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Human Capital as an Untapped Resource: Technology Infrastructure and Funding Deficits as Barriers to 21st Century Skills and Artificial Intelligence Integration in Nigerian Schools

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Abstract

Human capital is increasingly recognised, alongside natural resources, as one of Sub-Saharan Africa's most consequential yet under-harnessed development assets, and the global shift toward Science, Technology, Engineering, Arts, and Mathematics (STEAM) education has placed 21st century skills and Artificial Intelligence (AI) literacy at the centre of national development strategies, including Nigeria's. However, the realisation of this vision in Nigeria, and by extension in much of Sub-Saharan Africa, remains constrained by deep-seated technology infrastructure deficits and chronic underfunding of the education sector. This paper interrogates the extent to which inadequate ICT infrastructure, unreliable electricity, low internet penetration, and insufficient capital budgetary allocation undermine the integration of AI and 21st century skills into Nigerian basic, secondary, and tertiary education. Drawing on recent national data, policy documents, and empirical studies, the paper situates the discourse within Nigeria's 2024 National Artificial Intelligence Strategy and the Federal Ministry of Education's 2026 digitalisation drive, while highlighting the contradictions between policy ambition and infrastructural reality. The paper adopts a qualitative, document-analysis approach and is anchored on the Diffusion of Innovation Theory and the Digital Divide framework. Findings reveal that funding for education remains far below the UNESCO-recommended benchmark, that capital expenditure on educational infrastructure has declined in real terms, and that rural-urban disparities in ICT access continue to widen learning inequalities. The paper argues that without deliberate, equity-focused investment in power supply, broadband connectivity, teacher capacity, and locally relevant AI tools, Nigeria risks reproducing rather than resolving educational inequality through technology. The paper concludes with policy-relevant recommendations for government, tertiary education funding agencies, and school administrators on bridging the infrastructure-funding gap so that Nigeria, and Sub-Saharan Africa more broadly, can build and explore its human capital as a

genuine resource and opportunity for inclusive, multi-disciplinary, and sustainable development in the 21st century.

Keywords: 21st century skills, Artificial Intelligence, technology infrastructure, education funding, STEAM education, digital divide, Nigeria

Introduction

The twenty-first century has redefined what it means to be educated. Beyond literacy and numeracy, learners are now expected to demonstrate critical thinking, collaboration, communication, and creativity, the so-called "4Cs" that recur across major frameworks including the Partnership for 21st Century Skills, EnGauge, and the Assessment and Teaching of 21st Century Skills initiative (Shek, Chau, Lee, 2025). Thornhill-Miller et al. (2023) note that these competencies, alongside digital literacy and, increasingly, fluency in Artificial Intelligence (AI) tools and applications, are widely regarded as prerequisites for participation in a knowledge-driven, technology-mediated global economy. For Nigeria, a nation with one of the youngest and fastest-growing populations in the world, with a median age of just 18 years and more than half of its population are under 30 (World Economic Forum, 2025) the urgency of equipping learners with these skills is matched only by the scale of the infrastructural and financial obstacles standing in the way. Nigeria's digital literacy rate stood at only 50% as of mid-2025, and over 60% of primary school teachers reportedly lack digital proficiency, while persistent gaps in electricity and internet access continue to constrain digital skills acquisition, particularly in rural areas (African Leadership Magazine, 2025; TC Insights, 2025). The theme of this conference, "Create, Build and Explore Sub-Saharan African Resources and Opportunities for Sustainable Development in the 21st Century: A Multi-Disciplinary Approach," rightly identifies human capital, alongside natural resources, as a resource Sub-Saharan Africa must deliberately build and explore, and foregrounds the structural conditions that determine whether technology-enhanced education succeeds or merely exists on paper. Nigeria's Federal Ministry of Education has, in recent years, articulated an ambitious digital-first agenda, including the Digitalisation of Public Schools Initiative launched in October 2025, the planned migration of technical and vocational curricula to digital platforms, and the federal mandate for computer-based testing by the West African Examinations Council (WAEC) and the National Examinations Council (NECO) by 2026 (Lawal, 2026).

Yet beneath this policy ambition lies a more sobering reality. The same government reports that motivate the push toward AI-enabled, technology-rich classrooms also concede that many Nigerian public schools remain unfenced, lack stable electricity, and cannot support the deployment of modern ICT systems (Lawal, 2026). This paper examines that contradiction. It interrogates the gap between Nigeria's technology-in-education aspirations and the infrastructural and financial base required to realise them, with specific attention to how this gap shapes the integration of 21st century skills and AI in classrooms across the country.

Statement of the Problem

Despite growing global and national consensus on the necessity of integrating AI and 21st century skills into education, Nigerian schools continue to operate under conditions that make such integration largely aspirational rather than operational. Successive studies report that ICT infrastructure in Nigerian secondary schools remains grossly inadequate, with poor internet connectivity, unreliable power supply, and a near-

total absence of computers and digital devices in many rural and even some urban schools (Okwe & Eromosele, 2025; Mohammed, 2026).

Compounding this infrastructural deficit is a persistent funding shortfall. Nigeria's education budget has consistently fallen short of the UNESCO-recommended benchmark of 15 to 20 percent of national annual budgets (Edugist, 2024). Even where nominal allocations have increased, the real value of education spending has declined due to currency depreciation and inflation, while capital expenditure dedicated to infrastructure, laboratories, and ICT facilities fell by approximately 18 percent in a single budget year (BusinessDay, 2026). The problem, therefore, is not merely an absence of policy intent but a structural mismatch between the technological ambitions embedded in national education policy and the financial and physical infrastructure available to schools, teachers, and learners to act on that intent. This paper interrogates this mismatch and its implications for sustainable development.

Objectives of the Paper

This paper specifically sets out to:

1. examine the current state of technology infrastructure available for 21st century skills and AI education in Nigerian schools;
2. assess the extent and impact of funding deficits on the integration of AI and digital technologies in Nigerian basic, secondary, and tertiary education;
3. explore the implications of the infrastructure-funding gap for equity and sustainable development in Nigerian STEAM education; and
4. proffer evidence-based recommendations for bridging the gap between Nigeria's AI and 21st century skills policy ambitions and its educational infrastructural realities.

21st Century Skills

21st century skills refer to a broad set of competencies considered essential for success in contemporary life and work, commonly grouped into learning skills (critical thinking, creativity, collaboration, communication), literacy skills (information, media, and technology literacy), and life skills (flexibility, leadership, initiative, productivity, and social skills) (Adeoye et al., 2024). Within the Nigerian context, these skills are increasingly framed around STEAM disciplines and digital competence, reflecting the conference theme's multi-disciplinary emphasis on creating, building, and exploring Africa's human and natural resources for sustainable development.

Artificial Intelligence in Education

Artificial Intelligence in education (AIEd) describes the application of machine learning, natural language processing, and intelligent systems to support teaching, learning, assessment, and school administration. In Nigeria, AI applications in education currently range from adaptive learning platforms and AI-powered homework support tools, such as those deployed by edtech platforms like uLesson, to proposed AI-driven classroom observation and analytics tools for teacher supervision (Gambo et al., 2026). Nigeria's National Artificial Intelligence Strategy, published in 2025 by the Federal Ministry of Communications, Innovation and Digital Economy, identifies education as a priority domain for AI-driven social development and sets a target of equipping at least 70 percent of the youth workforce, including 50 percent women, with AI-related skills by 2029 (OECD.AI, 2026).

Technology Infrastructure and Funding Gaps

Technology infrastructure, in this paper, encompasses the physical and systemic foundations required for digital and AI-enabled learning: electricity supply, internet connectivity and broadband penetration, computing devices, digital learning platforms, and the technical capacity to maintain them. Funding

gaps refer to the disparity between the financial resources required to establish and sustain this infrastructure and the resources actually allocated and disbursed by government and institutional budgets. The interaction between these two concepts forms the central problem this paper addresses, as inadequate funding directly constrains the scale and quality of technology infrastructure available to schools.

Human Capital as a Sub-Saharan African Resource

Consistent with this conference's framing of Sub-Saharan African resources and opportunities for sustainable development, this paper treats human capital, the knowledge, skills, and digital and AI literacy of Africa's people, as a resource in the same conceptual sense as the continent's natural resources: an asset that must be deliberately built and explored rather than assumed to develop on its own. The African Union's Agenda 2063 explicitly names a well-educated citizenry and a science, technology, and innovation-driven skills revolution as prerequisites for the continent's first aspiration, a prosperous Africa built on inclusive growth and sustainable development (African Union, n.d.). Experts at the African Development Bank's 2025 Annual Meetings likewise argued that achieving Agenda 2063 depends on Africa deliberately leveraging its human, financial, natural, and digital resources together, rather than treating human capital development as separate from resource-based growth strategies (African Development Bank, 2025). Yet Sub-Saharan Africa continues to record some of the world's largest human capital deficits: the region's working-age population is projected to grow by more than 620 million people over the next 25 years, even as weak education and health systems mean many countries could raise labour income by 58 to 76 percent if outcomes matched better-resourced peers, with Nigeria alone estimated to have room to improve its Human Capital Index score by around 70 points (Ecofin Agency, 2026). Read together with the World Bank's observation that the region's rich natural resources and large market give it the potential to chart a new development path by harnessing its resources and people (World Bank, 2026), these findings reinforce this paper's central argument: technology infrastructure and funding deficits do not merely limit AI and 21st century skills acquisition in Nigerian schools, they constrain the conversion of one of Sub-Saharan Africa's most important resources, its people, into the human capital that this conference's theme identifies as central to inclusive, multi-disciplinary, and sustainable development.

Theoretical Framework

This paper is anchored on two complementary theoretical perspectives: Rogers' Diffusion of Innovation Theory and the Digital Divide framework.

Rogers' Diffusion of Innovation Theory explains how, why, and at what rate new ideas and technologies spread through a social system. The theory identifies infrastructure, relative advantage, compatibility, and observability as key determinants of adoption. Applied to Nigerian education, the theory helps explain why AI tools and digital learning platforms, despite their demonstrated advantages elsewhere, diffuse slowly and unevenly across Nigerian schools: the absence of supporting infrastructure such as electricity and connectivity disrupts the conditions necessary for sustained adoption, regardless of how compelling the innovation itself may be.

The Digital Divide framework, on the other hand, conceptualises technology access inequality not merely as a binary of "have" and "have-not," but as a layered phenomenon spanning access, usage, and outcome divides (Esteban-Navarro et al., as cited in Sotayo et al., 2026). This framework is particularly useful for understanding how Nigeria's infrastructure and funding gaps do not merely delay AI and 21st century skills integration uniformly, but actively widen the gap between urban and rural learners, and

between public and well-resourced private schools, thereby threatening the equitable, opportunity-driven development that this conference's theme explicitly envisions for Sub-Saharan Africa.

The State of ICT Infrastructure

Empirical evidence consistently points to a low baseline of ICT infrastructure across Nigerian schools. A descriptive survey of public secondary schools in Edo State found that the availability of ICT facilities was very low, with limited infrastructure, unreliable power supply, and inadequate facilities identified as the principal barriers to utilisation (Okwe & Eromosele, 2025). Similarly, a study of secondary schools in Oyo State reported that poor infrastructure, lack of teacher training, and inadequate funding combined to produce a generally low level of ICT adoption in school management, even though ICT was comparatively well-utilised for narrow administrative functions such as record-keeping (Mohammed, 2026).

At a national level, Nigeria's internet penetration remains a binding constraint: approximately 46 percent of the country's estimated population of over 200 million people still lack access to internet connectivity (Businessday NG, 2023; Sotayo et al., 2026). This connectivity gap is not evenly distributed; it is most acute in rural and remote communities, where socioeconomic status, electricity access, and the absence of coherent ICT policy compound one another to produce what researchers describe as digital exclusion (Sotayo et al., 2026).

A broader survey of educational facilities found that inadequate ICT resources were reported by close to half of respondents, alongside high rates of poor ventilation, inadequate sanitation, and frequent infrastructure failure, indicating that ICT deficits in Nigerian schools rarely occur in isolation but as part of a wider pattern of infrastructural neglect (Africanscholarpub, 2026). The Universal Basic Education Commission has likewise reported that more than half of Nigeria's public schools lack adequate classrooms and basic amenities, underscoring that AI and digital technology integration is being layered onto a foundation that, in many cases, has not yet secured basic physical infrastructure (Edugist, 2024).

Funding Trends and Their Implications

Nigeria's education funding has long fallen short of international benchmarks. UNESCO recommends that countries allocate between 15 and 20 percent of their annual national budgets to education (Edugist, 2024); Nigeria's allocations have persistently fallen below this threshold. In the 2025 fiscal year, the Federal Government allocated ₦3.52 trillion to education, the highest nominal figure in the nation's history, yet experts characterised the sum as insufficient given the scale of the sector's challenges and the depreciating value of the naira (ICIR, 2026). The situation was compounded by a reported 18 percent year-on-year decline in real education spending, with capital expenditure, the budget category most directly responsible for ICT facilities, laboratories, and infrastructure renewal, bearing a disproportionate share of the cuts (BusinessDay, 2026).

Beyond the question of allocation lies the equally consequential question of disbursement. Analysts have noted that funds budgeted for infrastructure and institutional development often remain underutilised due to delays in release and weak transparency in how allocated funds are spent (ICIR, 2026). The Federal Government's recent introduction of the Tertiary Institution Governance and Transparency Platform, which mandates public disclosure of capital expenditure and other financial data by tertiary institutions, represents a tacit acknowledgement of this disbursement problem (ICIR, 2026).

***Table 1**: Selected Indicators of Nigeria's Education Infrastructure and Funding Gap*

Indicator	Reported Figure
UNESCO-recommended education budget share	15%–20% of national budget
2025 Federal education allocation	₦3.52 trillion (highest nominal figure on record, yet deemed insufficient)
Year-on-year change in real education spending (2025)	Declined by approximately 18%
Population without internet access	Approximately 46% of over 200 million people
Public schools lacking adequate classrooms/amenities	Over 50%
National AI skills target (youth, ages 16–35) by 2029	70% (including 50% women)
Nigeria's public R&D investment	Approximately 0.2%–0.3% of GDP (constrained)

Source: Compiled by the author from Edugist (2024); BusinessDay (2026); ICIR (2026); Olanrewaju et al. (2026); and OECD.AI (2026).

Implications for 21st Century Skills and AI Integration

The infrastructure and funding deficits documented above carry direct implications for the quality and equity of 21st century skills and AI education in Nigeria. First, they constrain the pace of policy implementation. The Federal Government's mandate that WAEC and NECO transition to computer-based testing by 2026, and its parallel digitalisation of public schools, depend on a stable supply of electricity and functioning ICT equipment that many schools simply do not possess (Lawal, 2026). Without addressing the underlying infrastructure deficit, such mandates risk producing a two-tier examination and learning system: one for well-resourced schools that can comply, and another for the majority that cannot.

Second, the gap exacerbates rather than narrows educational inequality. Because ICT and AI access correlate strongly with urban location and socioeconomic status, learners in rural and underserved communities, who arguably stand to benefit most from AI-enabled personalised learning and remediation, are precisely those least likely to access it (Sotayo et al., 2026). This dynamic directly undermines the inclusive-growth and social-equity dimensions of the conference's theme, since technology-driven reform, absent deliberate redistribution of infrastructure and funding, tends to amplify existing advantage rather than democratise opportunity.

Third, the funding gap constrains teacher capacity-building. Several studies identify inadequate training, alongside poor infrastructure and funding, as a central barrier to ICT and AI adoption in Nigerian classrooms (Okwe & Eromosele, 2025; Mohammed, 2026). Teachers cannot be expected to model AI literacy and digital fluency for learners when professional development budgets are themselves casualties of the broader capital expenditure decline. The National Artificial Intelligence Strategy's ambition to embed AI across Nigerian education will, therefore, remain substantially aspirational unless matched by deliberate, ring-fenced investment in teacher training infrastructure (OECD.AI, 2026).

Finally, there is a risk of policy incoherence between competing visions of technology in education. Some Nigerian educationists have cautioned against an uncritical, "digital-first" approach, arguing that foundational infrastructure, including electricity, security, and even basic textbooks, should precede

large-scale technology deployment (Lawal, 2026). This caution does not negate the value of AI and 21st century skills integration; rather, it reinforces the central argument of this paper, that infrastructure and funding adequacy is a precondition for, not a parallel track to, meaningful technology integration in Nigerian education.

Strategies for Bridging the Infrastructure-Funding Gap

Addressing the challenges identified in this paper requires coordinated action across multiple levels of the Nigerian education system. The following strategies are proposed:

- Progressive alignment of education budget allocation with the UNESCO benchmark of 15–20 percent of national budget, with capital expenditure for ICT and AI infrastructure explicitly ring-fenced and protected from in-year budget cuts.
- Strengthened transparency and accountability mechanisms, building on initiatives such as the Tertiary Institution Governance and Transparency Platform, to ensure that funds budgeted for infrastructure are actually disbursed and utilised for their intended purpose.
- Leveraging public-private partnerships and corporate social responsibility programmes, following the model of solar-powered AI hubs deployed in rural schools through collaborations between government, UNICEF, and private technology firms, to extend connectivity and devices to underserved areas.
- Prioritising renewable and decentralised power solutions, such as solar installations, for schools in off-grid and unstable-grid areas, recognising that unreliable electricity supply is consistently identified as a root barrier to ICT and AI adoption.
- Embedding AI and digital literacy into pre-service and in-service teacher education curricula, with dedicated, protected funding lines, so that teacher capacity does not lag behind the technology being introduced into classrooms.
- Adopting a "leapfrogging" approach where genuinely appropriate, using AI simulations and virtual laboratories to substitute for physical equipment that is costly or unavailable, while avoiding the assumption that digital tools can substitute for foundational infrastructure such as electricity and basic learning materials.
- Developing locally relevant AI datasets and tools suited to Nigerian languages, curricula, and contexts, rather than relying solely on imported platforms, to ensure that AI integration strengthens rather than bypasses local educational needs.
- Strengthening Tertiary Education Trust Fund (TETFund) and Universal Basic Education Commission (UBEC) interventions specifically targeted at ICT and AI infrastructure in colleges of education and teacher training institutions, given their central role in preparing the next generation of technology-literate educators.

Conclusion

Nigeria's aspiration to reimagine STEAM education through the integration of 21st century skills and Artificial Intelligence is well-founded and timely, situated within a global context in which technological fluency increasingly determines economic competitiveness and social mobility. However, this paper has argued that the realisation of this aspiration is currently constrained less by a deficit of policy ambition than by a persistent and well-documented gap between that ambition and the technology infrastructure and funding base required to support it. Unreliable electricity, low internet penetration, inadequate ICT facilities, and education budgets that fall short of international benchmarks combine to slow, and in some cases actively undermine, the equitable diffusion of AI and digital learning tools

across Nigerian schools. If left unaddressed, this gap threatens to deepen rather than dissolve existing inequalities between urban and rural, and public and private, educational provision. Bridging it will require sustained political commitment to funding, transparent disbursement of allocated resources, decentralised and renewable infrastructure solutions, and a teacher workforce equipped and supported to use these tools meaningfully. Only on such a foundation can Nigeria, and Sub-Saharan Africa more broadly, create, build, and explore its human capital as the genuine resource and opportunity for sustainable development envisioned in this conference's theme.

Recommendations

Based on the foregoing discussion, this paper recommends that:

1. the Federal and State Ministries of Education progressively increase education budget allocation toward the UNESCO-recommended threshold, with specific, protected capital lines for ICT and AI infrastructure;
2. the National Assembly and relevant oversight agencies strengthen monitoring of budget disbursement and implementation to close the gap between allocated and utilised education capital funds;
3. State governments, in partnership with development agencies and private technology firms, prioritise solar and decentralised power solutions for schools in off-grid and educationally disadvantaged areas;
4. Colleges of education and teacher-training institutions, including Federal Colleges of Education, receive dedicated TETFund-supported investment in AI and digital literacy curricula for pre-service teachers; and
5. policymakers ensure that AI and digital technology deployment in schools is sequenced alongside, not as a substitute for, foundational infrastructure such as electricity, classrooms, and basic learning materials, in order to safeguard equity across Nigeria's diverse school contexts.

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