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ALU AFRICAN LEADERSHIP UNIVERSITY

Artificial Intelligence in Sub-Saharan Africa

Education Report

Contents

1.

Executive Summary:
AI as a Bridge to Africa's Education Crisis

In the small village of Bunkure, northern Nigeria, 12-year old Aisha wakes before dawn to walk five kilometers to school each day. Her classroom is crowded, with over 70 students sharing a single teacher. Like many of her peers, Aisha struggles to keep up—not because she lacks intelligence or determination, but because the resources around her fall short of what she needs to thrive. Her school lacks enough textbooks, there are too few desks, so Aisha often stands during lessons, and with no computers or internet, the digital world remains out of reach for students like her. Her teacher, stretched thin, cannot provide the individual attention each student needs.

The conditions Aisha faces are a stark reflection of the systemic education challenges across sub-Saharan Africa. The region has the **highest** rates of education exclusion of the world regions. Aisha is bright and determined, but the odds are stacked against her. And her story reflects the fate of millions across sub-Saharan Africa, where the education system is buckling under the weight of resource shortages, overcrowded classrooms, and inadequate infrastructure.

Africa's education systems are under immense pressure. In sub-Saharan Africa, the average primary school class size **exceeds** 40 students, compared to the global **average** of 21. Today, more than **60% of youth aged 15 to 17** in sub-Saharan Africa are out of school, and of those who do attend, many face learning environments where basic necessities like textbooks and teachers are scarce. Furthermore, education is often expensive relative to household incomes, affecting access to education across Sub-Saharan Africa. For instance, the World Bank indicates that the **cost** of sending a child to school in Uganda varies from USD 68 for government schools to USD 420- USD 680 for private schools, in a country where 42% of the population live on **USD 785** per year. In stark contrast, OECD countries spent around **USD 10,000** per student per year at the primary level. This significant funding gap exemplifies the disparity in educational outcomes.

Only **9%** of young adults continue from secondary to tertiary education and nearly 90% of schools lack access to computers. These gaps translate into low literacy rates: more than **one in three** adults in sub-Saharan Africa cannot read, 48 million youth (ages 15-24) are **illiterate** and the region holds the highest number of illiterate youth. With limited resources, most teachers are overwhelmed, and even those with a passion for teaching find themselves unable to provide the personalised attention that students like Aisha desperately need. Furthermore, only 24% of secondary school teachers in Africa are trained to use digital tools in education, highlighting a critical skills gap.

60%

of 15 to 17 year olds are out of school

9%

of learners continue from secondary to tertiary education

90%

of schools lack access to computers

1 in 3

adults in Sub-Saharan Africa cannot read

Average primary school class size in sub-Saharan Africa:

40+

VS

Global average class size:

21

Annual cost of sending a child to school in Uganda:

$168

VS

Annual cost of primary school in OECD countries:

$10k

These statistics tell a story of a deep-rooted crisis: overcrowded classrooms, teacher shortages, and limited access to quality education. For rural communities, where infrastructure is lacking, the situation is even more dire. Around 82% of students in sub-Saharan Africa do not have access to the internet, and 89% lack computers at home, making it nearly impossible to bridge the digital divide.

If Aisha's educational trajectory doesn't change, she will likely join the ranks of the millions of children who are not in school. Without the skills needed to participate in a modern economy, her chances of finding a stable job will remain slim. This digital divide—where technology widens the gap between those who can access quality education and those who cannot—threatens to deepen, trapping millions of African children in a cycle of low opportunity and poverty.

But the story doesn't have to end here.

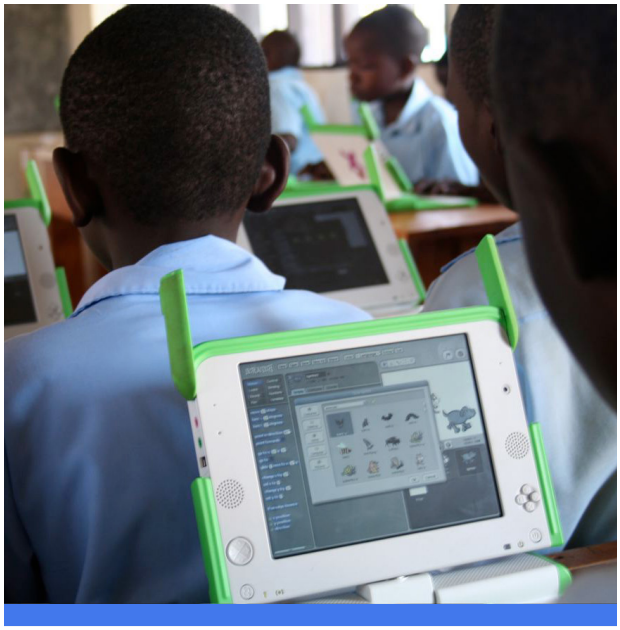
Artificial Intelligence (AI) potentially offers a lifeline to children like Aisha, presenting an opportunity to bridge the educational gaps in Africa. Perhaps by integrating AI into the continent's education systems, we might begin to address some of the most critical challenges.

> Innovative AI technologies are breaking down barriers by offering personalised, scalable, and localised learning solutions that can function even in resource-constrained environments.

From Ghana to South Africa, there are solid examples of AI's transformative potential for adaptive learning systems, intelligent tutoring, and multilingual education tools that support both students and teachers.

However, these opportunities are tempered by substantial barriers. In 2021, sub-Saharan Africa recorded a digital non-readiness score of 56.6%, indicating the significant infrastructural and readiness hurdles to fully leveraging AI technologies. This report explores the possibilities and obstacles of AI adoption in African education, focusing on six countries: Ghana, Nigeria, South Africa, Rwanda, Togo, and Kenya, although other African examples are referenced where relevant. It highlights success stories like **Foondamate** in South Africa, which provides educational resources in 13 languages through an AI-powered WhatsApp chatbot, and **Rori** in Ghana, an AI tutor helping over 45,000 children improve their math skills. By examining these real-world applications, we present a blueprint for harnessing AI to support more inclusive, equitable, and effective education systems across Africa. The key findings and recommendations outlined below provide a roadmap for stakeholders—

including policymakers, educators, and private sector partners—to harness AI's potential in creating a future where every African student has access to high-quality education, regardless of their geographic or socioeconomic conditions.



1.1 Key Findings

1. AI as a tool for overcoming infrastructure limitations

Many African schools, particularly in rural and underserved areas, lack reliable internet, electricity, and digital devices, limiting educational access. Offline-first AI-powered platforms such as those explored in this report, demonstrate how the technology can reach underserved regions by using mobile networks to deliver lessons, even in areas with limited or no internet access. In Kenya, platforms like **M-Shule** already deliver personalised lessons via SMS to students in areas without the internet, showing how AI can reach even the most remote learners. Virtual classrooms and AI-driven tutoring systems can bridge gaps in teacher availability, particularly in remote and rural areas. This support is essential in regions where teacher-to-student ratios can exceed 50:1.

2. Personalised learning for diverse student needs

AI AI-driven platforms like Nigeria's uLesson and Kenya's Eneza Education are providing students with personalised learning pathways, enabling individualised support in large, often overcrowded classrooms. These adaptive tools cater to each student's strengths and weaknesses, making learning more engaging and effective while addressing the constraints faced by teachers in managing large student-to-teacher ratios.

3. Support for multilingual and special needs education

Africa's linguistic diversity presents challenges to standardised education, but AI-powered natural language processing (NLP) can help bridge language gaps. NLP offers real-time translations and personalised content in local languages. Tools such as **Foondamate** in South Africa, which provides educational resources in 10 African languages, ensure that students across linguistic divides can access an education in their native languages. AI-driven accessibility tools, such as text-to-speech and speech-to-text, further enhance inclusivity for students with disabilities or literacy challenges.

4. Teacher-centric AI solutions to reduce workloads

Teachers are a critical leverage point in the education delivery value chain, and in African classrooms, often face high workloads and limited resources. AI tools, like **uLesson**'s teacher support system, reduce administrative tasks, including grading and lesson planning, aligning lesson plans with national curricula, and allowing teachers to focus more on instruction. AI can automate administrative tasks, such as grading, scheduling, and performance tracking, allowing educators to focus more on teaching.

5. Building a sustainable talent ecosystem

Developing a sustainable talent ecosystem that supports AI in education is essential for long-term success. This includes cultivating a network of local AI developers, curriculum experts, and technologists who can create and adapt AI solutions that meet Africa's unique needs. Collaborative initiatives with educational institutions and AI-focused training programs will be critical to building the necessary expertise and fostering innovation in the sector.

6. Fostering Global Competitiveness

By supporting critical thinking, problem-solving, and technological skills, AI-driven education can position Africa's youth to compete in the global digital economy. Institutions such as **Sprints AI** in Egypt are already leveraging AI to connect education with employment opportunities, ensuring that students are workforce-ready.

1.2 Challenges

1. Infrastructure and connectivity limitations

The digital divide is real, and while AI-powered offline and mobile-first solutions are addressing some infrastructural barriers, limited internet access, electricity shortages, and device scarcity remain substantial obstacles. Many schools in rural and underserved regions lack access to basic infrastructure such as reliable electricity and high-speed internet. As of 2021, 89% of learners do not have access to household computers. The situation is more dire in some countries than others. For instance, only 42% of Nigerian households have internet access, let alone the infrastructure required to support AI tools. The region faces a 56.6% digital non-readiness score, indicating significant gaps in the digital infrastructure required for effective AI integration in education.

of secondary school teachers have received training in digital technology

2. Digital Literacy and Skills Gaps

Limited digital literacy among both educators and students is a significant barrier to AI adoption. While AI can enhance teaching and learning, many educators are not sufficiently trained to integrate these technologies into their classrooms, and only 24% of secondary school teachers in the region have received training in digital technology, leading to underutilisation and resistance to change. Without proper capacity-building support, even AI tools with high impact potential will go underutilised.

3. Data and privacy concerns

Effective AI systems rely on vast amounts of data, which many African institutions struggle to collect and manage. Furthermore, issues surrounding data privacy, security, and ethical use of AI technologies are emerging as key concerns. Without proper data infrastructure and clear regulatory frameworks, the absence of trust in of AI-powered models may hinder meaningful integration.

4. High costs and resource disparities

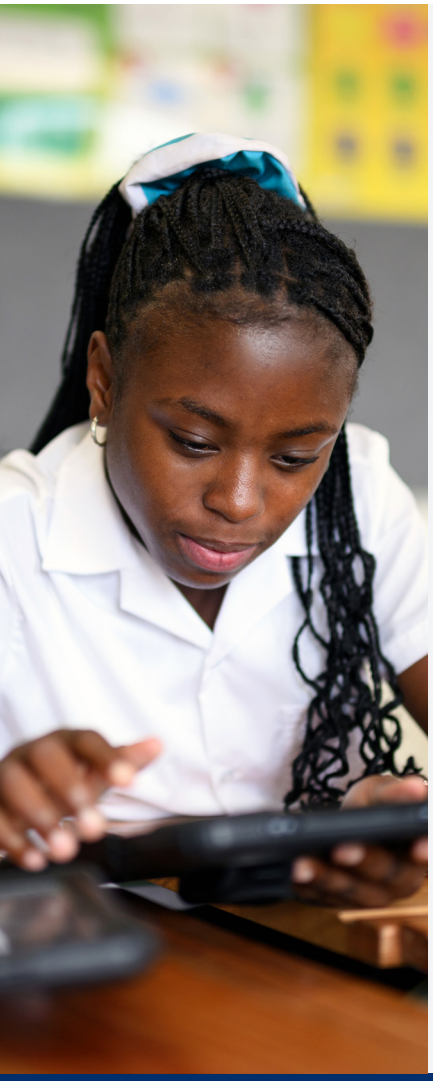
While AI offers scalable solutions for enhancing education, the technical and financial cost of deploying these technologies, particularly in schools with limited budgets, poses a significant challenge. Funding for AI in African education remains limited, with EdTech accounting for a small fraction of startup investment in the continent. Schools in under-resourced areas, particularly in rural regions, often struggle to allocate funds for AI integration, making it difficult to implement such tools effectively. Innovative financing mechanisms, such as public-private partnerships, social bonds, and impact investment, are needed to bridge the funding gap.

5. Widening educational inequities

The disparity between urban and rural areas, as well as between public and private schools, presents a critical challenge. If AI solutions are not deployed thoughtfully, they risk deepening existing inequalities rather than bridging them. Schools in wealthier regions with better infrastructure may benefit disproportionately, leaving behind students in more disadvantaged settings. Ensuring equitable access to AI tools, resources, and support will be essential to prevent the widening of the digital divide in education.

6. Bias and Linguistic Barriers

AI solutions, while often touted as tools for overcoming barriers in education, can inadvertently introduce bias when developed without consideration for local contexts. Many AI systems are created primarily for non-African environments, leading to misalignment with the unique cultures, languages, and educational goals found within Africa's diverse societies. This challenge is particularly pronounced in multilingual regions, where off-the-shelf AI solutions may overlook the needs of various linguistic groups, resulting in ineffective support for learners. As a result, there is an urgent need to develop localised datasets, particularly for language and cultural alignment, to ensure AI tools are relevant and effective.



1.3 A Call to Action

If we do not act now, the digital divide will continue to widen, and children like Aisha will remain trapped in a cycle of educational disadvantage.

Realising AI's potential for education will require coordinated efforts from governments, policymakers, educators, and the private sector:

Invest in digital infrastructure and localised AI development

Scaling AI in education will require robust digital infrastructure, particularly in rural and underserved areas. Investment in mobile and offline-first technologies, along with device access programs, will be essential to overcoming connectivity and hardware limitations. Additionally, creating localised AI datasets, especially in African languages, and establishing local AI research centers are critical to ensure AI solutions are culturally relevant, unbiased, and aligned with regional educational goals.

Ensure accurate and relevant educational content

Effective AI integration in education depends on getting the content right first. This includes developing high-quality, localised datasets that support language diversity and culturally

relevant pedagogy, as well as horizontal AI infrastructure that facilitates scalable solutions. Emphasis should be placed on creating public resources around core teaching methods, aligned with local curriculum standards. For instance, resources on effectively teaching foundational skills, such as math in lower primary and secondary, should be accessible as public goods. This allows developers to design AI solutions tailored to specific regional needs, such as those of learners in northern Nigeria, coastal Kenya or rural Rwanda, ensuring that content is language-specific and curriculum-aligned.

Develop AI-Ready policies and regulatory frameworks

Policymakers must establish regulatory frameworks that promote the ethical, inclusive, and equitable use of AI in education. These policies must prioritise data privacy, security, and access, ensuring that AI-driven solutions benefit marginalised communities as much as urban centers. A centralised Remote Education Administration Unit could oversee the strategic implementation and monitoring of AI technologies across the continent.

Promote outcome-focused educational models

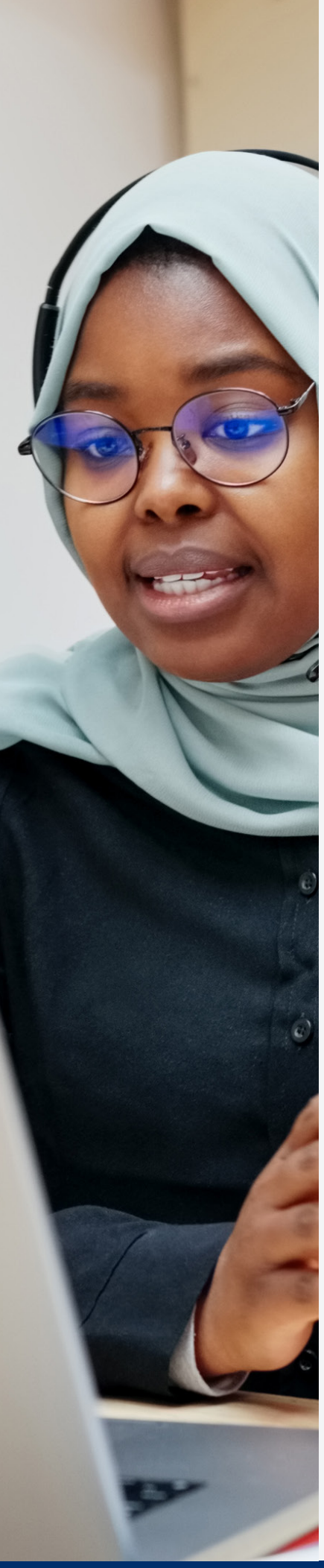
AI's ability to provide real-time data and personalised feedback allows for an outcomes-focused approach, where student achievements and learning growth are prioritised over input measures like classroom size. Policymakers and educational leaders are encouraged to adopt outcome-focused frameworks that leverage AI-driven insights, shifting from traditional input-based metrics to ones that directly measure student learning and development.

Support a sustainable talent ecosystem

A sustainable AI-driven educational system depends on local expertise. Supporting a talent pipeline of teachers, developers, curriculum experts, and technologists is essential for developing, implementing, and maintaining AI tools in African classrooms. Partnerships with educational institutions, AI training programs, and incentives for local research and development will cultivate a strong ecosystem of professionals who can create and refine tools that address Africa's unique needs.

Leverage public-private partnerships for funding and innovation

Financial constraints are a significant barrier to AI adoption in African education. Innovative funding mechanisms, such as public-private partnerships, impact investing, and development grants, are essential for scaling promising AI-driven tools and addressing the ongoing funding gap in EdTech. Collaboration with private sector and international partners can accelerate access to resources, facilitating the development of AI solutions that reach even the most underserved areas.



Build teacher capacity

Training educators to effectively use AI tools is critical. Governments and educational stakeholders should invest in comprehensive teacher training programs that focus on AI and digital literacy. Continuous professional development will empower educators to integrate AI and indeed other useful technologies into their classrooms, improving teaching quality and student outcomes. To build trust and motivation in AI-driven education, stakeholder engagement is essential. Governments, schools, and private sector actors should work together to validate the impact of AI tools through data-driven case studies and pilot programs. Engaging educators, students, and parents in the implementation process will help build confidence in AI's potential to improve educational outcomes, increasing its adoption in schools across various regions.

Prioritise AI literacy and ethical use

Equipping teachers and students with foundational AI literacy will help ensure responsible and effective use of AI in the classroom. Training programs for teachers should focus on AI's applications, ethical considerations, and potential biases, building trust and proficiency in AI tools. Introducing AI literacy into school curricula will prepare students to be discerning users and ethical practitioners of technology in a rapidly digital world.

Address procurement barriers for AI tools

Governments must streamline procurement processes to enable faster, more efficient adoption of AI tools in public schools. By aligning procurement strategies with national education priorities—such as integrating AI into foundational subjects like numeracy and literacy—governments can reduce bureaucratic hurdles that delay AI adoption. Simplified procurement processes will make AI solutions more accessible, particularly in schools with limited financial and administrative capacity.

Aisha's future doesn't have to be one of limited opportunities. With the right investments and policy frameworks, AI can provide her—and millions like her—with the education they need to thrive in a rapidly changing world. This report outlines a roadmap for leveraging AI's transformative power to create an inclusive, equitable, and resilient education system for Africa's next generation. Importantly, the study emphasises that a thoughtful, context-sensitive approach to AI implementation, supported by sustainable investment and local expertise, is essential to achieving these outcomes and fostering an inclusive educational future for all African students.

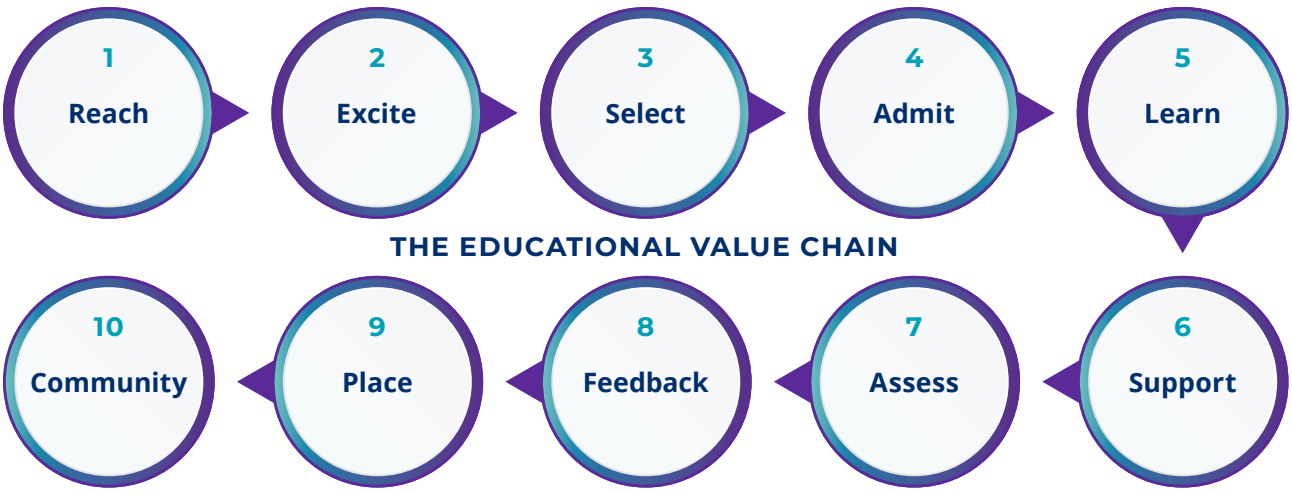
2.

The Evolution of Education: A Value Chain Perspective

Education has been at the heart of human development, serving as the engine that drives societal progress. Across history, education's central role has remained constant: it provides the skills, values, and knowledge needed to ensure the development and continuity of communities. Whether in the context of ancient societies or modern economies, education follows a consistent process—a value chain—that ensures the transmission of knowledge, skills, and values from one generation to the next. It has evolved from the informal transmission of knowledge in early societies to the structured, formal systems seen today. In Africa, this evolution has been marked by significant milestones, from colonial-era education systems to post-independence reforms aimed at increasing access and improving quality.

A review of academic literature identified thirteen roles for AI across six key domains: **learning**, **teaching**, **administration**, **assessment**, **feedback**, and **placement**. The education value chain can be understood as a sequence of interrelated processes that together contribute to the delivery of educational outcomes.

This value chain can be broken down into distinct stages:



Component	Description	Key elements
Learning (Student Engagement and Success)	Reaching, exciting, and engaging students to ensure active participation and learning success.	Engagement strategies, student motivation, learning resources, interactive content, personalised learning
Teaching (Instruction and Workload Management)	Encompasses all instructional activities, improving teaching quality, and managing instructor workloads.	Pedagogical improvement, curriculum delivery, workload optimisation, instructor training, educational technology
Assessment (Evaluation and Feedback)	Evaluating student performance, providing feedback, and supporting continuous learning.	Grading systems, feedback mechanisms, exams, projects, formative and summative assessments, skills evaluation
Educational Administration (Operational Support and Curriculum Management)	Managing the operational aspects of education, including student data, curriculum design, and admissions.	Student information systems, curriculum development, admissions, scheduling, policy development, resource management
Student Placement and Community (Career and Networking Support)	Supporting students transitioning into the workforce or further studies through job placements and networking.	Career counseling, job placement programs, alumni networks, industry partnerships, internships, mentoring, post-graduation support

2.1 From Hunter-Gatherers to Modern Classrooms: The Timeless Process

Even in early human societies, the educational value chain was at work. Imagine a hunter-gatherer community where the elders **reach** a group of young members, **exciting** their curiosity by demonstrating the techniques of weaving baskets or identifying edible plants. The most interested and capable among them are **selected** to learn more deeply. These selected few are **admitted** into an intimate learning environment— perhaps a small group around a fire—where they begin to **learn** the necessary skills. Throughout this process, they receive **support** from their elders, who guide them patiently.

As they progress, the learners' skills are **assessed** through practical tests, such as successfully weaving a basket or identifying the correct plant species. Feedback is immediate, personal and practical —praise for success, correction for mistakes, and learners knew they succeeded if they could replicate a task, like weaving a basket, which held direct relevance to their daily lives. Once their training is complete, these individuals are **placed** into roles within the community—perhaps as master weavers or gatherers—where they contribute to the collective well-being. Their work enhances the community, creating a cycle of knowledge and skill transfer that sustains the society. In these communities, learning was deeply integrated into the social fabric. Educational success was not measured through exams but by the individual's ability to contribute meaningfully to the community's survival and prosperity. The learning model was an early version of adaptive, personalised learning—a system that today's AI technologies strive to replicate by responding to individual students' needs.

2.2 Technological Shifts in the Value Chain: Printing Press to Internet 3.0

Fast forward to the 15th century, when the invention of the printing press transformed the **reach** stage of the educational value chain. For the first time, written knowledge could be disseminated widely and quickly, exciting the curiosity of far more people than ever before. However, this technological leap required subsequent stages of the value chain to evolve as well. Schools and universities emerged to **select** and **admit** students from a broader population, **support** them with structured curricula, **assess** their knowledge through formal exams, and provide **feedback** that prepared them for roles in a rapidly industrialising society. Amongst other things, this technological shift paved the way for the emergence of schools and universities, which standardised education by organising large groups of students and providing consistent curricula.

The advent of the internet and, more recently, Internet 3.0, has again expanded the reach of education exponentially. Today, platforms like Coursera and edX can admit millions of learners into virtual campuses that transcend geographical boundaries.

Each major advancement—radio, television, personal computers, and the internet—expanded education's reach and accessibility, bringing new possibilities to the value chain. However, these shifts were often restricted to areas with the infrastructure to support them, leaving many African communities underserved. Today, AI, particularly through tools like adaptive learning platforms and intelligent tutoring systems, is poised to further this transformation by making learning more personalised and accessible. AI-powered tools are beginning to offer personalised support and feedback at a scale previously unimaginable, assessing learners' progress in real-time and adapting the content to their needs.

In OECD countries:

40%

of adults have a tertiary credential

40%

have attained upper secondary education

20%

have not completed upper secondary education

In Sub-Saharan Africa:

20%

of children aged 6 to 11 are out of school

33%

of youth aged 12 to 14 are not in school

60%

of youth aged 15 to 17 are not in school

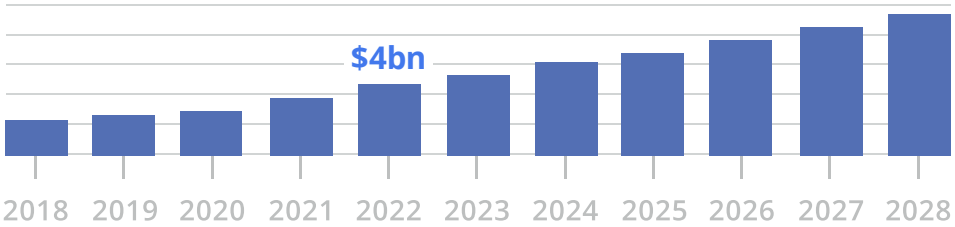
2.3 The Modern African Classroom: The State of Education

Highly educated individuals tend to be more socially engaged and have higher employment rates and earnings. These benefits strongly incentivise individuals to pursue education. Additionally, many governments have adopted policies to expand access to education due to its societal and economic benefits. As a result —and unsurprisingly— educational attainment has significantly increased worldwide — including in **Africa** — in recent decades.

But there are stark differences in educational attainment across world regions. Today, Africa faces complex educational challenges that mirror global issues but are magnified by unique regional barriers. In Sub-Saharan Africa, UNESCO **reports** the highest rates of educational exclusion, especially at younger ages. Over one-fifth of children aged 6 to 11 are out of school, one-third of youth aged 12 to 14 are not in school, and almost 60% of youth aged 15 to 17 are not in school. Without urgent action, UNESCO reports, the situation is likely to worsen as the region faces increasing demand for education due to a growing school-age population. The African Union notes in its **Continental Education Strategy (2016-2025)** there has been growth in the number of children and young people accessing school at all levels. Despite this, it is noted that this growth in enrolment masks huge disparities, system dysfunctionalities and inefficiencies with "severe" underdevelopment in pre-primary, technical and non-formal education, inequalities and exclusion at all levels. Specifically the greatest progress in enrollment is noted in primary education, followed by secondary and tertiary education. This is attributable to resource mobilisation for primary education and activation towards enrollment that resulted in policy directives such as free primary education.

In this context, research indicates that applying technologies such as intelligent tutoring systems, chatbots, and automated assessment can support and enhance learning outcomes. These technologies offer students more personalised and adaptive learning, help teachers understand students' learning processes, and provide machine-supported queries and immediate feedback. Consequently, the role these technologies can play in education has attracted investment. According to a Global Markets Insights **report**, the education technology market reached USD 4 billion in 2022 and is projected to grow by more than a 10% compound annual growth rate from 2023 to 2032.

Education Technology Market (USD Billion)



23.5%

The difference between the highest average scores for private versus public school pupils in Ghana.

> But adopting AI in education presents challenges. Beyond the need for models that fit various curricula, both students' and teachers' readiness and openness are crucial to unlocking AI's benefits in enhancing learning.

Additionally, a significant divide exists between public and private schools in their capacity to integrate AI. **Private schools**, particularly in urban areas, tend to have better resources, access to technology, better-trained teachers, and internet connectivity, which fosters quicker adoption of AI-driven tools. In contrast, **public schools**, especially in rural areas, face challenges such as overcrowding, teacher absenteeism, poor internet connectivity, and unreliable electricity, impeding the adoption of AI technology — or indeed any other technology driven educational tools. This divide translates directly into material outcomes for learners. For instance, the **2016 National Education Assessments in Ghana** found a 23.5 percentage point difference between the highest average scores for private versus public school pupils.

Furthermore, despite significant investments in technology for education across Africa, many initiatives have struggled to achieve meaningful impact, primarily due to misalignment with local needs, infrastructural challenges, and insufficient teacher training. For instance, digital tools that are dependent on high-speed internet and constant power supply, such as interactive tablets, proved largely ineffective in rural and remote areas with limited infrastructure, leading to high rates of abandonment. Kenya's one-laptop per child policy was quietly **retired**, because technology is not a magic bullet in and of itself. In addition, many teachers had limited computer skills, and a single week of government-provided training was insufficient to make them proficient. One clear lesson is the importance of designing solutions with a localised, often low-tech approach. AI-driven, mobile-first platforms, like SMS-based learning tools and offline-first AI systems, have shown promise in overcoming connectivity and infrastructure limitations.

In May 2023, the U.S. Department of Education published a **paper** — the result of sessions held in 2022 with over 700 individuals, including parents and educators, to gather perspectives on AI in education. The findings indicated a strong desire among stakeholders to collaborate proactively to get ahead of the anticipated surge in AI integration into educational technologies. This study makes similar efforts —albeit on a smaller scale with under 100 stakeholders engaged— to similarly test the sentiments held by various stakeholder groups around the integration of education in Africa: from parents, teachers and students, local edtech companies providing AI solutions, to global companies with experience deploying AI solutions at scale, in homogenous markets.

2.4 The Future of Education: AI as the Next Leap in Educational Transformation?

As the continent stands on the cusp of further technological advancements, the possibilities for transforming the educational value chain are substantial. Education systems in Africa have evolved from traditional, community-based learning to more formalised structures aimed at broadening access and improving quality.

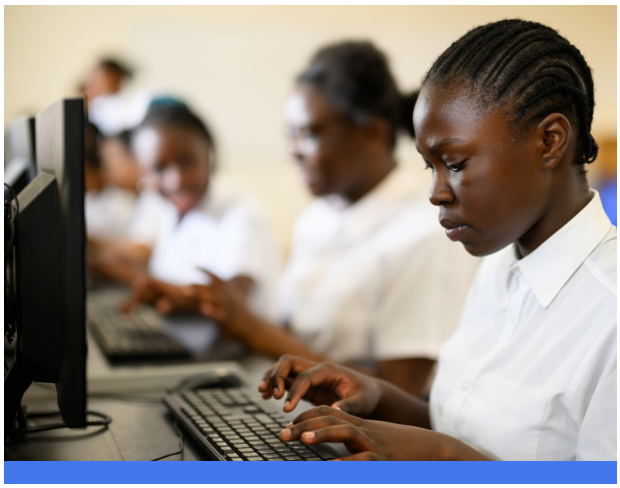
The integration of AI represents the latest advancement in this evolution, promising to enhance various stages of the educational value chain—from access and engagement to assessment and placement, as follows:

- **Expand Access**
  AI-powered innovations can reach remote learners who have traditionally been left out of the education system, via mobile-first or offline-first technologies.

- **Reaching and engaging students**
  AI can adapt educational content to meet the individual needs of students, fostering engagement, By analysing students' responses and progress, AI systems create adaptive learning paths that maximise engagement, even in overcrowded classrooms.

- **Supporting teachers and reducing workload**
  By automating administrative tasks and providing data-driven insights, AI can empower teachers to focus on personalised instruction and student development. AI tools can automate repetitive tasks, like grading, scheduling, and lesson planning, allowing teachers to devote more time to actual instruction and student engagement. In Kenya, educators are beginning to use AI-driven mobile apps that generate on-demand worksheets, enabling teachers to offer additional resources to students who finish early, supporting differentiated learning.

As Africa stands on the cusp of an AI-powered educational revolution, the potential for transformation is immense. However, realising this potential requires outcomes-based thinking. Our education systems must move from input-based measures (such as classroom size) to outcomes-focused approaches. AI can track learning progress, helping stakeholders focus on real knowledge and achievements, rather than just rote memorisation or physical resources. In addition, insights uncovered as part of this study suggest that the system may benefit more from AI tools that alleviate workload and allow teachers —who are crucial to the delivery value chain — to concentrate on personalised instruction. With platforms like uLesson and M-Shule, teachers in African classrooms are using AI to manage large classes more effectively and provide additional attention where needed. Deeper insights uncovered suggest that AI solutions for the continent should be even more nuanced, and should support both teacher and student needs, creating a holistic learning environment where adaptive learning for students is complemented by supportive tools for teachers. This combined approach maximises the impact of AI by ensuring that both learning and teaching processes are empowered.



2.5 Scaling with Sensitivity to Local Needs

To integrate AI into African education, it is as critical to understand what has gone wrong with previous techno-solution powered attempts, as it is to address the continent's unique socio-cultural and infrastructural contexts:

- **Creating public resources on pedagogy**
  To ensure consistent educational outcomes, stakeholders must create open-access resources on effective teaching practices, which developers can adapt for local contexts. This includes language-specific resources, local curriculum alignment, and tools that respect the nuances of memory and cognition in young learners.
- **Building horizontal infrastructure**
  AI's potential relies on foundational infrastructure, such as centralised resources on pedagogy, regional datasets, and models tailored to low-resource settings. Such infrastructure supports developers and institutions in creating scalable, culturally relevant AI solutions for diverse African communities.

Even then, education within Africa varies significantly based on context—whether in public or private schools, in urban, peri-urban, or rural settings, and in economically empowered or constrained communities.

However, some common characteristics are evident even across these diverse settings:

1. Instructor-driven learning

In most African educational settings, teaching is heavily instructor-led, with teachers delivering information and facilitating student engagement with educational content. Many African countries face severe teacher shortages, leading to high student-teacher ratios. This imbalance often hinders personalised instruction and leaves teachers overwhelmed.

2. Resource availability depends on socio-economic status

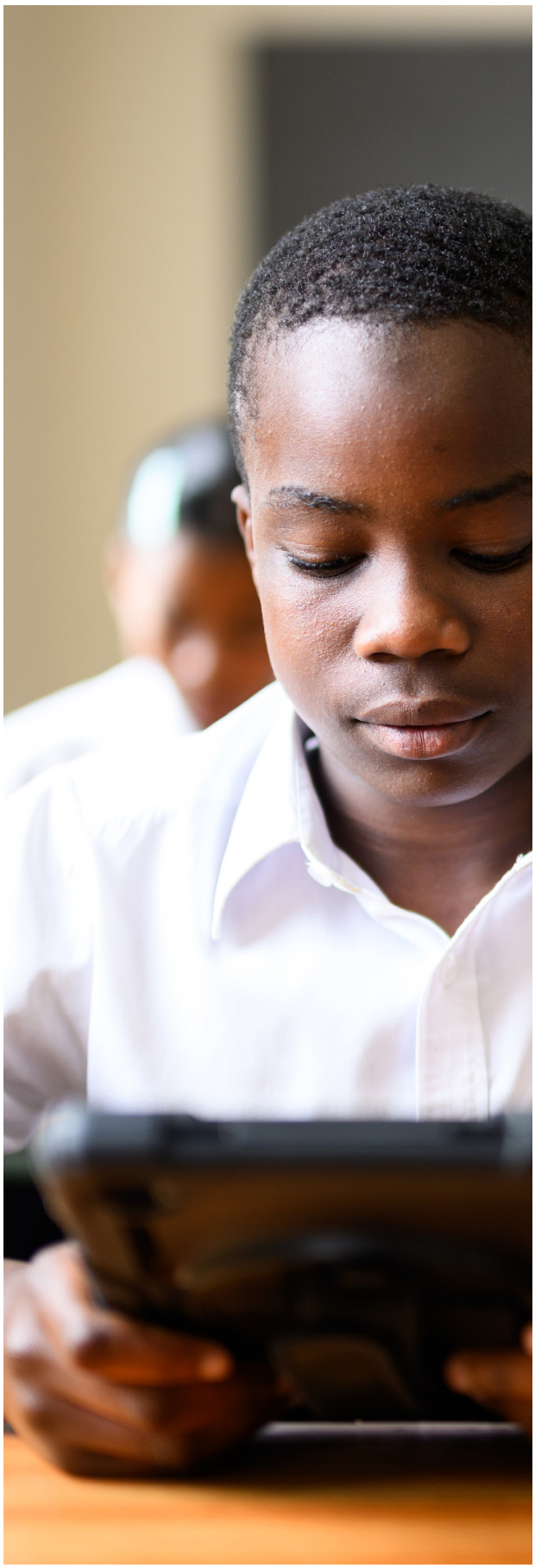
Students from wealthier backgrounds are more likely to have access to personal computing devices such as computers, tablets, or smartphones. In contrast, those from lower-income families often rely on devices owned by others, such as parents, guardians, or siblings, or they must visit communal centers like cybercafés, school computer labs, or public computer hubs. The availability of these devices is further influenced by factors like the willingness of the device owner, the cost of data or access fees, and the scheduling of computer lab hours. Without sufficient support, the use of technology can become unsustainable, leading to reduced access.

3. Limited support outside of school

Like students around the world, African students often require additional learning support outside the classroom, whether for completing assignments or furthering their understanding of new concepts. However, the support they receive from their immediate environment may be limited. Family members or guardians may be unavailable, unprepared, or unable to assist, and access to the necessary tools, such as a computer and internet connectivity, may be lacking. These constraints can significantly hinder a student's ability to succeed outside the structured school environment.

4. Instructor-supported learning

Teachers play a critical role in guiding students' learning, often answering questions and moving between students to monitor comprehension, skill development, and application. In some cases, senior students or informal tutors may step in to provide feedback and additional tutoring. This hands-on support is essential for students to acquire the skills needed to progress in their education.



5. Language barriers

In many African countries, the language of instruction in schools —usually nationally determined official languages— may be different from the language spoken at home or in daily life. This language gap complicates the learning process, making it harder for students to grasp new concepts. It also limits their ability to seek help from family or community members, who may not be proficient in the official language used in education.

In light of these challenges, **imagine** an educational system where every learner receives the exact **support** they need, precisely when they need it, ensuring that no one falls behind, and everyone reaches their full potential.

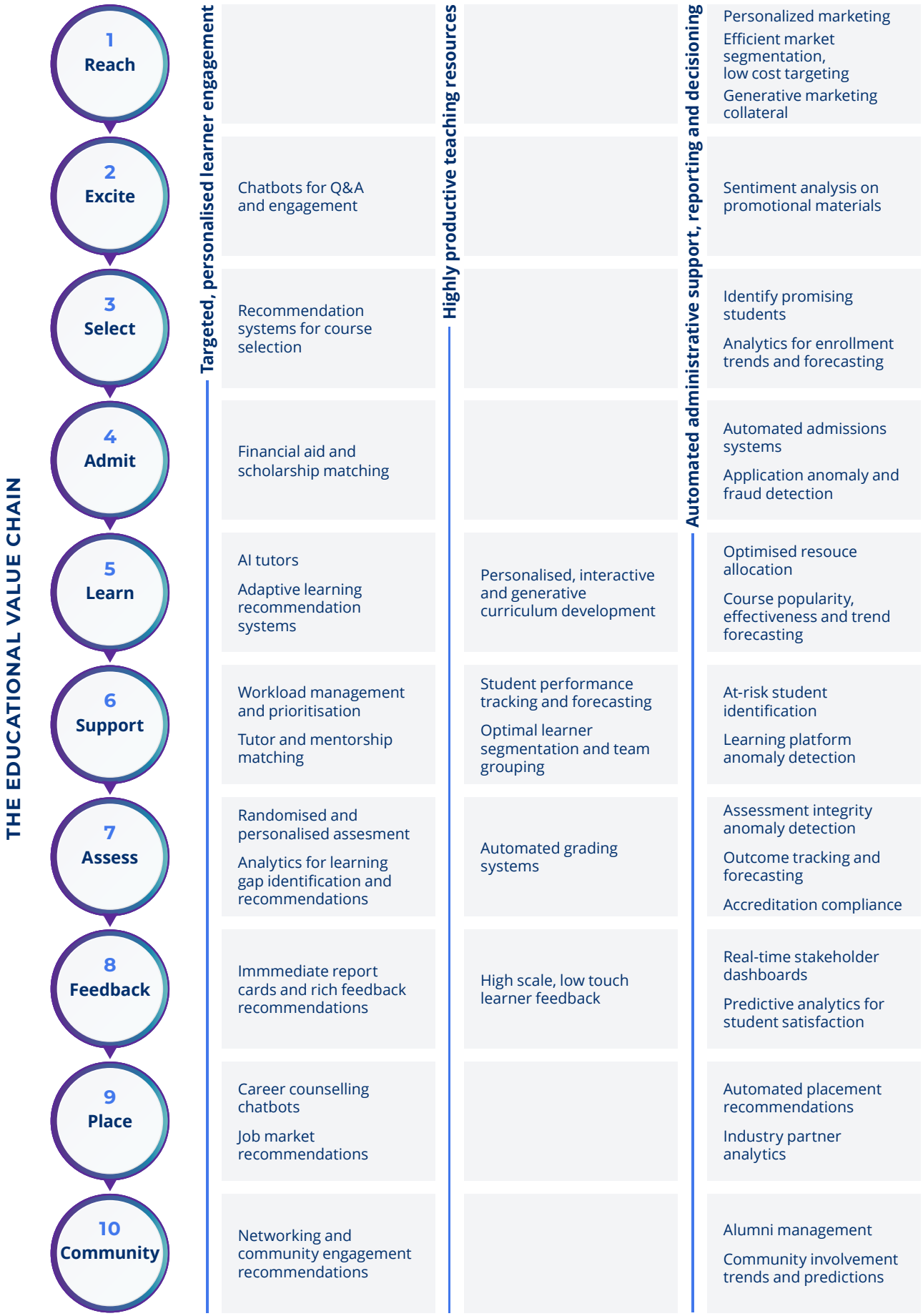
Imagine a teacher, overwhelmed by the sheer number of students, is able to streamline administrative tasks both in and out of the classroom—freeing up time and energy to focus on each student's individual needs.

Imagine students with limited access to technology receiving educational content through affordable, time-efficient solutions designed to accommodate their resource constraints and lack of supportive environments at school and home.

Imagine a learner mastering the required curriculum in their native language or a bilingual context, without being disadvantaged by the transition between languages of instruction.

Imagine if AI could not only provide personalised feedback but also predict and select the right candidates for specific careers based on a deep analysis of their skills, learning styles, and even their potential to innovate.

Admittedly, the learning experience is shaped by a complex web of challenges affecting both teachers and students. Meaningful transformation must address these and other contextual factors, focusing interventions where they will have the greatest impact.


THE EDUCATIONAL VALUE CHAIN
1 Reach
2 Excite
3 Select
4 Admit
5 Learn
6 Support
7 Assess
8 Feedback
9 Place
10 Community
Targeted, personalised learner engagement
Chatbots for Q&A and engagement
Recommendation systems for course selection
Financial aid and scholarship matching
AI tutors
Adaptive learning recommendation systems
Workload management and prioritisation
Tutor and mentorship matching
Randomised and personalised assesment
Analytics for learning gap identification and recommendations
Immmediate report cards and rich feedback recommendations
Career counselling chatbots
Job market recommendations
Networking and community engagement recommendations
Highly productive teaching resources
Personalised, interactive and generative curriculum development
Student performance tracking and forecasting
Optimal learner segmentation and team grouping
Automated grading systems
High scale, low touch learner feedback
Automated administrative support, reporting and decisioning
Personalized marketing
Efficient market segmentation, low cost targeting
Generative marketing collateral
Sentiment analysis on promotional materials
Identify promising students
Analytics for enrollment trends and forecasting
Automated admissions systems
Application anomaly and fraud detection
Optimised resouce allocation
Course popularity, effectiveness and trend forecasting
At-risk student identification
Learning platform anomaly detection
Assessment integrity anomaly detection
Outcome tracking and forecasting
Accreditation compliance
Real-time stakeholder dashboards
Predictive analytics for student satisfaction
Automated placement recommendations
Industry partner analytics
Alumni management
Community involvement trends and predictions

3.

Scaling Disruption: The Opportunity Landscape

Leveraging AI in education is not only about integrating cutting-edge technology but also about adapting it to work within Africa's unique contexts, including its linguistic diversity, infrastructural constraints, and varied socioeconomic conditions.

This section explores the opportunity landscape for AI in African education, highlighting how the continent's dynamic EdTech ecosystem, coupled with specific AI applications, can transform educational delivery, accessibility, and impact. We also examine the potential of AI to support both students and educators in unprecedented ways, paving a path to scalable, context-aware educational innovation.

3.1 Africa's Edtech Ecosystem and AI

In recent years, Africa's EdTech sector has seen accelerated growth, driven by factors such as mobile phone penetration, increasing internet access, and a growing youth population hungry for education. The COVID-19 pandemic further underscored the need for scalable digital solutions, with many African countries turning to EdTech to bridge gaps in classroom learning during lockdowns.. While these ventures do not substantially incorporate AI as a solution, their use of technology to expand access to education in Sub-Saharan Africa presents opportunities that may align with the growing interest and demand for AI in education.

According to Disrupt Africa, over **300 edtech ventures** are active across the continent, with 23 edtech startups raising USD 34.6 million in 2023—a 40% increase from 2022. Despite this growth, edtech still only represents 1.4% of total African startup funding, indicating relatively low investment compared to other sectors, like fintech.

For instance, Nigeria, which was previously a leader in edtech funding, saw a significant decline in 2023, raising only USD 399.9 million and dropping to fourth place behind Kenya, Egypt, and South Africa. This low investment in edtech must be understood within the broader context of Africa's venture capital landscape, which experienced a 54% drop in 2023, falling to USD 2.3 billion. Several edtech startups are beginning to explore AI-driven solutions, albeit in different ways.

African Tech Startup Funding by Country, 2023

Country	USD
Kenya	673,781,000
Egypt	590,268,000
South Africa	512,316,000
Nigeria	399,909,000
Rwanda	44,000,000
Ghana	27,276,000

The table below provides a snapshot of the values that some of these companies prioritise:

Country	Institution	Engagement with AI
Kenya	Kytabu	Kytabu views AI as peripheral, mainly because policymakers and teachers perceive it as relevant only for wealthier populations. They believe that teachers are crucial to the successful integration of technology in education, noting that no tech solution will succeed if teachers do not use it. Their experience shows that student-focused tools often fail because they add extra work for teachers. Kytabu thus stresses the importance of solving teachers' problems—such as classroom administration and content creation—rather than focusing solely on student-facing tools.
South Africa	Vambo AI	In Vambo AI's view, securing funding is challenging because not all governments are comfortable with the application of AI in education. They believe that investors often want to see proven results before committing funds, but demonstrating success and scaling up can be difficult without that initial investment. They emphasise the importance of developing AI solutions and building local expertise before considering integration into a larger, continent-wide ecosystem.
Nigeria	Schoolinka	Schoolinka believes that the access to education challenge often overshadows the importance of education quality, including student engagement and teacher effectiveness. They argue that poor teaching quality can be as problematic, if not more so. They thus see AI as a means to address poor teaching quality by integrating AI tools that improve engagement and teacher effectiveness. Their focus is on creating ecosystems where access to education, content, and engagement are interconnected.

3.2 Applications of AI and Machine Learning (ML) in Education

AI and ML are increasingly reshaping education globally and in Africa, offering new ways to enhance learning experiences, improve teaching methodologies, and provide personalised support.

Some researchers point out that recent advancements in AI are primarily driven by machine learning (ML), meaning that most AI tasks and functions are handled by ML algorithms. ML uses statistical techniques to help computers "learn" without being explicitly programmed. As a result, in the education space, machine learning is used in learning analytics: collecting, measuring, and using data about learners to build profiles and analyse student behavior. This, for instance, is the approach taken by **M-shule** in Kenya, which uses an in-house AI system to assess each child's competency and deliver the right lesson at the right time, thus personalising the learning experience.

While advanced AI techniques are rapidly transforming various sectors, education is lagging behind in their adoption. The limited use of advanced AI techniques in education is largely due to factors such as the high cost and complexity of implementing sophisticated technologies, integration challenges with existing curricula and systems, and the lack of customisation of off-the-shelf solutions for specific educational contexts. Additionally, educational institutions often face difficulties in collecting and managing the large amounts of data required for effective AI, and there is a gap between advanced AI capabilities and pedagogical needs. Resistance to change, ethical and privacy concerns, and a focus on practical, single-purpose solutions further contribute to the relatively slow development and adoption of advanced AI in the education sector.

Nonetheless, in Africa, where many countries face challenges like overcrowded classrooms, resource limitations, and diverse language needs, AI can offer scalable solutions to address these issues.

1. AI for Personalised Learning and Adaptive Learning Systems

AI's ability to deliver personalised learning at scale, is one of its most impactful applications in education.

> Adaptive learning systems use AI to tailor educational content and teaching methods to the needs, abilities, and learning progress of individual students.

These systems analyse data from student interactions—such as quiz results, time spent on lessons, and areas of difficulty—to recommend personalised learning paths that are dynamically adjusted in real-time.

For example, Khan Academy's **Khanmigo** AI tutor uses GPT-4 to offer personalised instruction and feedback, ensuring students receive content tailored to their learning pace. Similarly, platforms like M-Shule in Kenya deliver personalised lessons via SMS to students in regions with limited internet access. This allows students to receive education in areas with little or no internet connectivity, adapting lessons based on their progress and ensuring that students in underserved regions have access to quality, tailored educational content.

Adaptive learning platforms are also effective in addressing the needs of students who require more support, such as those with learning disabilities or who are learning in multilingual environments. By tailoring content to each student's learning pace and style, AI can help reduce the disparities in education that are often exacerbated by overcrowded classrooms and limited teacher availability.

2. Intelligent Tutoring Systems (ITS) and AI-Driven Assessment Tools

Intelligent Tutoring Systems (ITS) simulate the experience of one-on-one tutoring by using AI to provide real-time guidance and feedback to students without requiring constant teacher intervention. These systems provide real-time feedback and guidance to students without requiring constant teacher intervention. They use machine learning to monitor a student's progress and adapt to their individual learning needs. ITS tools are invaluable in classrooms with high student-to-teacher ratios, where educators may struggle to give every student the attention they need.

Examples of ITS include **MwalimuPLUS**, which provides learning materials and step-by-step guidance to learners; **iMlango**, which delivered individualised simulated maths tutoring; **Brainly**, which integrates GPT-4 to power AI-driven study sets, offering students personalised assistance with their homework; **Thinkster Math**, which uses AI to create custom learning programs in mathematics by analysing student performance; **Khanmigo** by Khan Academy, which uses GPT-4 to offer interactive tutoring, and **Rori** in Ghana, an AI-driven math chatbot, which help students improve their proficiency in core subjects through real-time tutoring and feedback, demonstrating how ITS can be adapted to local contexts.

AI may also transform the way assessments are conducted. Automated grading systems, powered by computer vision and natural language processing (NLP), can grade tests, essays, and assignments more efficiently than manual grading. This not only reduces teachers' workloads but also ensures faster feedback for students, allowing them to quickly identify areas where they need improvement. Grading systems like **Kejarcita** streamline the grading of assignments and tests, allowing teachers to focus more on instruction than administrative tasks.

iFlyTek in China is also a useful example of intelligent assessment, offering automated grading and performance tracking for large classrooms—a potential model for African education systems to follow.

3. AI for Idea Generation and Prompt Engineering

Teachers have acknowledged that AI can stimulate creative thinking and idea generation, particularly when used at the beginning of tasks. AI tools can help spark creative thinking, helping teachers generate lesson content tailored to their students' needs or offering students new perspectives that might not emerge from traditional methods alone. However, educators stress the importance of prompt engineering—the skill of knowing exactly what to ask AI to receive valuable and meaningful results.

Prompt engineering will likely become increasingly important as AI tools are integrated more deeply into learning environments. By framing the right questions or providing precise instructions, teachers and students can maximise the value they get from AI tools. This skill is expected to play a pivotal role in how AI is adopted and used effectively in education.

4. Machine Learning in Learning Analytics and Predictive Insights

Machine learning is particularly powerful in generating predictive insights based on large datasets of student performance. Predictive analytics can forecast student outcomes, identify learning gaps, and recommend timely interventions to prevent students from falling behind. This is especially valuable in environments where teachers may be responsible for large classes.

In African contexts, with high student-to-teacher ratios, ML-based predictive analytics can serve as an invaluable tool for identifying students who are at risk of dropping out or underperforming. Students who repeat grades or require remedial education consume more resources, increasing per-student costs. In South Africa, for example, grade repetition has been identified as a significant drain on educational resources: in financial terms, the expense of retaining repeaters in the public education system amounted to at least ZAR 20 billion in 2018 prices (USD 1 billion), accounting for 8% of the total national budget allocated to basic education that year. By analysing data on student performance and engagement, AI systems can alert educators to students who need additional support, allowing for timely assistance that can reduce the need for costly remedial programs, or enable early interventions to prevent dropouts.

This data-driven approach is already being used in platforms like **M-Shule**, which uses AI to analyse student performance and adapt learning materials to ensure each student receives the appropriate level of support. Elsewhere, by analysing data from learning activities, tools like Absorb LMS and Docebo use AI to monitor student behavior, track their progress, and suggest content based on their individual needs. These learning management systems (LMS) help teachers understand where students might struggle and tailor their instructional strategies accordingly.

The expense to the South African national budget of retaining repeaters in the public education system in 2018:

R20bn

5. Natural Language Processing (NLP) for Multilingual Education

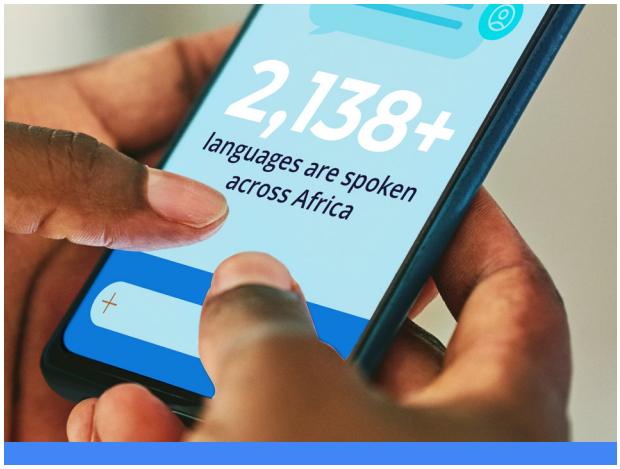
> **"Africa lacks a centralised repository of knowledge, highlighting the need for centralisation to support those building for the continent. The diversity across the continent brings many nuances, with no standardisation in languages, which are spoken differently even within a single country. There's a significant gap in the underlying infrastructure, with limited investment in language technology."**
>
> INDIGENOUS LANGUAGE AI FOUNDER

AI's natural language processing (NLP) capabilities are highly effective in supporting multilingual education, which is crucial in many African countries where students may speak multiple languages at home and in school. AI-powered tools that utilise machine learning, specifically, Natural Language Processing (NLP) can help break down language barriers by providing real-time translations and facilitating content in students' native languages.

For example, **Foondamate** in South Africa uses AI to support students in 10 different languages, making educational content accessible to diverse linguistic communities. The **Mahlahle app** makes African languages more accessible to children through a multilingual app that focuses on fundamentals and vocabulary. Similarly, AI-driven tools that offer text-to-speech or speech-to-text capabilities can support students with learning disabilities or those who require additional help in reading and comprehension. Google Assistant, Siri, and Cortana are examples of voice assistants that use NLP to interact with students in natural language, facilitating learning in their native tongue.

A significant opportunity for AI in Africa's education ecosystem lies in addressing the continent's linguistic diversity. With over 2,138 languages **spoken** across Africa, AI-powered translation and language processing tools have the potential to revolutionise access to educational content. This is particularly relevant to the multilingual context of many countries on the continent. The Democratic Republic of Congo, where over 200 languages are spoken, exemplifies the complexities of multilingual education. A 2005 World Bank **review** of the country's educational context noted that linguistic diversity complicates teaching and learning, especially in rural areas, where many students lack the ability to practice the official school language at home and where many teachers may not be familiar with the mother tongue of the students. AI could play a crucial role in overcoming these challenges by providing personalised, language-specific educational resources.

Companies like **Lelapa AI** in South Africa are leading the way in developing tools for underrepresented African languages, while **Google Labs in Accra** has developed speech-to-text tools designed for non-standard speech patterns, demonstrating AI's potential to support literacy and learning in multilingual environments. However, for AI to be effective, tailored content creation must go hand-in-hand with infrastructural improvements and investment. Many educational institutions and private providers continue to face challenges in accessing the resources needed to integrate AI technologies into their systems, or indeed, to even digitise their systems. These challenges are discussed in greater detail elsewhere in this report.



The monthly cost of simple generative AI systems that teachers can use in lesson planning:

$25

6. The Role of AI and ML in Reducing Educational Inequity

AI also holds significant potential for addressing the challenges of multilingual education and supporting students with special needs. For example, Google Labs in Accra, Ghana, has developed an AI tool that transcribes speech into text, aiding communication for people with non-standard speech.

AI tools like **Cram101** use smart content algorithms to summarise textbooks and highlight key points, which can be especially beneficial for students with learning disabilities, making complex materials easier to understand and engage with.

7. The Role of AI in Reducing Administrative Work and the Cost of Education

AI may not only transform how students learn but also how educators teach. Tools like **Blackboard**, an AI-powered system that integrates quizzes, assessments, and homework assignments, allow teachers to manage coursework more efficiently. These systems use AI to continuously learn and update information based on student needs, reducing the administrative burden on teachers and enabling them to focus more on personalised instruction.

Furthermore, AI-powered voice assistants, like those offered by Google Assistant and Cortana, allow students to access educational materials anytime, providing instant explanations and assistance without requiring constant teacher supervision. This helps students learn independently while freeing up teachers' time to address more complex tasks.

There is an economic angle to consider. Tasks like grading, scheduling, and student monitoring consume substantial time and resources. In many African countries, limited educational budgets mean that funds allocated to administrative staffing could otherwise enhance teaching quality or infrastructure, allowing educators to focus more on teaching and less on administrative duties, potentially improving educational outcomes without additional costs or with significant savings. Simple generative AI systems that teachers can use in lesson planning can cost **USD 25** monthly.

However, successful AI integration hinges on the capacity of teachers to effectively use such technologies. For instance, in **Kenya**, the deployment of one million devices and the training of 80,000 teachers under a Digital Literacy Program (DigiSchool), led to clear improvements in student outcomes, such as higher school attendance and greater engagement in learning. However, the impact was undermined by critical shortage of ICT-competent personnel, as many devices remained unused.

For teachers, developing AI literacy may be similar to mastering a new instructional approach— it involves not only learning how

the technology works, but also understanding how to apply it effectively in the classroom. This combined knowledge enables educators to make thoughtful choices about integrating AI, just as they determine when to use conventional teaching methods versus digital tools. As such, training cannot be a one-off effort; instead, governments and educational stakeholders must invest in continuous professional development programs focused on AI and digital literacy, to empower educators to integrate AI into their classrooms.

The aim should be to ensure AI supports rather than substitutes human-led instruction. Programs like Google's **Generative AI for Educators** initiative helps educators learn to use generative AI tools to save time on tasks, personalise instruction and enhance lessons.

8. Ethical and Cultural Considerations for AI Use in Education

As AI becomes more prevalent in education, ethical considerations will need to be addressed. Teachers in focus groups have expressed concerns that students may become overly reliant on AI tools, which could hinder the development of critical thinking skills. Furthermore, there are ethical concerns regarding data privacy and the use of AI-generated content in assignments. Teachers have stressed the need for clear guidelines and training on how to effectively integrate AI into the classroom while maintaining academic integrity.

In response to these concerns and particularly in the African context, it is crucial that AI tools are designed with the needs of African educators and students in mind. This includes content that is culturally relevant and tailored to local educational needs. Most AI models are built on data from non-African contexts, which can lead to culturally inappropriate or biased content if not adapted to local needs. Customising AI solutions, such as integrating local languages or adapting content for specific cultural contexts, ensures that these tools are not only effective but also equitable. This requires collaboration between educators, AI developers, and policymakers to create tools that respect the diverse needs and values of students across the continent.

Nuanced integration of AI also includes ensuring that AI platforms can operate in regions with limited infrastructure, and providing teachers with the necessary training to use these tools effectively. Discussions about the integration of AI must also assess discrepancies between the prospects of its integration and the reality on the ground in most nations on the continent. Barriers to AI adoption by educational institutions or private providers are multifaceted and include limited infrastructure, concerns about equity, the scarcity of expertise, and ethical considerations surrounding data privacy. These challenges are well documented and discussed elsewhere in this report.

9. AI-Focused Research and Training Initiatives Across Africa

In parallel with the growth of AI-driven edtech, several research initiatives are advancing AI's role in education across Africa. These initiatives focus on fostering local talent, conducting ethical AI research, and building a robust foundation for AI adoption in educational institutions.

The success of AI in education is highly dependent on the availability of representative datasets. However, Africa faces a significant challenge in this area. Many AI systems, including global benchmarks such as Google's Gemini and OpenAI's GPT-4, are developed and evaluated based on Western contexts, overlooking the unique realities of African students. Without inclusive datasets that reflect the diversity of African educational systems, AI technologies risk producing skewed and ineffective outcomes. For instance, GPT-4's 2023 benchmarks did not include data from African contexts, illustrating the pressing need for localised research, data collection, and AI evaluation processes.

Country	Institution	Engagement with AI
Tanzania	AI4D Africa	One of the flagship initiatives, AI4D Africa's Anglophone Research Lab, established at Tanzanian institutions such as the University of Dodoma and the Nelson Mandela African Institute of Science and Technology, is dedicated to improving AI research and teaching capabilities across Anglophone Africa. The lab promotes collaboration between academia, industry, and public institutions, distributing high-quality educational materials and enhancing research in AI.
Burkina Faso	CITADEL	The Centre of Excellence in Artificial Intelligence for Development (CITADEL) was created through a partnership between Open Burkina and Burkina Faso Virtual University to address the shortage of AI academic resources in Francophone Africa. This lab focuses on developing AI solutions that are fair, inclusive, and aligned with the region's unique educational needs.
Ghana	RAIL	Located at Kwame Nkrumah University of Science and Technology, the Responsible AI Lab (RAIL) focuses on ethical AI development in sectors like agriculture and biomedical sciences. This lab also serves as a "Maker Space," fostering innovation in AI and addressing skills gaps by offering educational programs in data science and machine learning .
Pan-African	ARCAI	The African Research Centre on Artificial Intelligence (ARCAI), established with support from the United Nations Economic Commission for Africa (UNECA), focuses on closing the digital divide by providing AI training and promoting job creation. ARCAI offers fellowships, research grants, and collaborative partnerships, ensuring that African students and researchers have access to cutting-edge AI education.

4.

Stories of Transformation: Local heroes in African Education

SCHOOLINKA

4.1 Schoolinka, Nigeria

350K

The number of new teachers needed in Nigeria by 2030 to meet the demand for quality education at primary and secondary levels.

PROBLEM

Nigeria faces a severe teacher shortage and significant skill gaps within its education system. According to the United Nations, the country needs at least 350,000 new teachers by 2030 to meet the demand for quality education at primary and secondary levels. The shortage is especially dire in rural areas, where schools often rely on unqualified or underqualified teachers, exacerbating poor student outcomes. Moreover, many teachers lack access to continuous professional development (CPD), which is critical for staying updated with modern teaching methodologies and technologies

SOLUTION

Schoolinka, a Nigerian education technology (edtech) platform, is tackling these challenges by leveraging AI-powered recommender systems to connect qualified teachers with schools that need them most. The platform also identifies skill gaps among educators and provides tailored professional development programs to address them. Its solution is twofold: it not only helps schools to streamline recruitment processes but also offers a continuous learning pathway for teachers.

Using AI, Schoolinka identifies specific areas where teachers need improvement—whether it's in subject matter expertise or pedagogical techniques—and recommends personalised training modules. These modules, accessible online, are designed to fit into the teachers' schedules, enabling them to upskill without disrupting their current roles. The platform uses data analytics to track progress, helping educators continuously refine their teaching methods.

> The impact of Schoolinka's model is important. Teachers who use the platform report higher job satisfaction and improved teaching quality.

By streamlining recruitment and focusing on continuous professional development, Schoolinka ensures that educators are well-equipped to meet the diverse needs of their students. This approach empowers teachers to improve educational outcomes for thousands of students, reducing the learning gaps exacerbated by under qualified teaching staff. Schoolinka's initiative is part of a broader effort in Nigeria to professionalise teaching and improve educational quality through technological solutions

foondamate

4.2 Foondamate, South Africa

7M

South African students in rural areas face significant barriers to accessing quality education

PROBLEM:

South Africa's education system, particularly in rural areas, struggles with limited access to quality educational resources. Despite significant investments in education, disparities in infrastructure and resources persist, leaving rural students at a disadvantage. Many of these students do not have access to modern learning tools like computers or internet services. A report by the South African Human Rights Commission highlighted that over 7 million students in rural areas face significant barriers to accessing quality education.

SOLUTION:

Foondamate, a South African edtech startup, provides a solution that addresses these disparities using AI. Leveraging autoregressive LLMs like Meta Llama, Foondamate has created an "AI robot study buddy" on WhatsApp, one of the most widely used social media platforms in Africa. The chatbot serves as a learning companion, helping students with their schoolwork by providing instant access to educational resources in 13 languages, including South Africa's official languages

> Foondamate's AI-powered system can solve math problems by analysing photos of equations using computer vision technology.

This feature is particularly useful for students who do not have access to tutors or teachers outside of school hours. The chatbot allows students to upload photos of their homework or exam questions, after which the AI analyses the problem and offers a step-by-step solution, helping students understand the concepts behind the questions.

RESULTS:

In addition to offering support in multiple languages, Foondamate has used over 1,000,000 exam answers to train its AI, ensuring the chatbot can provide accurate and contextually relevant support to students from diverse linguistic and cultural backgrounds. This personalised learning experience has proven invaluable, particularly for students in rural areas where traditional educational resources are lacking. By using WhatsApp, a low-cost and widely available platform, Foondamate has made learning more accessible, efficient, and relatable for students across South Africa.

M-Shule

4.3 M-Shule, Kenya

18%

of rural households in Kenya have internet access

30%

of adults in Kenya own a smartphone

PROBLEM:

In Kenya, many students, particularly in rural areas, face challenges in accessing the internet and smartphones—tools that are increasingly important for modern learning. Only 36.3% of households have internet at home, with just 3.4% of rural households connected . This lack of connectivity has created a significant barrier to the transformative potential of educational technology solutions, leaving many students without access to the resources they need to succeed.

SOLUTION:

M-Shule is an AI-driven platform designed to overcome these barriers by delivering personalised lessons to students via SMS, a technology that requires neither smartphones nor internet access. The platform uses machine learning algorithms to tailor lessons to each student's individual learning pace and needs. By analysing student performance data, M-Shule continuously adapts its content to ensure that students receive relevant and targeted educational support.

> The platform's reach extends to students in remote areas with little or no access to traditional educational resources.

For example, it delivers daily SMS lessons in subjects such as mathematics, English, and life skills, ensuring that every learner can benefit from a structured educational experience, regardless of their physical location or economic circumstances. Parents and teachers can also receive feedback on students' progress via SMS, enabling them to support their children's learning journeys more effectively.

RESULTS:

M-Shule's impact is promising. It not only democratises access to education for students in marginalised areas but also provides a scalable model for how AI can be deployed to address significant infrastructural gaps. By leveraging a simple yet powerful technology—SMS—M-Shule has created an inclusive, low-cost solution that ensures all students, regardless of their socio-economic background, have the opportunity to receive a quality education.

4.4 Rori, Ghana

16.8%

of households in Ghana have internet access

PROBLEM:

In Ghana, like much of sub-Saharan Africa, the education system faces significant infrastructural challenges, especially when it comes to personalised learning; which hampers educational outcomes. With high student-to-teacher ratios and limited resources, many students struggle to receive the individual attention they need to succeed in critical subjects like mathematics. In addition, just around 16.8% of households in Ghana have access to the internet, which further limits the potential for digital learning

SOLUTION:

Rori, an AI-driven mathematics chatbot tutor, addresses these challenges by providing personalised, interactive math tutoring to over 45,000 students across seven African countries. The platform uses conversational AI to engage students in real-time, offering personalised feedback on their progress and guiding them through complex mathematical problems.

> Rori's AI engine is designed to adapt to each student's learning style, offering hints and explanations based on their individual performance.

RESULTS:

Rori is helping to ensure that no student is left behind due to a lack of personalised learning opportunities. The platform has been especially impactful in helping students improve their proficiency in mathematics, a subject that is often a barrier to further academic success and employment opportunities. With Ghana's low internet penetration rates, Rori operates across multiple digital platforms, ensuring accessibility even in areas with limited infrastructure. The chatbot can be used on both smartphones and basic mobile phones, providing flexibility and broad access. Through Rori, students are able to improve their mathematical skills and build the confidence needed to tackle other academic challenges.

5.

What Does It Really Take?

The Roadblocks and Catalysts

For AI to realise its transformative potential in African education, several structural and contextual challenges must first be addressed. These challenges can be categorised into three primary areas: **technical**, **financial**, and **social/cultural**. Within each category, there are key leverage points that can act as catalysts to overcome the roadblocks.

5.1 Challenges to the African opportunity

> **"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 score of 56.6% for the region and a digital literacy rate of 31%. The limited deployment of ed-tech initiatives in the region is also characterised by the exclusion of some population groups. For instance, edtech 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."**
>
> 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.

The UNESCO **Education in Africa report 2023** describes the core of challenges faced by education as equity, "leaving no child behind ", calling upon governments to put equity at the heart of their decision making. African children are "left behind" in a manner of speaking, due to a complex web of factors. African learners' experiences is a materialisation of the combination of personal and national factors magnified depending on level of education(primary versus secondary), their location (rural, urban in their degrees) in combination with other social and economic realities.

As one stakeholder interviewed for this study aptly noted, "Bringing in AI is like wanting to drive a car. Once you have the car, you need good infrastructure (roads), the right tools (cars), skilled drivers (teachers), the fuel (digital and AI content), and a place where driving is encouraged (administration and systems)." This metaphor encapsulates the multifaceted barriers facing AI deployment in education across Africa. This section prioritises barriers to AI use in the educational context, over broader AI deployment and adoption on the continent, although there are significant overlaps.

1. Technical Leverage Points

- **Infrastructure Gaps**
  A major hurdle to AI adoption is the lack of adequate infrastructure. At the most fundamental level, this might simply be a lack of school infrastructure, which might provide a setting within which to deploy AI solutions. There are also other enablers. As of 2021, 89% of learners in sub-Saharan Africa do not have access to computers, and 82% lack internet access at home. Around 20 million learners reside in areas without mobile network **coverage**. Without reliable electricity and internet, AI tools also cannot be effectively deployed. Moreover, the infrastructure that exists is often concentrated in urban areas, leaving rural learners at a significant disadvantage. One potential leverage point is to establish communal access points, such as shared learning hubs or mobile learning

89%

of learners in sub-Saharan Africa do not have access to computers

82%

of learners in sub-Saharan Africa lack internet access at home

centers, which could offer a stopgap solution while broader infrastructure improvements are underway.

More specifically to AI-integration however, is the idea of **horizontal AI infrastructure development**. Establishing foundational AI infrastructure—such as centralised datasets, cloud computing resources, and open-access content libraries—can support a variety of educational applications. Such infrastructure serves as a "horizontal" layer that developers and institutions can build upon, making it easier to scale AI tools across different contexts and regions. For example, a **publicly accessible library of effective teaching resources** on topics such as early literacy or math can enable developers to create solutions that are both curriculum-aligned and region-specific. This infrastructure not only supports scalability but also encourages local innovation by empowering African developers to build contextually relevant solutions.

- **Data Availability and Digitisation**
  Access to relevant, high-quality data is fundamental for deploying effective AI solutions in education. In many African countries, large amounts of government-held data remain locked in legacy systems, and the pace of digitisation has been slow. This limits the ability to collect and apply educational data to AI models, which require extensive, up-to-date datasets to function optimally. Furthermore, many regions lack organised, centralised data systems, creating gaps in the information needed to develop accurate AI tools. To address this, efforts must focus on digitising existing records, creating comprehensive data repositories, and strategically utilising new data being generated across educational institutions. Without this foundational step, even improvements in connectivity infrastructure and hardware deepening may not fully drive AI adoption.

- **Bias in AI Models and Localised Datasets**
  AI systems can unintentionally propagate biases present in their training data, leading to unequal treatment or misrepresentation of certain student groups. One of the critical challenges in implementing AI in African education is the bias inherent in many existing AI models, which are often trained on datasets from non-African contexts. This lack of contextual relevance can lead to skewed or inappropriate results when AI is applied in African schools, particularly in areas like language processing, curriculum alignment, and student assessments.

> **"Data residency and model bias are crucial issues that require our attention. By developing our own models and managing our own data, we can reduce model bias effectively. The Electronic Transaction Law serves as a framework to regulate data privacy and cybersecurity. Building our own models necessitates infrastructure and skills, highlighting the role of data labs. Any policy or regulatory measures should align with a National AI strategy. It's essential to establish policies for data access, as the government holds vast amounts of unstructured data. Providing SMEs access to this data can enable them to create valuable products for citizens. This approach allows us to learn and adapt over time."**
>
> GOVERNMENT DIGITAL AGENCY, CHIEF DIRECTOR

Additionally, Africa's vast linguistic diversity adds complexity, as educational AI tools must be linguistically inclusive to be effective across the continent. To address these issues, it is essential to develop localised, culturally relevant datasets that reflect African languages, educational goals, and societal values. Investment in language-specific datasets would enable AI tools to support natural language processing (NLP) in a wide range of African languages, making tools like text-to-speech and speech-to-text more accessible for students, including those with disabilities or literacy challenges. This also involves establishing local AI research labs and supporting initiatives that focus on building African-focused AI solutions, ensuring that AI applications are sensitive to the diverse needs of African learners. By prioritising localised datasets and reducing bias in AI models, we can create educational tools that are responsive to the unique realities faced by students and educators in Africa.

- **Sustainable Talent Ecosystem**
  Although Africa has made contributions to AI development, such as through content moderation and data annotation services (via platform, gig and outsourced work), there is a critical gap in higher-level AI expertise, particularly in education, as the sparse talent available is attracted into more lucrative, often private sector endeavours.

> **"The edtech industry is new. When discussing challenges in this space, we must ask: What skills are we actually referring to? To what extent do we help people understand the importance of AI? The development of schooling systems must be supported by engineers who can build solutions specific to their countries."**
>
> PERSONALISED LEARNING SOLUTIONS AI COMPANY, CEO

Governments, edtech companies, and educational institutions must collaborate to build an AI talent pipeline capable of supporting the unique needs of Africa's education sector. Africa must prioritise building a sustainable talent ecosystem that supports and sustains these technologies. This involves nurturing a network of teachers, curriculum experts, AI developers, technologists, and policy-makers who collectively contribute to the development, deployment, and continual improvement of AI solutions in educational contexts. Local experts, such as teachers and curriculum designers, play a crucial role in aligning AI tools with Africa's diverse educational needs, while developers and technologists bring the technical expertise needed to create and adapt these tools.

2. Financial Leverage Points

- **Funding for Solutions**
  This study does not make an argument for increasing investment across the educational value chain — that much has been evident for the last decade. Implementing AI in education requires more than just technological infrastructure—it demands intentional investments that go beyond acquiring AI tools and extend to maintaining and scaling these solutions. Governments and private sector actors must collaborate to identify sustainable funding models that support not only the deployment of AI systems but also the infrastructure needed to sustain them, such as electricity, internet, and learning hubs.

- **Funding for Research**
  To address the lack of contextually relevant AI models in Africa, investment in local research is critical. While technical leverage points like bias in AI models identify the need for localised data, funding for research highlights the importance of financially supporting local AI research and development initiatives. A paper from the Open African Innovation Research (OAIR) initiative highlights the importance of local AI research and development to ensure that tools meet the needs of African students and educators. This includes providing grants to universities,

supporting R&D hubs, and fostering collaborations with local researchers who understand the African education context. Without adequate financial backing, the development of AI models that account for local languages, learning environments, and cultural contexts will be stifled. Investment in research is therefore distinct from the technical task of building models—it's about ensuring financial resources are directed to creating the datasets and expertise necessary to make those models effective.

1. Social and Cultural Leverage Points

- **Community Buy-In**
  Africa's cultural diversity presents both challenges and opportunities for AI integration in education. Educational technology, especially AI, can face resistance from communities due to differing attitudes towards mobile devices, data privacy, and the role of technology in education. Securing community buy-in is essential for AI tools to gain acceptance. Early adopters must account for, and work closely with communities to ensure that AI solutions are culturally relevant, particularly in terms of language and content. By designing AI tools that reflect and honour local customs, languages, and stories, resistance can be reduced, and engagement can be enhanced.

- **Cultural Relevance**
  As reiterated consistently in this report, AI tools need to be culturally relevant to the local context in which they are deployed. This includes providing solutions in local languages and ensuring that the AI tools reflect the values and educational goals of the communities they serve. For example, AI tools should address language barriers by offering support in the region's most commonly spoken languages. This is particularly important in rural and underserved communities, where access to formal education is often limited.

- **Teacher Training**
  Teachers are a critical leverage point within the education value chain. To harness the benefits of AI, training initiatives must be prioritised. By integrating AI-focused pedagogical strategies into professional development, educators will be equipped to not only to understand AI, but to apply it effectively in their lesson plans.

5.2 Catalysts for Success

While the challenges are significant, there are clear opportunities to leverage existing resources and create a more conducive environment for AI in education.

- **Public-Private Partnerships**
  These partnerships can act as powerful catalysts for AI adoption. Governments can provide access to public schools and policy support, while private companies can offer the technological expertise and resources needed to develop and implement AI tools. Collaborative efforts could include piloting AI solutions in classrooms to gather feedback and refine the tools before scaling them across the education system. Partnerships are also a key mechanism to attract the necessary investments, ensuring that resources are available to address the long-term operational costs of AI systems, including teacher training and system maintenance. This is distinct from addressing infrastructure gaps alone, as it emphasises securing the funding streams necessary for both initial implementation and ongoing support.

- **Building Innovation Ecosystems**
  The fabric of Africa's edtech innovation ecosystem is still being woven. Strengthening these ecosystems, particularly by fostering connections between edtech companies, researchers, educators, and policymakers, can accelerate the development of AI tools suited to Africa's unique challenges. Innovation hubs that focus on AI in education, similar to those emerging in the fintech space, can provide a platform for developing, testing, and scaling AI tools. These hubs could also offer training and capacity-building initiatives to ensure that local talent is prepared to engage with the growing AI landscape.

6.

Market Readiness: A Deep Dive into Six African Nations

AI readiness refers to the capacity of countries and organisations to harness AI technologies for growth, social development, and improved welfare. This readiness is influenced by several key factors, including the establishment of clear AI policies, the enhancement of education and training programs, access to data, and the development of a skilled workforce.

For AI to be effectively integrated into various sectors, in particular, education, Africa must address these factors by fostering responsible regulation, ethical AI practices, and a supportive environment for startups. By doing so, the continent can unlock significant opportunities.

According to the Oxford Readiness Index, Mauritius is currently the highest-ranked African country in terms of AI readiness. This rating reflects Mauritius's advancements in governance, innovation capacity, data management, and infrastructure.

However, AI readiness reports and rankings—while evaluating critical factors such as infrastructure, education, policy, and innovation—may not fully capture the nuances of each country's AI ecosystem.

Factors such as political stability and cultural attitudes can significantly impact readiness.

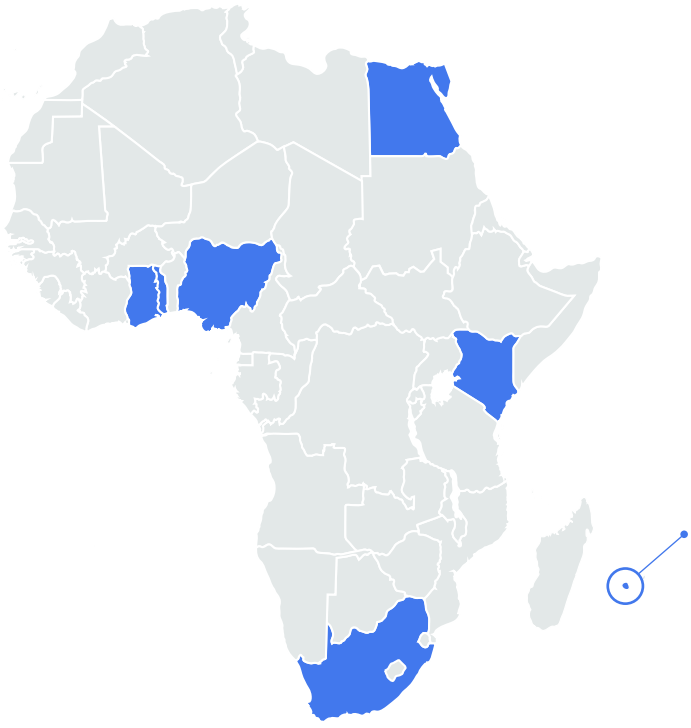
As a result, while AI presents diverse opportunities across Africa, the continent's countries are at varying stages of readiness, influenced by their national priorities, infrastructure, and resource availability.

Educational curricula are profoundly shaped by national and local education policies, which set the framework and standards for what students learn and how education is delivered, guiding the inclusion of new skills such as digital literacy and AI. Local policies adapt these frameworks to address regional needs and cultural contexts, ensuring relevance and equity.

> **"Governments are not adequately addressing issues related to training data for AI in education, such as copyright concerns, quality assurance, and the alignment and relevance of content. The prioritisation of AI tools is still far from large-scale implementation in Sub-Saharan Africa (SSA), with most AI-driven ed-tech solutions being in the early stages of development."**
>
> FOUNDER, EDUCATION SOCIAL ENTERPRISE

AI Readiness Ranking

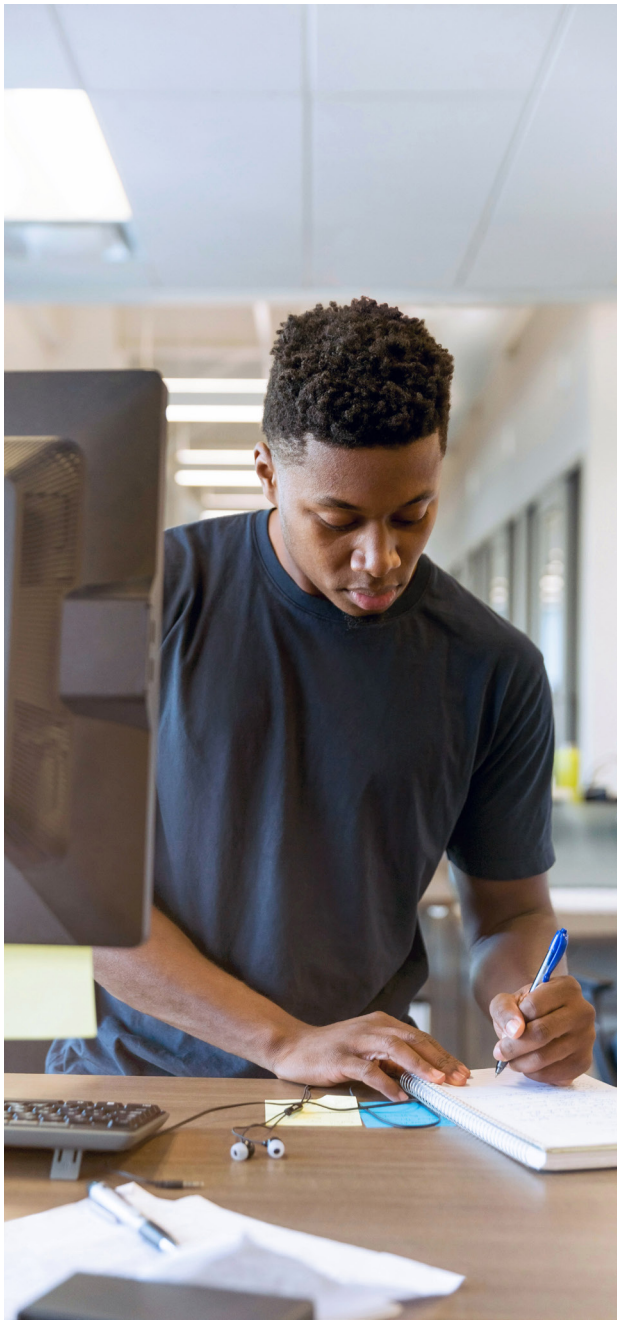
Country	Rank
Mauritius	61
Egypt	62
South Africa	77
Rwanda	84
Kenya	101
Nigeria	103
Ghana	141
Togo	158



Mauritius is the highest ranking African country on AI readiness according to the Oxford AI readiness Index

Countries like South Africa, Kenya and Rwanda are progressing more rapidly in integrating AI into their educational systems compared to others still addressing fundamental educational challenges. South Africa is progressively **incorporating AI and digital literacy** into their national curricula, reflecting a forward-thinking approach. Meanwhile, other nations are at the early stages of curriculum reform. Through the introduction of the **Competency-Based Curriculum (CBC)** to equip students with 21st-century skills, including digital literacy and coding; Kenya is localising AI education to address specific national needs, focusing on digital literacy and problem-solving skills to prepare students for a technology-driven future. The success of AI in education will depend on addressing these varied needs and adapting solutions to the unique conditions of each country.

> **"Different regions display varying levels of tech advancement and understanding of AI. In places like South Africa, Mauritius, and in Northern Africa, there's significant progress, with strong internet connectivity in classrooms, and Senegal is aggressively driving tech adoption.**
>
> **However, disparities remain. While there's a desire for AI integration, there are challenges with policy navigation, resource availability, and tech affordability. Internet access and teacher capacity building are crucial. Compared to the Global North, Africa appears to be playing catch-up, but there is a push to optimise data usage to better understand and improve the current situation.**
>
> **Leveraging local learning materials and ensuring that teachers can afford and effectively use AI are essential steps in advancing education."**
>
> **EDUCATION-FOCUSED DEVELOPMENT ASSOCIATION, COMMUNICATIONS SPECIALIST**



National and international initiatives reflect the growing importance of AI in education. As of 2024, no countries have implemented specific regulations on the use of generative AI in education, although France and Korea have proposed regulations pending approval. In the absence of formal regulations, some countries have published non-binding guidance on using generative AI in education. This is also the case in Africa, where countries like Rwanda, Mauritius, and Egypt include education as part of a broader National Strategy on AI.

6.1 Readiness Levels Overview

STANDARDS				
Ready	Policy has been adopted that enables the flexible, diverse, appropriate and meaningful access to digital education opportunities and resources.	Digital education curriculum in place and used in teacher preparation.	Made significant investments in technology and have allocated resources effectively to support AI development.	Relatively high internet penetration and reliable electricity.
Partially Ready	Policy has been adopted that enables the flexible, diverse, appropriate and meaningful access to digital education opportunities and resources.	Ad hoc digital education curriculum in place and applied in unstructured ways in teacher preparation.	Have begun investing in technology but still face challenges in resource allocation.	Urban areas have better internet connectivity and more reliable electricity compared to rural regions.
Not Ready	There is neither a process of policy development nor procedures guiding access to digital education.	No digital education curriculum in place to support teacher preparation.	Limited resources allocated for technology and AI development.	Lower internet connectivity and inconsistent electricity supply present significant challenges to AI integration in education.

AI Readiness across African countries in relation to education can be segmented into: **"Ready"**, **"Partially Ready"** and **"Not Ready"**. Factors such as teacher training, resource allocation, the adoption of policies facilitating digital education, digital education curricula, investment in AI technology and resources, and the supporting infrastructure for internet connectivity and electricity play crucial roles in determining a country's readiness. Each readiness level reflects the country's progress in these areas and its capacity to leverage AI for educational advancement.

Market Readiness Assessment

Country	Infrastructure	Policy & Legal Framework	Teacher Capacity	Curriculum Framework	AI Readiness
South Africa	◉	◉	◉	◉	◉
Kenya	◉	◉	◉	◉	◉
Rwanda	◉	◉	◉	◉	◉
Ghana	◉	◉	◉	◉	◉
Mauritius	◉	◉	◉	◉	◉
Nigeria	◉	◉	◉	◉	◉
Togo	◉	◉	◉	◉	◉

While policies and infrastructure are crucial for AI readiness, the practical constraints of resource allocation present a significant challenge across all readiness levels. Regardless of a country's policy framework, the availability of resources—both financial and infrastructural—can either accelerate or hinder AI adoption, particularly in the education sector. These constraints are especially evident in countries where socioeconomic disparities and the digital divide limit access to necessary technology and infrastructure.

6.2 Resource Allocation and Equity

Resource allocation is **pertinent** to a country's ability to invest in AI and technology. The digital divide and socioeconomic disparities hinder access to AI-driven education, particularly in rural and underserved areas where schools often lack necessary technology and infrastructure. The affordability of AI-powered educational tools poses a challenge for lower-income schools and students, further widening the gap between wealthier and underfunded schools. Addressing these issues is crucial for ensuring equitable access to AI-driven education. Infrastructure, especially internet connectivity and reliable electricity, varies widely across Africa. Urban areas typically enjoy better access, while rural regions often face significant limitations. This disparity in infrastructure directly impacts AI integration, particularly in education, where lower connectivity poses serious challenges.

Even countries with relatively high internet penetration struggle with ensuring equitable access across all regions. Innovative solutions, such as solar-powered ICT **labs** being explored in Ghana, aim to bridge these infrastructure gaps. However, socioeconomic disparities remain a major barrier, hindering access to AI-driven education in underserved areas where schools often lack the necessary technology and funding to maintain these resources.

Addressing these issues is crucial for ensuring equitable access to AI-driven education. For instance, South Africa can leverage its resources and infrastructure through national strategies like the Fourth Industrial Revolution (4IR). In contrast, nations with fewer resources may prioritise more immediate educational needs over long-term AI investments, slowing their progress toward AI readiness.

7.

Policy Recommendations: Paving the Way for AI-Enhanced Education

To harness the transformative potential of AI in African education, governments, policymakers, and educational stakeholders must address the existing challenges through a comprehensive and coordinated approach. Given the few countries with AI policy or AI referenced in national education policies and curricula, there is a gap in top-down guidance at a policy level.

This section provides actionable recommendations to pave the way for an equitable and effective integration of AI into education systems across the continent:

Build Infrastructure for the Future

To ensure that AI-driven educational tools can be widely adopted, significant investments in digital and physical infrastructure are required. Governments must prioritise expanding high-speed internet access and ensuring reliable electricity, especially in rural and underserved regions. Leveraging innovative solutions like solar-powered ICT labs as seen in Ghana, and mobile learning centers can help bridge infrastructure gaps, ensuring that all students—regardless of their location—have equitable access to AI-powered education.

Foster Public-Private Partnerships

Collaboration between governments, the private sector, and educational institutions is essential to fund and scale AI-driven solutions in education. Public-private partnerships can pool resources and expertise, allowing for the co-development of AI tools that are both technologically advanced and tailored to local educational needs. Governments can provide strategic direction, while the private sector offers the necessary technological capabilities and financial backing. This cooperation will accelerate the adoption and long-term sustainability of AI in education.

Develop AI-ready Policies and Regulatory Frameworks

Policymakers must update and develop regulatory frameworks that support the ethical, inclusive, and effective use of AI in education. These frameworks should focus on safeguarding data privacy, promoting equity, and ensuring access to AI-driven solutions, particularly in marginalised and underserved communities. A key aspect of this policy shift should be the establishment of a centralised body—such as a Remote Education Administration Unit—to oversee the strategic implementation and monitoring of AI technologies in education across the country.

Ensure Cultural Relevance and Inclusivity in AI Tools

For AI to be successfully integrated into African education systems, the solutions must be culturally relevant and inclusive. AI models

should reflect local languages, customs, and educational goals to resonate with both students and teachers. Machine learning, the most common form of AI used in education as discussed elsewhere, relies on extensive datasets for training. If these datasets do not align with students' and teachers' aspirations and government school curricula, especially if developed abroad, their adoption rates in schools are likely to remain low, even if the digital infrastructure gap is addressed. Contextualising AI tools to align with national curricula and educational priorities will drive higher adoption rates, particularly in rural and multilingual regions. Localised AI solutions will also help ensure that marginalised communities are not left behind in the digital revolution.

Address Procurement Barriers for AI Tools

The complexity of government procurement processes often hinders the adoption of new technologies in education. To streamline this process, governments should align procurement strategies with national education priorities, ensuring that AI tools are integrated into foundational subjects such as numeracy and literacy alongside more advanced skills like coding. Simplified procurement will enable faster access to AI-driven solutions in public schools, particularly those with limited financial and administrative resources.

Boost Funding for Local AI Research and Development

Local AI research is crucial to creating contextually relevant and effective educational tools. Governments, in collaboration with universities and private sector partners, should invest in research and development (R&D) initiatives that focus on AI for education in African contexts. This will help ensure that AI tools are designed with local educational challenges in mind, such as language barriers and infrastructure gaps. Increasing funding for local R&D will support the development of AI solutions that can be tailored to the specific needs of African students and educators.

Build Capacity for Educators Through Comprehensive Training

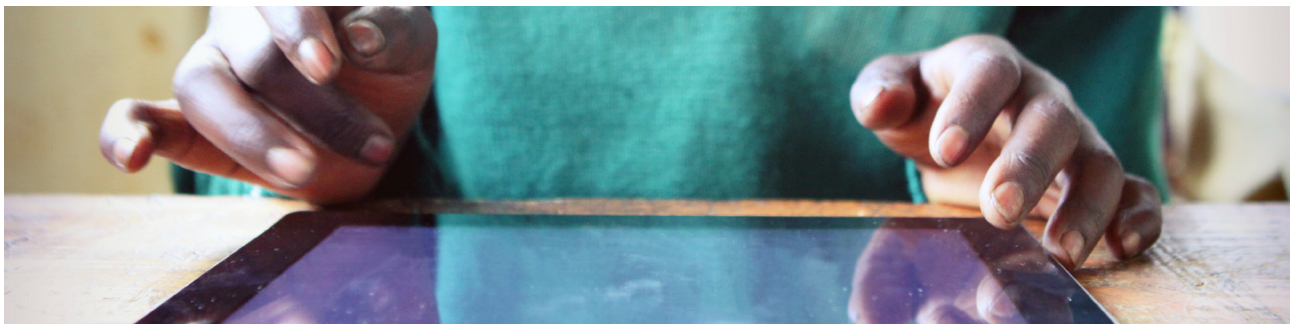
Effective integration of AI in classrooms requires that educators are equipped with the necessary digital skills and tools. Governments and educational stakeholders must prioritise teacher training programs that focus on AI and digital literacy, providing continuous professional development to adapt to emerging technologies. By empowering teachers with the knowledge and confidence to use AI-driven tools, education systems can begin to leverage AI's potential to improve learning outcomes.

Foster Stakeholder Engagement and Build Trust

AI's novelty in education, combined with concerns about data privacy and its effectiveness, has created a trust gap among stakeholders. Governments, educational institutions, and private sector actors should work together to build trust by validating the impact of AI tools through data and case studies. Engaging stakeholders—particularly educators, students, and parents—in the implementation process will help foster confidence in AI's role in improving educational outcomes, increasing its adoption across schools.

8.

Use Cases for the African Context: Where to Focus Our Attention



To ensure that this study delivers relevant and actionable insights for the African education context, this report focused on moving beyond research insights, into practical applications of AI. Recognising the diverse challenges within Africa's education landscape, a methodology was developed to prioritise the most urgent and responsive AI use cases. This involved identifying critical pain points across the educational value chain and aligning use cases that could effectively address them.

Given the unique nuances of the African context, it was crucial that the methodology be contextually sensitive, with criteria defined as follows:

CRITERIA	HIGH (5)	MODERATE (3)	LOW (1)
Impact potential	The challenge, if addressed, would lead to significant improvements in educational outcomes across the continent.	Addressing the challenge would lead to noticeable improvements in educational outcomes, but the effects may be limited to specific regions or populations rather than broadly felt across the continent.	The challenge has a more localised or minimal impact on educational outcomes.
Urgency	The challenge is critical and needs immediate attention due to its effect on learning outcomes.	The challenge is important and addressing it would be beneficial in the short to medium term. However, it does not require immediate intervention as its current impact on learning outcomes is manageable.	The challenge is important but can be addressed later due to its effect on learning outcomes.
Feasibility	The challenge can be effectively addressed with current AI technologies when considered alongside the existing resources in an educational environment.	The challenge can be addressed with current AI technologies, but there are some moderate barriers related to resources, infrastructure, or stakeholder support that would need to be navigated. Solutions would require careful planning and investment.	The challenge is difficult to address due to significant resource or technological barriers.
African Readiness	The market, infrastructure, and stakeholders are not only ready but actively seeking and driving the adoption of AI solutions. There is strong demand, clear alignment with existing policies or frameworks, and the capacity for immediate scale-up.	The market, infrastructure, and stakeholders are ready for adoption of AI solutions, but there may be some hesitancy or gaps in resources, policy alignment, or capacity that could slow down the pace of adoption or scale-up	The market and stakeholders are not ready, requiring more groundwork before adoption.

The following matrix maps education-specific challenges against the criteria defined above. As discussed elsewhere in this document, educational outcomes are particularly poor in rural and peri-urban areas, especially within public institutions. This matrix focuses on the challenges unique to these institutions, intentionally excluding private institutions that typically benefit from better resources, including infrastructure and teacher quality. However, it is important to acknowledge that some challenges may overlap due to the systemic nature of these issues.

The Value Chain	Challenges to the Educational Delivery Value Chain	Impact Potential	Urgency to Address	Feasibility	African Readiness	Total
LEARNING (Student Engagement and Success)	Overcrowded classrooms limit teacher-student interaction and engagement	5	5	4	3	17
	Lack of learning support outside of formal classroom environments hampers growth potential	5	3	4	2	14
	Inadequate infrastructure (poor / lack of facilities) hampers learning access / quality	5	5	3	3	16
	Language barriers and lack of localised content limit accessibility for diverse student groups, including disabled students	5	5	2	1	13
TEACHING (Instruction and Workload Management)	High teacher-student ratios reduce attention per student.	5	5	4	1	15
	Inadequate teacher training and professional development limit instructional effectiveness	3	3	3	1	12
	Poor remuneration and lack of incentives contribute to teacher absenteeism and low morale, affecting teaching quality.	5	5	1	3	14
	Teachers lack time for content development, grading, and providing timely feedback due to heavy workloads.	4	3	3	3	13
ASSESSMENT (Evaluation and Feedback)	Manual marking, feedback and assessment development contribute to overload on teacher capacity, hampering timely, personalised feedback and post-assessment actions such as remedial and retaking courses.	4	3	4	1	12
	Lack of coordinated data systems for monitoring and evaluating educational outcomes across regions and institutions which hampers regional and national strategy for education.	3	3	3	1	10
ADMIN (Operational Support and Curriculum Management)	Outdated curricula that do not reflect contemporary knowledge or skill needs, especially in tech-driven fields.	4	3	3	2	12
	Inefficient administrative processes due to reliance on manual systems for attendance, grading, and reporting	3	3	3	1	10
	Bureaucratic bottlenecks and slow decision-making affect curriculum development and update cycles.	4	2	3	1	10
	Lack of data analytics and insights to improve school management and student performance tracking.	2	3	3	1	9
PLACEMENT & COMMUNITY (Career and Networking Support)	Weak linkages between education institutions and the job market, leading to poor student placement outcomes.	4	3	3	1	11
	Limited or no industry-academia partnerships to support internships, apprenticeships, or work-study programs.	3	3	2	1	9
	Lack of career counseling and networking opportunities to guide students through transitions from education to employment.	3	2	4	1	10
	Limited platforms for alumni engagement and community building, reducing opportunities for mentorship and career growth.	1	2	4	1	8

Based on the preceding prioritisation matrix, the three most pressing challenges appear to be:

1. **Overcrowded Classrooms**
   This challenge limits student attention, engagement, and learning outcomes. It is primarily student-facing and adversely affects educational results from the learner's perspective. Overcrowding removes opportunities for personalised learning, which is crucial for addressing individual needs. The derived need statement is:

> "Learners need personalised learning experiences to enhance their engagement with learning material and academic success.

2. **High Teacher-Student Ratio**
   This issue heightens teacher workloads and restricts their capacity to provide adequate attention to each student. It is specifically teacher-facing and suggests that enhancing teachers' capacity can alleviate the challenges posed by a high teacher-student ratio, leading to improved educational outcomes. The accompanying need statement is:

> "Teachers need support and resources to effectively manage large classrooms and provide individualised attention to students.

3. **Lack of Infrastructure**
   In many communities, the absence of schools entirely hampers access to education and undermines the quality of learning opportunities. This challenge not only limits educational effectiveness but also prevents children from receiving any formal education. The revised need statement is:

> "**Communities need access to educational facilities and resources to ensure that all children have the opportunity to receive a quality education.**

Having defined the need, this report thus explores some use cases that might address the same:

Use case 1: Personalised Learning Enhancement

NEED STATEMENT

> "**Learners need personalised learning experiences to enhance their engagement with learning material and academic success."**

There are a number of applications that respond to the identified need. The need highlights significant challenges faced by students in overcrowded classrooms. Large class sizes hinder students' ability to engage in meaningful conversations and reduce the personalised support teachers can provide.

Traditional methods of teaching are often unable to adapt to the diverse learning needs of students in such environments. To address these issues, effective AI solutions must focus on enhancing communication in learning settings, and individualised learning. Automatic Speech Recognition

(ASR), Text2Speech, Large Language Models (LLMs) offer promising solutions to these issues by enabling more interactive, accessible, and personalised learning, even in large or resource-constrained classrooms:

1. Automatic Speech Recognition (ASR)

ASR technology can transcribe spoken language into text, enabling students to engage with learning materials in real time. In crowded classrooms, ASR can facilitate group discussions by capturing students' contributions, making them accessible to all. In Nigeria, uLesson, is leveraging ASR to help students learn in a more interactive way, making content more accessible during lessons. uLesson uses ASR to provide real-time transcription of lessons, enabling students to engage with the content more interactively. This application helps students in crowded classrooms by making the material more accessible during and after lessons.

2. Text-to-Speech (TTS)

TTS applications convert written text into spoken words, making educational materials more accessible, particularly for struggling readers or those with learning disabilities. In various African contexts, initiatives like the Bookshare program in South Africa provide TTS functionality to support students with visual impairments. In particular, South Africa's BookDash initiative provides TTS capabilities for children's books, enhancing reading accessibility for young learners, particularly those with learning difficulties. Globally, tools like Google's Read Aloud feature in Google Docs enhance accessibility in classrooms.

3. Large Language Models (LLMs)

LLMs can provide personalised tutoring and instant feedback on students' questions, helping to bridge the gap left by large teacher-student ratios. In Africa, platforms like M-Shule in Kenya utilise AI-driven chatbots to deliver personalised learning content and quizzes based on individual student performance. This low-tech solution is ideal for regions with limited internet access, ensuring students can still benefit from personalised learning. The Learning Hub Rwanda platform utilises AI chatbots to provide real-time feedback and tutoring, addressing individual student needs as they progress through the curriculum. This instant support helps to improve engagement and retention, particularly in overcrowded classrooms.

EdTech startup, Eduspot, uses LLMs to provide customised quizzes and learning content based on individual student performance, addressing the unique needs of learners in various subjects. In Nigeria, companies like Andela are working on LLMs to enhance coding education, providing personalised guidance and feedback to students as they learn programming skills. This approach helps students in large classes receive specific guidance, enhancing learning outcomes, particularly in high-demand skills like coding. Internationally, tools such as OpenAI's ChatGPT can assist learners by answering queries, offering explanations, and guiding them through problem-solving processes. This tool is especially useful in large classrooms where teachers may not have the time to address every student's question individually.

Use case 2: AI Solutions for Enhanced Teaching Support

NEED STATEMENT

> **Teachers need support and resources to effectively manage large classrooms and provide individualised attention to students.**

As efforts to deepen school enrollment make headway, the teacher-to-student ratio becomes increasingly unbalanced, placing greater strain on teachers. Managing large classrooms makes it difficult to provide differentiated tasks tailored to individual student needs. Teachers face heavy workloads, including content development, material preparation, in-class follow-up, and providing feedback. This lack of capacity to give each student adequate attention hampers learning outcomes, making it harder to identify issues, assess needs, and provide the necessary support.

AI can alleviate these pressures by optimising key teaching processes. For example, AI tools can analyse educational resources and suggest how they align with the curriculum. Additionally, AI can generate culturally relevant learning materials, ensuring that content resonates with students' backgrounds and experiences. In the African context, where connectivity can be a challenge, AI applications that provide personalised learning through offline devices are highly valuable. These tools can enable effective teaching and learning even in areas with limited internet access, enhancing engagement and understanding through localised content:

1. AI-Driven Resource Analysis

uLesson (Nigeria) – AI tools can analyse and align educational resources with the curriculum, ensuring relevance and cultural appropriateness. uLesson provides tailored educational content aligned with local curriculums. Through the use of AI and machine learning, the platform curates lesson plans and quizzes relevant to Nigerian students' syllabi, helping teachers by providing pre-built, contextually relevant resources. Knewton (USA) – Knewton's adaptive learning platform uses AI to analyse resources and suggest materials that fit students' needs. The platform aligns content with school curriculums, helping educators create targeted lesson plans based on individual performance.

2. Personalised Learning on Offline Devices

In areas with limited connectivity, AI can be integrated into offline devices, allowing for personalised learning experiences without relying on internet access. Kenya's M-Shule leverages AI-powered SMS-based learning platforms to provide personalised tutoring for students without needing internet access. Teachers and parents can track students' progress, and AI algorithms adjust content based on individual learning needs. Elsewhere, Kolibri by Learning Equality provides an offline-first platform that delivers personalised learning materials in

low-connectivity environments. It may be widely used in African countries and refugee camps, where internet access is limited. In particular, it has helped build foundational and socio-emotional skills for out-of-school refugee children in Uganda.

3. Large Language Models (LLMs)

Andela uses AI and LLMs to create educational resources for tech training. LLMs generate coding challenges and provide personalised feedback to learners, helping teachers manage large groups of students by automating feedback. China's Squirrel AI uses LLMs to generate adaptive learning content, helping teachers in large classrooms by automatically creating personalised learning paths for students based on their performance.

4. Natural Language Processing (NLP) – Text Generation

Obami in South Africa uses NLP to help educators generate quizzes and assessments that are tailored to the specific learning needs of students. This relieves teachers from manual preparation work. Google Classroom integrates NLP to help teachers create, distribute, and grade assignments automatically, reducing time spent on administrative tasks.

5. NLP – Summarisation

Ubenwa (Nigeria) applies NLP for newborn cry analysis, but the underlying AI framework is also being tested to summarise student performance and health assessments, which teachers can use to monitor students' wellbeing alongside academic performance. Grammarly's summarisation tools help educators quickly assess student writing and performance. Teachers can use these tools to scan through large volumes of text, saving time on grading and feedback.

6. Machine Learning – Dimensionality Reduction

Zindi, a Pan-African machine learning platform, allows teachers and schools to analyse student performance data and reduce the complexity of interpreting vast datasets. The AI simplifies insights, helping teachers identify at-risk students and focus on key areas for intervention. Coursera uses machine learning to track and analyse student progress, offering simplified performance dashboards for instructors, allowing them to focus on specific groups of students based on learning trends.

7. Audio Tools – Automatic Speech Recognition (ASR)

Nivi (Kenya, Ghana, and South Africa) – Nivi utilises ASR to support teachers by transcribing and analysing classroom conversations, enabling better tracking of student engagement. This allows teachers to give attention to each student's needs. Nuance Dragon (USA) – Nuance's ASR solution is widely used in educational settings to transcribe lectures and classroom discussions, helping teachers manage large classrooms by focusing more on individual student needs.

Use case 3: Enhancing Learning in Resource- and Infrastructure-Constrained Environments

NEED STATEMENT

> **Communities need access to educational resources and infrastructure to ensure that all children have the opportunity to receive a quality education, regardless of their socioeconomic conditions.**

In many low-income and rural communities across Africa, both physical and digital infrastructure are severely lacking. Schools often operate in dilapidated facilities with minimal electrification, limited internet access, and few or no computing devices. These infrastructure challenges create significant barriers to deploying AI tools that could otherwise enhance learning outcomes for both students and teachers. However, innovative uses of AI have emerged that work around these limitations, making quality education accessible even in resource-constrained environments. Two key approaches have shown promise: AI-powered offline learning via Unstructured Supplementary Service Data (USSD) and AI-driven chat applications leveraging existing mobile penetration. These approaches demonstrate how AI can provide personalised educational content and support, even in communities where digital infrastructure is sparse.

1. Offline USSD-Supported Learning

M-Shule's AI-driven platform delivers personalised lessons via SMS, making it possible to reach students in areas with limited or no internet access. By using machine learning, the platform tailors educational content to each student's needs, based on their performance and learning progress. This ensures that even in the most remote regions, learners receive the support they need to succeed. The platform collects and analyses student data to adapt lessons, demonstrating AI's ability to deliver high-quality, individualised learning experiences in environments where traditional digital infrastructure is lacking. This model addresses both infrastructure constraints and learner engagement by leveraging existing mobile networks, which have far greater penetration than internet services in many rural areas. M-Shule's success illustrates how AI can effectively deliver education in underserved communities, bypassing the need for advanced digital infrastructure.

1. AI-Driven Chat Applications for Education

AI chat applications, deployed through popular mobile platforms like WhatsApp, have also shown success in resource-constrained environments. These chatbots leverage existing mobile device penetration, providing low-tech yet highly accessible educational solutions. Platforms like Kitso by Digify Africa offer AI-driven chatbots for educators, parents, and students, delivering

educational support via simple text interfaces. This approach makes it easy to create educational communities, facilitating peer learning and support even where mobile devices are shared among students or caregivers. By relying on basic mobile phone functionality, these AI-powered chat platforms provide a scalable solution that can be rapidly deployed across underserved areas. They also address the teacher-student ratio problem by supplementing the teacher's role with AI-driven support and feedback, ensuring students receive personalised attention despite overcrowded classrooms.

9.

Conclusion:
The Future of Learning in Africa

The integration of Artificial Intelligence (AI) in African education represents a transformative opportunity to address some of the continent's most pressing challenges in the sector. From expanding access to quality education in remote and underserved regions to enabling personalised learning experiences and empowering teachers, AI offers a range of solutions that could revolutionise how education is delivered across Africa. However, realising this potential depends on addressing several structural and contextual barriers—many of which are deeply rooted in the historical, socioeconomic, and infrastructural realities that define education systems in the region.

At the core of this transformation lies the need for robust and forward-thinking investments in digital and physical infrastructure. Without reliable access to high-speed internet and electricity, the promise of AI will remain out of reach for millions of students and educators, particularly in rural and low-income areas. The spotlighted examples of AI-driven solutions like M-Shule's SMS-based personalised learning platform and Kitso's WhatsApp chatbot demonstrate how, even in the absence of advanced infrastructure, AI can still play a pivotal role. These models illustrate the importance of leveraging existing mobile networks and low-tech solutions to ensure that every child, no matter where they live, has access to education.

Beyond infrastructure, the effective integration of AI into African education requires a collective rethinking of policy frameworks. Current regulations around technology in education remain largely focused on basic ICT skills, often neglecting the more sophisticated and innovative possibilities that AI presents. Policymakers must prioritise the development of AI-ready regulations that not only safeguard data privacy but also promote equitable access to these tools. The establishment of a centralised body—such as a Remote Education Administration Unit—could play a key role in overseeing the strategic rollout and monitoring of AI across educational systems, ensuring that its implementation aligns with national priorities and that the benefits of AI are distributed equitably.

However, AI in education must not only address infrastructural and regulatory needs—it must also be culturally relevant. Africa's diverse linguistic and cultural landscape demands AI models that are tailored to local contexts. Solutions that fail to recognise these cultural nuances risk alienating students and teachers alike, reducing adoption and effectiveness. AI tools like Foondamate, which supports multiple African languages, exemplify how culturally sensitive design can enhance the inclusivity and accessibility of educational technologies. Moving forward, localised AI development must be a priority, with significant investments in research and development to create tools that reflect Africa's rich diversity.

In addition to the technical and cultural considerations, there is a pressing need to build capacity among educators.

> Teachers are the backbone of any education system, and their ability to effectively integrate AI into their classrooms will be essential to its success.

Without proper training, the potential of AI will remain untapped, and teachers may view these tools as burdensome rather than beneficial. Continuous professional development and AI-specific training programs must be prioritised to empower educators, allowing them to use AI as a complement to their instructional methods rather than as a replacement. Such capacity building will not only enhance teaching quality but will also ensure that AI is used to its full potential in improving student outcomes.

Further, the importance of collaboration cannot be overstated. Public-private partnerships are essential for mobilising the resources and expertise needed to implement AI solutions at scale. Governments must work closely with the private sector, educational institutions, and local communities to co-create solutions that are contextually relevant and sustainable. By fostering these collaborations, stakeholders can drive innovation while ensuring that AI technologies are effectively aligned with national educational goals.

This study has shown that while the path to AI-driven education in Africa is fraught with challenges, it is also filled with opportunities. Promising examples across the continent, such as M-Shule in Kenya, Rori in Ghana, and Schoolinka in Nigeria, demonstrate the transformative power of AI in enhancing learning outcomes, supporting educators, and bridging gaps in infrastructure. However, scaling these solutions requires urgent action. Governments, educational institutions, and private actors must act decisively to invest in the necessary infrastructure, develop supportive policies, and build capacity at all levels of the educational system.

The integration of AI into African education is not just a technological challenge—it is a social, cultural, and political undertaking. It requires a shared commitment to innovation, equity, and inclusivity, with a focus on creating solutions that meet the needs of Africa's most vulnerable learners. By addressing the gaps in infrastructure, policy, and capacity, and by fostering collaborative approaches, AI can truly revolutionise education across the continent, ensuring that every child has the opportunity to learn, grow, and thrive in the digital age.

10.

Appendix

10.1 Methodology

1. Research Scope

The research focuses on six African countries: Ghana, Nigeria, South Africa, Rwanda, Togo, and Kenya, aiming to provide a comprehensive understanding of the AI-enabled educational landscape in these regions. The study seeks to identify key trends, opportunities, and challenges in the deployment of AI technologies within the education sector. By conducting detailed research in markets that exhibit varying degrees of technological development, this report assesses the readiness and potential of these countries to adopt AI-driven solutions to improve educational outcomes.

The study involves a multi-faceted approach:

DATA SOURCE	OBJECTIVE
Desktop research A review of data from existing sources, including reports, academic papers, and case studies relevant to AI in education across Africa and globally	To understand the education landscape in Africa and identify opportunities for AI deployment in the sector. Additionally, gaps were identified to help strengthen the environment in each country. The desktop research focused on regional trends, challenges, and innovations in AI across Africa, utilising local publications and expert reports. To provide a comparative perspective, global trends and benchmarks in AI education technologies were analysed, drawing lessons from global leaders in the field.
Country-workshops 8 - 12 stakeholders across Ghana, South Africa, and Rwanda, drawing participants from the private sector, civil society organisations (CSOs), non-governmental organizations (NGOs), academia, and development partners	The aim was to identify country-specific contexts, gaps, and opportunities within the AI landscape in education. These sessions progressively tested assumptions and gathered insights from stakeholders on the current state and potential of AI in their respective countries.
Semi-structured stakeholder interviews 38 interviews, including at least four key informant interviews per focus country and globally.	These interviews explored use cases, challenges, and opportunities specific to the education sector and AI deployment. The use of virtual means ensured the inclusion of insights from stakeholders in Togo and Kenya where country workshops were not conducted. Interviews with international AI experts and education technologists provided a global perspective, contextualising local challenges within broader technological advancements.
Steering committee and advisors Monthly and adhoc engagements with the study's Steerco and senior level advisors, to receive strategic guidance, feedback, and oversight to ensure the research	This group provided strategic guidance and expert oversight throughout the research process, ensuring that the study focused on the most critical areas of investigation. They offer feedback on the research design and findings, helping to align the study with key priorities and recommending the incorporation of diverse stakeholder perspectives.
Focus group discussions With teachers, students, and parents, with 5-12 participants in each session	These discussions aimed to validate findings and gather firsthand insights into how AI solutions are perceived and utilised (if at all) in classrooms. Special attention was given to understanding where the desire for AI integration into the education context starts and ends, and understanding the real-world impact of these technologies on teaching and learning experiences from the perspectives of these key users.
Country validation workshops	TBD

2. Research Limitations

While this research provides valuable insights into the use of AI in education across six African countries, several limitations must be acknowledged. The geographical scope of the study is extensive, but the on-ground workshops and focus groups were conducted in only four of the six focus countries—Rwanda, Nigeria, Ghana, and South Africa. Togo and Kenya were included through virtual stakeholder interviews, which, while offering meaningful insights, may not fully capture the nuances and localised experiences as thoroughly as in-person engagements.

Moreover, the research relies heavily on secondary data from existing literature and reports, particularly where primary data collection was limited or impractical. While every effort was made to include diverse perspectives, the availability of data, especially from smaller markets like Togo, presented a challenge.

The findings should thus be interpreted as indicative of broader trends and emerging use cases in AI-enabled education across these regions, rather than definitive conclusions. The study is also limited by the evolving nature of AI technologies, which means that current solutions and use cases may rapidly change. Future research should dive deeper into specific regional contexts, barriers, and ethical considerations regarding AI deployment in education, especially in terms of inclusivity and long-term sustainability.