ1158251

Oneyibo, O. (2021, November 18). Technology, funding, learning models: What is the next frontier for ed-tech startups in Africa? *Techpoint Africa.* https://techpoint.africa/2021/11/18/the-next-frontier-ed-tech/

Oshodi. (2022). *A review of the impact of Education Technology in developing countries* (A case study of Nigeria). http://dx.doi.org/10.13140/RG.2.2.10596.30084

Otieno, J., & Taddese, A. (2020). *EdTech in Kenya: A Rapid Scan (Country Scan No. 7).* EdTech Hub. https://doi.org/10.53832/edtechhub.0032

Padayachee, K. (2017). A snapshot survey of ICT integration in South African schools. *South African Computer Journal, 29*(2), 36-65. https://hdl.handle.net/10520/EJC-c5c2b5952

Pallaruelo, M. P., Ngom, M. & Walker, O. (2022). Ed-tech for Improved Learning Outcomes for Primary and Secondary Students in Kenya. L*ondon School of Economics–Sochin Research Institute.* https://static1.squarespace.

com/static/593d2e8ad1758ea7078001e6/t/6246cbc9f42e9d07e4bc19ca/1648806865719/Ed-tech+for+Improved+Learning+Outcomes+for+primary+and+secondary+students+in+Kenya.pdf

Parliamentary Monitoring Group. (2016). *Provision of ICT in schools: Department of basic education & department of telecommunications and postal services briefing.* https://pmg.org.za/committee-meeting/22096/

Pellini, A., Nicolai, S., McGee, A., Sharp, S., & Wilson, S. (2021). *A Political Economy Analysis Framework for Ed-tech Evidence Uptake*. (Ed-tech Hub: Policy Brief). https://doi.org/10.5281/zenodo.4540204

Regan, P. M., & Khwaja, E. T. (2019). Mapping the political economy of education technology: A networks perspective. *Policy Futures in Education, 17*(8), 1000-1023. https://doi.org/10.1177/147821031881949

Republic of South Africa. (2018). *National Integrated ICT White Paper.* https://www.gov.za/sites/default/files/gcis_document/201610/40325gon1212.pdf

Rodriguez-Segura, D. (2022). Ed-tech in developing countries: A review of the evidence. *The World Bank Research Observer, 37*(2), 171-203. https://doi.org/10.1093/wbro/lkab011

Roser, M. & Ortiz-Ospina, E. (2023). Primary and Secondary Education. Our World in Data.

Schmitt, L. (2021, August 17). Scaling personalized learning technology in Malawi: Lessons from our sandbox with onebillion. *EdTech Hub.* https://edtechhub.org/2021/08/17/scaling-personalized-learning-technology-in-malawi-lessons-from-our-sandbox-with-onebillion/

South African Government. (2010). *Teacher laptop initiative rollout launch.* Republic of South Africa. https://www.gov.za/teacher-laptop-initiative-rollout-launch#:~:text=The%20Teacher%20Laptop%20Initiative%20(TLI)%2C%20managed%20by%20the%20Education,overall%20quality%20of%20education%20by

Tanzanian Ministry of Communications and Transport. (2003). *National Information and Communications Technologies Policy.* http://www.tzonline.org/pdf/ictpolicy2003.pdf

Tembey, L., Baier, J., Ogolla, C., & Mohan, P. (2021). *Understanding Barriers to Girls' Access and Use of EdTech in Kenya During Covid-19* [Working Paper]. EdTech Hub and Busara Center for Behavioural Economics. https://doi.org/10.53832/edtechhub.0048

TechCrunch. (2023). Co-Creation Hub's ed-tech accelerator puts $15m towards African startups. https://techcrunch.com/2023/02/17/co-creation-hubs-ed-tech-accelerator-puts-15m-towards-african-startups/

Tetang, T. J. (2007). Survey of ICT and education in Africa: Cameroon Country Report. Survey of ICT in Education in Cameroon. In G. Farrell & S. Isaacs (Eds.), *Survey of ICT and Education in Africa, Country Reports, 2*(53). World Bank.

The Baobab Network. (2019, November 6). Training the Next Generation: Mapping the Ed-tech Ecosystem. https://insights.thebaobabnetwork.com/training-the-next-generation-mapping-the-ed-tech-ecosystem/

The Economist. (2023, January 26). Most children in poor countries are being failed by their schools. https://www.economist.com/international/2023/01/26/most-children-in-poor-countries-are-being-failed-by-their-schools

United Nations & Inter-agency Task Force on Financing for Development (2021). Financing for Sustainable Development Report. https://www.un.org/en/desa/financing-sustainable-development-report

United Nations Development Programme. (2020). *The next frontier: Human Development and the Anthropocene. Human Development Report 2020.* https://hdr.undp.org/content/human-development-report-2020

United Nations Educational, Scientific and Cultural Organization. (2019). *New Methodology shows that 258 million Children, Adolescents and Youth are Out of School* (Fact Sheet No. 56). UNESCO. https://uis.unesco.org/sites/default/files/documents/new-methodology-shows-258-million-children-adolescents-and-youth-are-out-school.pdf

United Nations Educational, Scientific and Cultural Organization. (2022). *Education in Africa: 5 priorities: demographics, financing, inclusion, quality, employment*. UNESCO. https://unesdoc.unesco.org/ark:/48223/pf0000381100

United Nations International Children's Emergency Fund & International Telecommunication Union. (2020). *How Many Children and Youth Have Internet Access at Home?* UNICEF. https://www.unicef.org/press-releases/two-thirds-worlds-school-age-children-have-no-internet-access-home-new-unicef-itu

United Nations International Children's Emergency Fund. (2021). *Transforming Education in Africa: an evidence-based overview and recommendations for long-term improvements.* UNICEF. https://www.unicef.org/reports/transforming-education-africa

United Nations International Children's Emergency Fund. (2022). The Impacts of COVID-19 on Education Spending in Africa and Possible Recovery Pathways. Education and Social Policy Working Paper. UNICEF Africa. https://www.unicef.org/esa/media/11486/file/Impacts-COVID-19-Education-Spending-Africa-Possible-Recovery-Pathways.pdf

United Nations International Children's Emergency Fund. (2023, September 2). *Federal Ministry of Education and UNICEF Celebrate 500,000 Registered Users on the Nigeria Learning Passport.* UNICEF. https://www.unicef.org/nigeria/press-releases/federal-ministry-education-and-unicef-celebrate-500000-registered-users-nigeria

United Nations, Inter-agency Task Force on Financing for Development (2021). Financing for Sustainable Development Report. New York: United Nations. Available from: https://developmentfinance.un.org/fsdr2021.

United Republic of Tanzania, Planning Commission. (2010). *The Tanzania Development Vision 2025*. http://www.tzonline.org/pdf/theTanzaniadevelopmentvision.pdf

Upadhyay, A., & Taddese, A. (2020). *EdTech in Senegal: A Rapid Scan* (Country Scan No. 9). EdTech Hub. https://doi.org/10.53832/edtechhub.0037

UVU Africa. (2022). Bolstering innovative Ed-tech to improve Africa's education system. https://uvuafrica.com/news/bolstering-innovative-ed-tech-to-improve-africas-education-system/

Uwezo. (2020). Are Our Children Learning? The Status of Remote-learning among School-going Children in Kenya during the COVID-19 crisis. Nairobi: Usawa Agenda. https://www.humanitarianresponse.info/es/operations/kenya/document/uwezo-2020-are-our-children-learning-status-remote-learning-among-school

Vegas, E., Zieglar, L. & Zerbino, N. (2019). How ed-tech can help leapfrog progress in education. Brookings. https://www.brookings.edu/articles/how-ed-tech-can-help-leapfrog-progress-in-education/

Vodacom. (2017). Virtual Teaching Becomes A Reality Through New Education Technology. *Vodacom*. https://now.vodacom.co.za/article/your-child-and-e-learning

Watson, J. (2020, March 31). Learning through television in low-income contexts: mitigating the impact of coronavirus (COVID-19). *Ed-tech Hub*. https://ed-techhub.org/2020/03/31/learning-through-television-in-low-income-contexts-mitigating-the-impact-of-covid-19/

Winthrop, R. (2022). Improving access to quality public education in Africa. *Brookings*. https://www.brookings.edu/articles/improving-access-to-quality-public-education-in-africa/

World Bank. (2018). *Learning to Realize Education's Promise*. https://www.worldbank.org/en/publication/wdr2018

World Bank. (2021a). Learning Poverty Measure. https://www.worldbank.org/en/topic/education/brief/learning-poverty-measure

Word Bank (2021b). Remote Learning During COVID-19 Lockdown is Preventing Learning Loss in Nigeria. *The World Bank*. https://www.worldbank.org/en/news/feature/2021/12/08/remote-learning-during-covid-19-lockdown-is-preventing-learning-loss-in-nigeria

World Bank. (2022). World Development Indicators [Data]. https://databank.worldbank.org/source/world-development-indicators

World Bank. (2023). From Connectivity to Services: Digital Transformation in Africa. *The World Bank*. https://www.worldbank.org/en/results/2023/06/26/from-connectivity-to-services-digital-transformation-in-africa

World Bank, United Nations Educational, Scientific and Cultural Organization, United Nations International Children's Emergency Fund, United States Agency for International Development, Foreign Commonwealth & Development Office, & Foundation Bill and Melinda Gates. (2022). The State of Global Learning Poverty: 2022 Update. https://www.unicef.org/reports/state-global-learning-poverty-2022on.pdf

World Bank. (2023). World Development Indicators [DataBank 2000-2018]. https://www.worldbank.org/en/results/2023/06/26/from-connectivity-to-services-digital-transformation-in-africa

World Economic Forum. (2017). *Africa Competitiveness Report 2017.* https://www.weforum.org/reports/africa-competitiveness-report-2017

World Reader. (n .d.). *Booksmart.* https://booksmart.worldreader.org/BookSmart

Youth Impact. (n. d.). Adapting to the Times Committed to the Cause: COVID-19 Response. https://www.youth-impact.org/covid-19response.

Annexes

Annex 1. Indicators relative to education

Countries	Demographics		Net enrolment (primary)	Net enrolment (secondary)	Completion (primary)	Student-teacher ratio	Out of school children (primary, %)
Nigeria	Gender	Male	69.95	NA	0.81	NA	0.27
		Female	58.11	NA	0.80	NA	0.27
	Level	Primary	64.14	NA	0.80	37.55	0.28
		Secondary	NA	NA	0.71	23.20	0.31
Sierra Leone	Gender	Male	94.74	42.52	0.64	NA	0.18
		Female	95.50	41.01	0.68	NA	0.15
	Level	Primary	98.11	NA	0.66	27.52	0.17
		Secondary	NA	41.77	0.43	22.04	0.24
Senegal	Gender	Male	71.27	35.94	0.47	NA	0.35
		Female	79.59	39.42	0.54	NA	0.27
	Level	Primary	75.38	NA	0.51	36.32	0.31
		Secondary	NA	37.67	0.28	18.88	0.47
Benin	Gender	Male	96.52	53.18	0.67	NA	0.1
		Female	83.58	39.81	0.59	NA	0.13
	Level	Primary	97.21	NA	0.62	39.20	0.12
		Secondary	NA	46.58	0.29	10.99	0.45

Kenya	Gender	Male	78.27	49.04	0.67	NA	0.08
		Female	81.69	45.80	0.81	NA	0.12
	Level	Primary	79.97	NA	0.74	30.65	0.09
		Secondary	NA	47.42	0.66	33.44	0.06
Rwanda	Gender	Male	94.44	32.93	0.52	NA	0.06
		Female	95.14	38.79	0.64	NA	0.04
	Level	Primary	94.79	NA	0.58	59.51	0.05
		Secondary	NA	35.87	0.29	28.25	0.09
Uganda	Gender	Male	94.10	23.74	0.38	NA	0.13
		Female	96.90	21.04	0.53	NA	0.1
	Level	Primary	95.49	NA	0.40	42.66	0.12
		Secondary	NA	22.37	0.34	18.47	0.33
Malawi	Gender	Male	91.95	33.72	0.40	NA	0.09
		Female	97.09	34.76	0.55	NA	0.08
	Level	Primary	97.65	NA	0.48	58.68	0.09
		Secondary	NA	34.24	0.25	72.31	0.2
Cameroon	Gender	Male	96.96	48.93	0.74	NA	0.12
		Female	88.72	43.03	0.79	NA	0.18
	Level	Primary	92.87	NA	0.76	44.83	0.14
		Secondary	NA	45.99	0.45	19.26	0.33
South Africa	Gender	Male	87.32	65.42	0.97	NA	0.09
		Female	86.70	78.52	0.98	NA	0.07
	Level	Primary	87.01	NA	0.98	30.33	0.08
		Secondary	NA	71.93	0.88	27.62	0.08

Note. Data from World Development Indicators (2021).

Annex 2. Characterisation of reviewed programs and interventions

Intervention aim	Intervention name	Description	Available country evaluations and studies	Country	Intervention years	Target population	Implementing Agency
To provide educational and cultural content with or without the internet.	EduAIrBox	EduAirbox is a media library created by EduAir that provides children with online and offline contents.	No existing study	Cameroon	2015 - present	Students and all learners	Private
To provide digital education tools to children.	Connect my School	Connect My School is an EU-funded UNICEF initiative aimed at connecting remote schools and students to technology and providing digital education tools to children from the far North of Cameroon.	Yijun Chen (2021)[33]	Cameroon	2017 - present	Out-of-school disabled children and teachers	Government
To facilitate access to quality learning to disadvantaged population.	Dastudy	Dastudy is a free online platform for sharing knowledge between students, learners and professionals. Students also have the opportunity to engage in self-learning.		Cameroon	2019 - present	Students, teachers and professionals.	Private
To integrate technology in teaching and learning in basic education.	Digital Literacy Programme (One Laptop per child)	The Digital Literacy Program is an initiative by the government of Kenya aimed at introducing primary school children to the use of digital technology and communication in learning.	Piper et al. (2017)[7]; Kaye (2021)[8]; Murithi & Yoo (2021)[9]; Uwezo (2020) [10]	Kenya	2016 - present	Grade 1 – 6 pupils	Government

To enhance early grade literacy quality.	Tusome Program	The Tusome program is a technology-enabled education intervention aimed at improving teacher quality and children's' literacy learning outcomes.	Kaye (2020)[11]; Piper et al. (2017) [12]; Piper et al. (2018)[13]	Kenya	2014-2022	Students and teachers	USAID
To improve learning outcomes of underserved learners.	Eneza Education	Eneza education is an ed-tech that offers a phone-based learning platform that enables users to access educational programs and ask questions to teachers through SMS (Myers et al., 2021).	Jordan & Mitchell (2020)[15]	Kenya	2011 - present	Learners (9-18) and teachers in rural communities	Private
To increase academic and digital literacy.	ELimu	ELimu is an ed-tech company that provides online and offline educational resources such as exam prep and lessons based on the Kenyan curriculum (USAID, 2022).	Margaret (2018)[17]	Kenya	2012 - present	Students and Teachers	Private
To improve the learning outcomes of children.	Community Based Learning Project	The Community-Based Learning project is an independent project by Onebillion across two rural villages to provide children with online courses through mobile devices.	No existing study	Kenya	2018-2019	Children aged 5 - 11	onebillion
To improve the quality of primary school education.	Unlocking Talent Initiative	Unlocking talent is an initiative made up of an alliance of partners focused on using education technology to help overcome the education challenges that hold learners back.[34]	Levasque et. al. (2022)[35]; Pitchford (2022)[36]	Malawi	2013 - present	Student and teachers	Government
To support children's learning at home.	Onetabs	Onetabs is an intervention introduced by Onebillion to support children's learning at home in response to to the closure of schools during the COVID-19 pandemic.[37]	Pitchford (2022)[38]	Malawi	2020 - present	Standards 2 and 3 students	The Tongole Foundation

To revolutionise and transform basic education	EdoBest	The EdoBEST initiative uses technology to enhance learning outcomes and streamline management in order to bring about widespread educational transformation in Edo State, Nigeria.	Oviawe et al. (2019)[1]; Alohan et al. (2021)[2]	Nigeria	2018 - present	Students and Teachers across all Basic Schools	Government
To improve literacy and Numeracy learning outcomes.	Mavis Talking Book	The Mavis Talking book initiative by the Mavis Computel aims to take education to rural communities in Nigeria by teaching subjects in a learner's native language and making books affordable.	Adeeso-Olateiu & Olumide (2019)[3]	Nigeria	2014-present	Children in underserved communities.	Mavis Computel
To improve digital and STEM education.	DigiSTEM	DigiSTEM is a pilot project that aims to increase the digital literacy skills of young people in primary and secondary schools through focused STEM and digital activities (ed-tech Hub, 2020)	Dele-Ajayi, et al. (2021)[4]	Nigeria	2017-2020	Primary pupils (7-11); Secondary school students (12-16)	Government
To introduce learners in rural communities to digital literacy.	BDEI	The Basic Digital Education Initiative is a program aimed at providing learners in impoverished communities with the fundamental digital literacy skills they need to flourish in the world and workplace of the twenty-first century.	USAID (2022)[5];	Nigeria	2020 - present	Students within the ages of 8-18	Tech4Dev
To create high-quality, affordable education for life-long learners.	ULesson	uLesson is a technological education startup which aims to grant all Africans access to high-quality, cheap education through live online classrooms with qualified tutors, video lessons, and individualised live homework help via its app and website.	Adie, Bisong & Obuop (2021)[6]	Nigeria	2020 - present	Students in pPrimary and sSecondary levels of eEducation	Private

To enhance primary education through ICT.	One Laptop Per Child (OLPC)	The One Laptop per Child Programme is a key project that aims to enhance education through the introduction of technology in primary schools through digital, interactive and animated graphical contents.	Munyantore & Mbalire (2017)[24];	Rwanda	2008 - present	Students and teachers in Primary Schools	Government
To expand access to quality education through the use of ICT.	Rwanda Education Commons (REC)	The Rwanda Education Commons (REC) was a program created to encourage the efficient application of ICTs in the classroom through both online and offline resources (Kimenyi, Chuang & Taddese, 2020) [25]	No existing study	Rwanda	2008 - 2012	Teachers	FHI360
To improve the digital competence of teachers and to equip schools with digital gadgets.	Capacity Development for ICT in Education	Capacity Development for ICT in Education is an initiative by the Rwandan government to improve the digital competency of secondary school teachers as they equip schools with ICT equipment.	-	Rwanda	2017 - 2020	Primary and secondary school teachers and students	KOICA
To grant easy access to learning materials among students in Rwanda.	Smart Class	Smart class is an initiative that operates and manages an online learning platform that connects high school students learning academic subjects and provides them with access to valuable learning materials and high-quality teachers.[26]	No existing Study	Rwanda	2018 - present	Secondary school students	private
To improve the reading skills of public primary school students.	Lecture Pour Tous	Lecture Pour Tour is an early grade reading program that piloted a self-guided distance professional development program for teachers, coaches, and school inspectors (Chemonics, 2023).	Upadhyay & Taddese (2020)[19]	Senegal	2017 - 2021	Grade 1 – Grade 3	Chemonics International

To support Learning from home	Learn at Home	Learn at home is a government initiative aimed at providing students and teachers with teaching and learning resources to support distance learning.	Upadhyay & Taddese (2020)	Senegal	2020 - present	Teachers and Students in all levels of education coupled with parents.	Government
To improve the management of the education system, teaching practices and learning conditions.	Free Education Project	The Free Education project is a World bank-led program tailored towards developing and delivering scalable technology-enabled in-service teacher training.	No existing study	Sierra Leone	2019 – present	Teachers	Government
To improve reading outcomes in children aged 3-12.	World Reader	World Reader is a global initiative with three projects in Sierra Leone aimed at providing primary school pupils with e-Readers loaded with contents.	Vegas et al. (2019) [39]	Sierra Leone	2015 – present	Primary school pupils	Private
To find new ways to improve learning outcomes in primary schools.	Education Innovation Challenge (EIC)	The Education Innovation Challenge is a program targeted at improving literacy and innovation in schools using an outcome-based model.	Directory of Science, Technology and Innovation (2020) [40]	Sierra Leone	2019 - present	Primary school pupils	Government
To provide students with self-directed offline resources.	Mobile Learning Lab	The Mobile Learning Lab is a platform that makes learning resources and content available to off-grid communities.	60 million girls (2018)[41]	Sierra Leone	2016 - present	Students in Grades 4 -6	60 million girls
To improve the educational space in Africa.	Mwabu	Mwabu is a tablet-based and school improvement initiative focused on providing e-learning resources for students and teachers to improve the educational space in Africa.	Conn (2017)[20]	South Africa	2017 - present	Teachers and Students	Private

To offer quality, globally competitive education.	Spark Schools	Spark is a network of 19 primary schools and one high school in South African cities committed to delivering quality, high-access education.	Languille (2016)[21]	South Africa	2012 - present	Students and Teachers	Private
To promote equitable access to quality learning and teaching.	UkuFunda Virtual School (UVS)	UVS is an innovative m-learning service that uses a social-networking platform to provide access to learning resources.	Shafika, Nicky &Garth (2019) [22]; Garth & Nicky (2016)[23]	South Africa	2014 - 2016	Students	Government
To provide free learning contents to students and teachers.	Kolibri	Kolibri is a free, open source education technology platform that allows in- and out-of-school pupils and students to learn in their own space, while providing teachers or mentors with educational resources.	Kabugo (2020)[27]	Uganda	2019 - present	Students and teachers	Government
To improve maths and treading literacy in primary schools.	Can't Wait to Learn	Can't wait to learn is an ed-tech startup working in collaboration with the government of Rwanda to improve the literacy and numeracy skills of children using the gaming approach to learning.[28]	No existing study	Uganda	2017 – present	Primary schools and refugee children aged 10-14	War Child Holland in collaboration with Ministry of Education
To enhance access to quality education for underserved and refugee students.	Simbi	Simbi foundation is an initiative on a mission to enhance access to education for underserved and refugee students through solar-powered education technology innovations.[29]	Education in Emergencies (2019)[30]	Uganda	2015 - present	Pupil aged 6-12	NGO
To provide learning resources to students.	Yaaka Digital Learning Network	Yakaa Digital Network (YDN) is a digital media platform for students and trainers in all levels of education to learn, train and share academic resources.[31]	African Union (2020)[32]	Uganda	2015 – present	Students at all levels	Private

To provide access to digital education tools for better learning.	Kio kit	Kio Kit is a fully integrated education platform designed in Africa made up of 40 Kio tablets used to digitise the classroom.	-	Uganda	2015 - present	Students	Private

southernvoice.org
SVoice2030
@SVoice2030