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STEAM & Economic Growth in Africa

Published by
Directorate of Policy and Research
Nexus International University, Uganda

Date Published: June, 2026

ISBN: 978 - 978 - 61370 - 8-7

DOI: 10.48028|iiprds|ap-26|STEAM-EGA.7087

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DEDICATION

Dedicated to the International Institute for Policy Review & Development Strategies for providing a platform that supports Institutional and Collaborative Research for Sustainable Development.

ACKNOWLEDGEMENT

Contributors are greatly acknowledged for supporting research on
STEAM & Economic Growth in Africa

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STEAM & Economic Growth in Africa

Introduction:
Unleashing Africa's Potential through STEAM Integration

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The narrative of economic development in the twenty-first century is increasingly defined by technological advancement and creative innovation. For Africa to accelerate its industrial growth and achieve sustainable developmental milestones, a transition from traditional educational paradigms to an integrated, multidisciplinary framework is essential. Science, Technology, Engineering, Arts, and Mathematics (STEAM) collectively combine technical specialization with human-centered creativity to drive systemic progress. This edited volume, STEAM & Economic Growth in Africa, explores how cross-disciplinary synergy can be leveraged to foster unprecedented innovation, productivity, and sustainable economic transformation across the continent.

The foundational objective of this book is to analyze the strategic pathways through which STEAM can optimize human capabilities and revitalize economic structures. To achieve this, the volume organizes its contributions into clear thematic pillars that address both localized initiatives and macro-level policies. The text opens with an examination of conceptual and theoretical perspectives, establishing a firm academic foundation before diving into practical sectors like arts, creativity, and the cultural economy. Acknowledging that true growth must be equitable, the volume highlights the critical role of gender, youth, and inclusion within STEAM disciplines, alongside targeted pathways for education and human capital development.

Furthermore, this volume confronts the operational demands of a modern digital economy. It unpacks the dynamics of technology, innovation, and industrial transformation, specifically focusing on digital transformation and the execution of the Fourth Industrial Revolution in Africa. Because structural evolution requires institutional stability, contributions offer robust evaluations of policy, governance, and institutional frameworks necessary to sustain growth, backed by global partnerships and cross-border knowledge exchanges. By grounding these concepts in real-world case studies and best practices of African STEAM initiatives, this collection successfully bridges the gap between academic theory and actionable governance, providing a definitive framework for the continent's post-industrial landscape.

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EXECUTIVE SUMMARY

STEAM & Economic Growth in Africa

Executive Summary

What You Need To Know About The Challenges of Stem in Africa

Dominic Chavez
World Bank

Africa's future hinges on transforming science, technology, engineering, and mathematics (STEM) education to unlock the talent of its youth and power sustainable development.

Why Focus on STEM Education in Africa?
STEM is key to drive innovation, economic growth and sustainable development in Africa. The increasingly more educated population is no doubt the strongest asset for the continent. By 2030, young Africans are expected to make up 42 percent of the world's youth and account for 75 percent of those under age 35 in Africa, highlighting the need to improve STEM education to harness their potential (Population Reference Bureau: "Africa's Future: Youth and the data defining their lives. This demographic boom presents a significant opportunity for economic growth, innovation, and job creation, but it also highlights the pronounced skills gap in STEM fields that poses a serious challenge to the continent. To meet the anticipated demand for skilled professionals in engineering, healthcare, IT, and other vital sectors, Africa needs an additional 23 million STEM graduates by 2030 to fill key roles ("World Economic Forums Future of Jobs Report 2023). Building a robust, contextually relevant STEM education system is essential to ensure accessible and culturally aligned learning that prepares students for the demands of the modern workforce. Key strategies include enhancing teacher training programmes, equipping classrooms with essential educational resources, and bridging the digital divide. These measures are key for cultivating a skilled, adaptable workforce capable of advancing sustainable development and driving technological progress throughout the continent.

Why is gender equality and inclusion in STEM important?
Gender equality and inclusion in STEM are vital for fostering a dynamic and innovative ecosystem across Africa. In Africa, 30% of science professionals are women (Women and girls in science and technology: Bridging the gender gap, UNDP). Despite progress, women and girls continue to face significant barriers, including cultural biases, limited access to female

role models, and insufficient supportive policies. These challenges contribute to stark disparities, exemplified by the fact that women constitute less than 15% of engineering and technology researchers in some West and Central African countries. This gender gap not only stifles individual potential but also constrains the diversity of ideas, perspectives, and solutions essential for meaningful innovation and progress.

Beyond gender, consideration must be given to how socio-economic status, disability, and location impede access to STEM education. Systemic obstacles such as inadequate infrastructure, limited digital access, and financial constraints can marginalize entire groups, thereby limiting the pool of talent and ideas available to advance STEM in Africa. By investing in targeted mentorship programmes, bolstering teacher training, implementing scholarships for underprivileged students, and creating accessible learning spaces, Africa can build an inclusive environment where all girls, boys, women, men, and individuals with diverse backgrounds can fully participate and contribute to the continent's growth.

What Role Does Innovation, Entrepreneurship and Engineering Play in Africa's STEM Future?

Innovation, entrepreneurship, and engineering are crucial pillars for shaping Africa's STEM future and unlocking its full potential. By fostering a culture rooted in STEM-driven innovation, the continent can empower its rapidly expanding youth population to spearhead transformative digital and economic progress. A 2024 report by the African Union Commission and the OECD highlights a critical gap: only 9% of youth aged 15-24 across 15 African countries have basic computer skills, with just 10% of the male workforce and 7% of the female workforce possessing these competencies. Enhancing digital literacy and technical skills is essential for Africa to remain competitive in the global economy and drive sustainable growth.

How Can Science Diplomacy and Partnerships Impact STEM Development in Africa?

Science diplomacy and strategic partnerships are vital for accelerating STEM development in Africa. They contribute to bridging gaps and creating opportunities for collaboration and growth. In 2018, sub-Saharan Africa had only 124 researchers per million inhabitants, far below the global average of over 1,000. Strengthening science diplomacy can help address this disparity by fostering cross-border collaborations, attracting international investments, and supporting South-South partnerships, which are essential for sharing resources and best practices in Africa. Collaborations with international organizations and the African diaspora can help retain local talent, mitigate brain drain, and promote innovation. Public-private partnerships can fund educational programmes, research, and technological growth, aligning resources from governments, businesses, and global entities. Strengthening science diplomacy and partnerships will enable Africa to address regional challenges, build capacity, and become a key player in STEM.

What Does UNESCO Do?

UNESCO supports national capacities to deliver gender-responsive STEM education. With financial support from partners UNESCO is building capacity-building of teachers in sub-Saharan Africa and Asia. UNESCO works to empower girls and women in acquiring basic competences and digital skills to help close the gender digital divide. For example, through

financial support from Intel, Prada and other partners, UNESCO is enhancing girls' digital skills for learning. Role models and mentors have been found to be particularly effective in tackling gender bias. They offer girls an authentic understanding of STEM studies and careers and show them that they too can become who they dream of being. UNESCO has expanded related initiatives at country level through innovative partnerships with Airbus, HNA, Intel, L'Oréal, Prada, WomEng and other partners.

UNESCO also produced a cutting-edge global report entitled "Cracking th Code: Girls and Women education in science, technology, engineering and mathematics (STEAM) back in 2017, mapping the status of girls and women in STEM education and identifying the factors hindering and promoting their participation, achievement and continuation in STEM fields. This report was the first to document the drivers of gender disparity in STEM studies globally. Through this comprehensive research exercise, UNESCO has built a strong knowledge base on the gender gap in STEM education and provided evidence-based policy recommendations to education ministries and stakeholders. UNESCO and the African Union Commission (AUC), together with key continental organizations, convened the Continental Conference on Transforming Science, Technology, Engineering and Mathematics (STEAM) in Africa. In Addis Ababa, Ethiopia, from 26 to 28 November 2024. Discussions focused on fostering partnerships among governments, educational institutions, and the private sector, attracting investments, and shaping inclusive policies that prioritize Africa's development goals. The Conference resulted in the Addis Ababa Communiqué serving as a road map on the way forward for STEM in Africa.

First Published: https://www.unesco.org/en/articles/what-you-need-know-about-challenges-stem-africa

Chapter 1

SCIENCE, TECHNOLOGY, ENGINEERING, ARTS AND MATHEMATICS (STEAM) IN AFRICA: CHALLENGES, OPPORTUNITIES AND LESSONS FOR NIGERIA

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Abstract
Science, Technology, Engineering, Arts and Mathematics (STEAM) education has emerged as a critical framework for developing the human capital required for innovation, industrialization, digital transformation, and sustainable development in the twenty-first century. Across Africa, governments and development partners increasingly recognize STEAM as a catalyst for economic competitiveness and knowledge-driven growth. This paper examines the evolution, interrelationship, challenges, and prospects of STEAM education in Africa, with particular emphasis on lessons for Nigeria. Drawing on contemporary literature, policy reports, and empirical studies, the paper explores the integration of science, technology, engineering, arts, and mathematics as complementary disciplines that foster creativity, problem-solving, entrepreneurship, and innovation. The study reveals that although several African countries have made progress in expanding STEM and STEAM education, significant challenges remain, including inadequate infrastructure, insufficient funding, shortages of qualified teachers, digital inequality, weak industry-academia linkages, and gender disparities. Comparative analysis indicates that developed countries outperform most African nations in research investment, technological innovation, digital infrastructure, and STEAM-related skills development. The paper highlights successful experiences from South Africa, Rwanda, Kenya, Egypt, China, Finland, and the United States and identifies policy lessons applicable to Nigeria. The study concludes that strengthening STEAM education is essential for Africa's industrial transformation and recommends increased investment in education, innovation ecosystems, research and development, digital infrastructure, and industry partnerships.

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Keywords: *STEAM Education, Innovation, Human Capital Development, Digital Economy, Industrialization, Africa.*

Introduction

The twenty-first century global economy is increasingly driven by knowledge, innovation, creativity, and technological advancement. The emergence of the Fourth Industrial Revolution (4IR), characterized by artificial intelligence, robotics, big data analytics, cloud computing, biotechnology, renewable energy technologies, and advanced manufacturing systems, has transformed the nature of production, employment, and economic competitiveness. Consequently, nations that invest significantly in Science, Technology, Engineering, Arts, and Mathematics (STEAM) education tend to experience higher levels of productivity, industrial development, technological innovation, and sustainable economic growth (World Economic Forum, 2024). In today's knowledge-based economy, the ability of a nation to generate, adapt, and utilize scientific and technological knowledge has become a critical determinant of its development trajectory. STEAM education represents an evolution of the traditional Science, Technology, Engineering, and Mathematics (STEM) framework through the integration of Arts and creativity into scientific and technological learning. While STEM focuses primarily on developing technical and analytical competencies, STEAM broadens the educational approach by incorporating creativity, design thinking, communication, innovation, and cultural awareness. The inclusion of Arts recognizes that technological breakthroughs often emerge from the intersection of scientific knowledge and creative thinking. As a result, STEAM promotes interdisciplinary learning, enabling learners to solve complex real-world problems through the application of both technical expertise and creative innovation (UNESCO, 2024).

Globally, governments and educational institutions are increasingly adopting STEAM approaches to prepare learners for emerging occupations and future workforce demands. The rapid advancement of digital technologies has created new opportunities in fields such as software engineering, artificial intelligence, cybersecurity, data science, renewable energy systems, biotechnology, digital media, animation, industrial design, and creative industries. These sectors require individuals who possess not only scientific and technical knowledge but also creativity, adaptability, collaboration, and critical thinking skills. Consequently, STEAM education has become a strategic tool for developing human capital capable of driving innovation, entrepreneurship, and economic transformation. For Africa, the significance of STEAM education is particularly profound. The continent is experiencing rapid population growth and possesses one of the youngest populations in the world. According to projections by the United Nations, Africa's population is expected to exceed 2.5 billion people by 2050, with a substantial proportion consisting of young people entering the labour market annually. This demographic trend presents both opportunities and challenges. On one hand, Africa's youthful population can serve as a powerful engine for innovation, productivity, and economic growth. On the other hand, the inability to equip young people with relevant skills for the modern economy could exacerbate unemployment, poverty, inequality, and social instability.

Recognizing the importance of science, technology, and innovation in development, the African Union's Agenda 2063 identifies technological advancement, knowledge creation,

innovation, and human capital development as essential pillars for achieving sustainable development and economic transformation across the continent. Similarly, the United Nations Sustainable Development Goals (SDGs), particularly Goals 4, 8, 9, and 17, emphasize quality education, decent work, innovation, industrialization, and partnerships as critical pathways toward inclusive development. These frameworks underscore the central role of STEAM education in building the skilled workforce required for Africa's future prosperity. Despite its immense potential, Africa continues to face significant challenges in the development and implementation of effective STEAM education systems. Many African countries struggle with inadequate educational infrastructure, limited funding for science and technology education, shortages of qualified teachers, weak research and innovation ecosystems, poor digital connectivity, and limited access to modern laboratories and learning resources. Furthermore, gender disparities remain prevalent in STEAM-related disciplines, with women and girls underrepresented in science, technology, engineering, and mathematics fields. These challenges have constrained the continent's capacity to fully harness its demographic advantages and compete effectively in the global knowledge economy.

Research and development (R&D) investment in most African countries remains considerably lower than global averages. While developed countries such as the United States, Germany, Japan, South Korea, and Finland invest substantial portions of their Gross Domestic Product (GDP) in research, innovation, and technological development, many African nations allocate less than one percent of GDP to these critical sectors. Consequently, the continent contributes a relatively small share of global scientific publications, patents, technological innovations, and high-technology exports. This gap has significant implications for Africa's industrialization efforts, economic diversification, and global competitiveness. Nevertheless, recent developments indicate growing momentum toward strengthening STEAM education across the continent. Countries such as Rwanda, South Africa, Kenya, Egypt, Ghana, and Mauritius have implemented various policies and initiatives aimed at improving digital literacy, coding education, innovation ecosystems, entrepreneurship development, and science education. Investments in technology hubs, innovation centres, digital infrastructure, and start-up ecosystems have also contributed to the emergence of vibrant innovation communities across several African cities. These developments demonstrate the growing recognition of STEAM as a catalyst for economic transformation and sustainable development.

The integration of Arts into STEM education has gained increasing attention because creativity and innovation are now recognized as fundamental drivers of technological advancement. In an era where automation is replacing routine tasks, uniquely human capabilities such as creativity, design, communication, empathy, and problem-solving have become increasingly valuable. The Arts component of STEAM fosters these competencies while enhancing learners' ability to develop innovative products, services, and solutions that respond to societal needs. Consequently, STEAM education provides a more holistic framework for preparing students for future careers and addressing complex development challenges. For Nigeria, the largest economy and most populous country in Africa, the relevance of STEAM education cannot be overstated. Nigeria's aspirations for economic diversification, industrialization, digital transformation, and global competitiveness

depend significantly on the quality of its human capital and innovation capacity. The country faces persistent challenges including high youth unemployment, inadequate technological infrastructure, weak research funding, skills mismatches, and limited industry-academia collaboration. Strengthening STEAM education therefore represents a strategic pathway for developing a workforce capable of driving innovation, entrepreneurship, industrial productivity, and sustainable development.

This chapter examines the state of Science, Technology, Engineering, Arts, and Mathematics (STEAM) education in Africa. It explores the conceptual foundations and interrelationships among the various components of STEAM, assesses the challenges confronting its development, compares Africa's performance with that of developed economies, and presents selected case studies of successful STEAM initiatives. The paper further identifies lessons and policy implications for Nigeria and highlights strategies for leveraging STEAM education as a catalyst for economic transformation, innovation, and sustainable development in Africa.

Objectives of the Study

The broad objective of this study is to examine the role of STEAM education in Africa and its implications for sustainable development.

Specific objectives are to:

i. Examine the conceptual relationship among Science, Technology, Engineering, Arts, and Mathematics.
ii. Assess the current state of STEAM education in Africa.
iii. Identify major challenges confronting STEAM development in African countries.
iv. Compare STEAM development in Africa with developed economies.
v. Examine selected international and African case studies.
vi. Draw lessons and policy implications for Nigeria.

Literature Review

STEAM Education

Science, Technology, Engineering, Arts, and Mathematics (STEAM) education is an interdisciplinary educational framework that integrates the knowledge, principles, and practices of science, technology, engineering, arts, and mathematics into a unified approach to teaching and learning. Unlike traditional educational models that treat these disciplines as separate and independent subjects, STEAM emphasizes their interconnectedness and encourages learners to apply concepts from multiple fields to address real-world challenges. The approach is designed to cultivate not only technical competence but also creativity, innovation, critical thinking, collaboration, and problem-solving skills that are essential in the twenty-first-century knowledge economy.

The concept of STEAM emerged as an extension of the Science, Technology, Engineering, and Mathematics (STEM) model. While STEM education focuses primarily on developing scientific and technical skills, educators and policymakers increasingly recognized the need to incorporate the Arts into the framework. The inclusion of Arts reflects the understanding that creativity, design, communication, and cultural awareness are critical components of

innovation and technological advancement. Many of the world's most transformative inventions and technological breakthroughs have resulted from the combination of scientific knowledge and creative thinking. Consequently, STEAM education seeks to produce well-rounded individuals capable of generating innovative solutions that are both technically sound and socially relevant.

Science, as a component of STEAM, provides the foundation for understanding natural phenomena and generating new knowledge through observation, experimentation, and research. Technology involves the practical application of scientific knowledge to develop tools, systems, and processes that improve human life. Engineering focuses on designing and constructing solutions to practical problems using scientific and mathematical principles. Mathematics provides the analytical and quantitative framework necessary for measurement, modelling, data analysis, and logical reasoning. The Arts contribute creativity, imagination, design thinking, communication skills, and aesthetic awareness, enabling learners to approach problems from multiple perspectives and develop innovative solutions.

According to UNESCO (2024), STEAM education promotes innovation, critical thinking, creativity, collaboration, and entrepreneurial competencies required for success in modern economies. It equips learners with the ability to adapt to rapidly changing technological environments while fostering inclusive and sustainable development. Through project-based learning, inquiry-based instruction, design thinking, and experiential learning methodologies, students are encouraged to engage actively in the learning process and develop practical skills that can be applied in diverse professional and social contexts. One of the defining characteristics of STEAM education is its emphasis on problem-solving and real-world application. Rather than memorizing isolated facts and theories, learners are challenged to investigate authentic problems, design solutions, test ideas, and evaluate outcomes. For example, students may be tasked with designing renewable energy systems, developing mobile applications, constructing engineering prototypes, creating digital art, or using mathematical models to solve environmental challenges. Such activities promote deeper understanding, enhance creativity, and strengthen learners' ability to transfer knowledge across disciplines.

STEAM education is also closely linked to the development of innovation and entrepreneurship. As economies become increasingly knowledge-driven and technology-oriented, employers seek individuals who can think critically, work collaboratively, communicate effectively, and adapt to emerging challenges. STEAM learning environments encourage students to develop these competencies by engaging in interdisciplinary projects that mirror real-world workplace situations. Consequently, STEAM education contributes significantly to workforce development, technological innovation, and economic competitiveness. Furthermore, STEAM plays a crucial role in preparing learners for emerging careers associated with the Fourth Industrial Revolution (4IR). Advances in artificial intelligence, robotics, machine learning, biotechnology, renewable energy, cybersecurity, data analytics, digital media, and advanced manufacturing have created new employment opportunities that require a combination of technical expertise and creative problem-solving abilities. By integrating scientific knowledge with artistic creativity and

technological innovation, STEAM education prepares students to thrive in these rapidly evolving sectors.

In the African context, STEAM education has become increasingly important as governments seek to address challenges related to unemployment, poverty, industrial underdevelopment, and technological dependence. The continent's growing youth population presents a unique opportunity to develop a highly skilled workforce capable of driving innovation and economic transformation. Through effective implementation of STEAM programmes, African countries can enhance human capital development, promote digital inclusion, strengthen research and innovation ecosystems, and improve their competitiveness in the global economy. Ultimately, STEAM education represents more than an educational philosophy; it is a strategic framework for fostering sustainable development, technological advancement, and socioeconomic transformation. By integrating science, technology, engineering, arts, and mathematics into a cohesive learning experience, STEAM equips individuals with the knowledge, skills, and attitudes necessary to navigate complex global challenges and contribute meaningfully to national and international development.

Table 1: Relationship Among STEAM Components

Component	Primary Function	Contribution to Development
Science	Discovery and knowledge generation	Research and innovation
Technology	Application of scientific knowledge	Digital transformation
Engineering	Design and problem-solving	Infrastructure and industrialization
Arts	Creativity and design thinking	Innovation and communication
Mathematics	Quantitative reasoning	Data analysis and modelling

The relationship among these disciplines is complementary. Scientific discoveries often lead to technological innovations; engineering transforms innovations into practical applications; mathematics provides analytical foundations; while arts enhance creativity, design, and user-centered innovation.

Theoretical Review

The theoretical foundation of this study is anchored on Human Capital Theory, Innovation Systems Theory, and Endogenous Growth Theory. These theories provide a comprehensive framework for understanding the role of Science, Technology, Engineering, Arts, and Mathematics (STEAM) education in promoting innovation, technological advancement, human capital development, and economic transformation in Africa.

Human Capital Theory

Human Capital Theory was pioneered by Theodore Schultz (1961) and further developed by Gary Becker (1964). The theory posits that investments in education, training, health, and skill acquisition enhance the productive capacities of individuals, thereby increasing their economic value and contribution to society. Human capital is viewed as a critical asset that contributes to productivity growth, innovation, income generation, and national economic development. According to Schultz (1961), education should not be regarded merely as a social service but as an investment that yields long-term economic returns for both individuals and society. Becker (1964) further argued that expenditures on education and

training improve workers' knowledge, competencies, and efficiency, leading to increased productivity and economic performance. The theory emphasizes that countries that invest heavily in education and skill development tend to experience higher levels of economic growth and competitiveness than those that neglect human capital formation.

In the context of STEAM education, Human Capital Theory provides a strong justification for investments in science, technology, engineering, arts, and mathematics. STEAM equips learners with critical competencies such as analytical reasoning, creativity, problem-solving, innovation, communication, and technological literacy. These skills are increasingly essential in the contemporary knowledge economy, where economic success depends largely on the ability to create, adapt, and utilize knowledge effectively. For African countries, investment in STEAM education represents a strategic mechanism for developing the skilled workforce required for industrialization, technological innovation, entrepreneurship, and sustainable development. As economies become more digitized and technology-driven, countries that successfully develop STEAM-related competencies are likely to enjoy higher productivity, increased innovation capacity, and improved global competitiveness. Conversely, inadequate investment in STEAM education may limit economic growth and constrain participation in the global knowledge economy. The relevance of Human Capital Theory to this study lies in its explanation of how investments in STEAM education contribute to the development of human resources capable of driving economic transformation and innovation across African countries. It supports the argument that strengthening STEAM education is essential for building a productive workforce and fostering sustainable socioeconomic development.

Innovation Systems Theory

Innovation Systems Theory emerged from the works of Freeman (1987), Lundvall (1992), and Nelson (1993), who argued that innovation does not occur in isolation but rather through interactions among various actors and institutions within an economy. The theory emphasizes that innovation is a systemic process involving collaboration among governments, universities, industries, research institutions, financial organizations, and other stakeholders. According to the theory, technological advancement and innovation are influenced not only by the activities of individual researchers or firms but also by the quality of relationships among institutions that generate, disseminate, and utilize knowledge. The effectiveness of a country's innovation system depends on the extent to which these actors collaborate to create an enabling environment for learning, research, technological development, and commercialization of innovations. The concept of National Innovation Systems (NIS) highlights the importance of policy frameworks, research infrastructure, educational institutions, funding mechanisms, and industrial linkages in fostering innovation. Countries such as the United States, Germany, South Korea, Finland, and Japan have developed robust innovation systems characterized by strong collaboration among universities, industries, and government agencies. These interactions facilitate knowledge transfer, technological development, entrepreneurship, and economic growth.

STEAM education occupies a central position within innovation systems because it serves as a primary mechanism for producing the human resources required for scientific discovery, technological innovation, engineering development, and creative problem-solving.

Effective STEAM ecosystems depend on partnerships among educational institutions, research organizations, industries, and government agencies. Such collaborations ensure that educational curricula remain relevant to industry needs and that research outputs contribute to technological and economic development. In many African countries, weak linkages among universities, industries, and governments have limited the effectiveness of innovation systems. Research findings often remain disconnected from industrial applications, while educational institutions frequently struggle to align their programmes with labour market demands. Innovation Systems Theory therefore provides a useful framework for understanding how strengthening collaboration among stakeholders can improve STEAM outcomes and stimulate technological advancement across the continent. The theory is particularly relevant to this study because it explains the institutional arrangements required for successful STEAM implementation and highlights the importance of creating innovation ecosystems that support knowledge creation, technological development, and economic competitiveness.

Endogenous Growth Theory

Endogenous Growth Theory was developed primarily by Paul Romer (1990) as a response to traditional growth theories that treated technological progress as an external factor. The theory argues that economic growth is generated from within an economy through investments in human capital, innovation, research and development (R&D), and knowledge creation. Unlike exogenous growth models, which view technological change as independent of economic activities, Endogenous Growth Theory emphasizes that knowledge and innovation are deliberate outcomes of investments made by individuals, firms, and governments. Romer (1990) contends that ideas, technological innovations, and knowledge accumulation are the primary drivers of long-term economic growth. The theory suggests that investments in education, scientific research, technological development, and innovation create positive spillover effects that increase productivity and stimulate sustained economic expansion. Knowledge is regarded as a unique factor of production because it can be used repeatedly without being depleted, thereby generating increasing returns over time.

The relevance of Endogenous Growth Theory to STEAM education is particularly significant. STEAM programmes promote the acquisition of scientific knowledge, technological competencies, engineering skills, mathematical reasoning, and creative capabilities that are essential for innovation. Through research, experimentation, and interdisciplinary learning, STEAM education contributes to the generation of new ideas, products, processes, and technologies that drive economic growth. In the contemporary global economy, countries that invest heavily in education, research, innovation, and technology development tend to achieve higher rates of economic growth and competitiveness. Nations such as South Korea, Singapore, China, and Finland have demonstrated how investments in science, technology, and innovation can transform economies and accelerate development. These countries have utilized education and research as strategic tools for fostering innovation-led growth and industrial transformation.

For Africa, Endogenous Growth Theory underscores the importance of investing in STEAM education as a foundation for sustainable development. By strengthening scientific research,

technological innovation, entrepreneurship, and digital transformation, African countries can reduce dependence on primary commodity exports and build knowledge-based economies capable of competing globally. The theory therefore supports the argument that enhanced investment in STEAM education can serve as a catalyst for economic diversification, industrialization, and long-term development.

Theoretical Implications for the Study

The Human Capital Theory, Innovation Systems Theory, and Endogenous Growth Theory provide a robust theoretical framework for examining STEAM education in Africa. Human Capital Theory explains how investments in STEAM education enhance workforce productivity and economic performance. Innovation Systems Theory highlights the importance of institutional collaboration and innovation ecosystems in promoting technological advancement. Endogenous Growth Theory demonstrates how knowledge creation, research, and innovation contribute to sustained economic growth and development. Together, these theories suggest that effective STEAM education can serve as a strategic instrument for developing human capital, fostering innovation, enhancing technological capabilities, and accelerating economic transformation in Africa. They further provide a basis for understanding the challenges confronting STEAM development on the continent and identifying policy measures necessary for strengthening Africa's innovation and knowledge economies.

Empirical Review

The empirical literature on Science, Technology, Engineering, Arts, and Mathematics (STEAM) education and its relationship with economic development provides strong evidence that investments in science and technology education significantly influence innovation capacity, productivity growth, and long-term economic transformation. Across both developed and developing economies, studies consistently demonstrate that countries with strong STEAM systems tend to exhibit higher levels of industrialization, technological advancement, and human capital development. A growing body of empirical research highlights the centrality of education, innovation, and institutional quality in shaping development outcomes in Africa. Anam and colleagues, in their series of studies on human capital development, entrepreneurship, digital transformation, and knowledge-driven economies in Africa, emphasize that sustainable economic growth is strongly dependent on the capacity of African economies to invest in education systems that promote innovation, technological adoption, and skills development. Their findings suggest that weak institutional frameworks, low research output, and limited integration between education and industry continue to constrain Africa's ability to fully harness the benefits of science and technology education. They further argue that strengthening STEAM-related competencies is critical for improving productivity, competitiveness, and economic diversification across African economies.

Similarly, UNESCO (2024) reports that Africa faces a severe shortage of STEM and STEAM-related skills despite possessing the world's fastest-growing youth population. According to the organization, millions of additional science, technology, engineering, and mathematics graduates will be required by 2030 to meet labour market demands and support industrial transformation. This skills gap presents both a challenge and an opportunity: while it

constrains current development efforts, it also highlights the potential for STEAM education to serve as a major driver of youth employment, innovation, and economic growth if properly implemented.

Empirical studies on African economic development further reveal strong correlations between technological advancement, innovation capacity, and economic performance. Countries that invest more heavily in education, research and development (R&D), and digital infrastructure tend to achieve better outcomes in productivity, industrial growth, and global competitiveness. Evidence from cross-country analyses suggests that economies with stronger innovation systems and higher levels of human capital development are more likely to transition from resource-dependent structures to diversified, knowledge-based economies.

Thematic Discourse on the State of STEAM in Africa

Before presenting the table, it is important to note that STEAM education across Africa is characterized by uneven development patterns. While some countries have made significant investments in curriculum reforms, digital literacy, and innovation hubs, others still struggle with basic educational infrastructure and limited access to science and technology resources. This disparity reflects broader structural inequalities across the continent, including differences in governance capacity, fiscal space, and institutional development.

Table 2: Summarizes Key Initiatives Across Selected African Countries, Highlighting Efforts to Strengthen STEAM Education and Innovation Capacity.

Country	Major Initiative
Rwanda	Digital literacy and coding programmes
Kenya	Competency-Based Curriculum (CBC)
South Africa	STEM-focused universities and innovation hubs
Egypt	National STEM Schools Initiative
Ghana	Robotics and coding education programmes

The table demonstrates that several African countries are actively reforming their education systems to align with global technological trends. Rwanda, for instance, has prioritized ICT integration and digital literacy as part of its national development strategy, while Kenya's Competency-Based Curriculum emphasizes practical skills, creativity, and problem-solving. South Africa and Egypt have invested in specialized STEM institutions and innovation ecosystems, whereas Ghana has introduced robotics and coding programmes to enhance early exposure to technology-driven learning. After examining these initiatives, it is evident that despite progress, implementation remains uneven across the continent. Many rural and underserved areas still lack access to laboratories, digital tools, trained teachers, and modern instructional materials. Consequently, the benefits of STEAM reforms are not uniformly distributed, leading to persistent regional and socioeconomic disparities in educational outcomes.

Table 3: Major Challenges of STEAM Education in Africa

Before presenting the table, it is important to emphasize that the challenges confronting STEAM education in Africa are multi-dimensional and interconnected. They include structural, institutional, economic, and sociocultural constraints that collectively hinder effective implementation of science and technology education. These challenges also reinforce each other, thereby making systemic reform more complex and requiring coordinated policy interventions across multiple sectors.

Challenge	Implication
Inadequate funding	Poor facilities and laboratories
Teacher shortages	Reduced learning quality
Weak digital infrastructure	Limited access to technology
Gender inequality	Underrepresentation of women
Brain drains	Loss of skilled professionals
Industry-academia disconnect	Skills mismatch

The table highlights that inadequate funding remains one of the most critical barriers to STEAM development in Africa. Insufficient investment leads to poorly equipped laboratories, outdated teaching materials, and limited access to modern technologies. Teacher shortages further exacerbate the problem, as many institutions lack adequately trained educators in science, technology, and engineering disciplines. Weak digital infrastructure also significantly limits the effectiveness of STEAM education, particularly in rural areas where internet access, electricity supply, and technological tools are unreliable. Gender inequality continues to restrict the participation of women in STEAM fields, thereby limiting the continent's full human capital potential. Additionally, brain drain results in the migration of highly skilled professionals to developed countries, further weakening Africa's innovation capacity. Finally, the disconnect between academic institutions and industry contributes to a persistent mismatch between graduates' skills and labour market requirements. After reviewing these challenges, it becomes clear that addressing them requires comprehensive policy reforms, increased investment, and stronger institutional coordination. Without such interventions, STEAM education in Africa may struggle to achieve its intended developmental impact.

Table 4: Comparative Analysis: Africa versus Developed Countries

Before presenting the comparative table, it is important to recognize that differences between Africa and developed countries in STEAM development are largely structural rather than merely educational. These differences reflect variations in economic capacity, governance quality, research investment, industrial base, and technological infrastructure. Developed countries have built mature innovation ecosystems over several decades, while many African countries are still in the early stages of developing such systems.

Indicator	Africa	Developed Countries
R&D Expenditure (% GDP)	Low	High
Digital Infrastructure	Limited	Advanced
Research Output	Moderate	Very High
Innovation Ecosystem	Emerging	Mature
Industry-University Collaboration	Weak	Strong
STEAM Graduate Employability	Moderate	High

The table illustrates significant disparities between Africa and developed countries across key indicators of STEAM development. Research and development expenditure in most African countries remains below global benchmarks, limiting their capacity for scientific discovery and technological innovation. In contrast, developed countries allocate substantial resources to research institutions, innovation hubs, and advanced laboratories. Digital infrastructure in Africa remains uneven, with many regions lacking reliable internet connectivity, modern laboratories, and access to advanced technologies. Developed countries, however, benefit from highly advanced digital ecosystems that support education, research, and industrial innovation. Similarly, research output and patent generation are significantly higher in developed economies due to strong investment in universities and research institutions. The table also highlights the maturity of innovation ecosystems in developed countries, where strong collaboration exists between universities, industries, and government agencies. In Africa, such linkages remain weak, limiting the commercialization of research outputs and slowing technological diffusion. Consequently, STEAM graduates in developed countries tend to enjoy higher employability due to the alignment between education systems and labour market needs. After examining these disparities, it is evident that bridging the gap requires strategic investments in education, research, infrastructure, and institutional reforms. Strengthening STEAM systems in Africa is therefore essential for improving global competitiveness and accelerating economic transformation.

Case Studies

Rwanda

Rwanda represents one of the most notable examples of STEAM-oriented transformation in Africa. The country has prioritized ICT integration, coding education, and digital literacy as part of its national development strategy. Through investments in innovation hubs, digital infrastructure, and technology-driven education reforms, Rwanda has significantly improved its human capital base. These initiatives have contributed to the growth of entrepreneurship, particularly among young people, and have positioned the country as a regional leader in digital transformation.

South Africa

South Africa remains the leading producer of scientific research in Africa, supported by strong universities, research institutions, and innovation systems. The country benefits from relatively higher investment in research and development, as well as established partnerships between academia and industry. South Africa's innovation ecosystem has contributed to advancements in fields such as engineering, health sciences, renewable energy, and information technology.

Finland

Finland provides a global benchmark for STEAM education due to its interdisciplinary and student-centered learning approach. The Finnish education system emphasizes creativity, problem-solving, collaboration, and real-world application of knowledge. By integrating arts and design thinking into science and technology education, Finland has successfully cultivated a highly innovative and skilled workforce.

United States

The United States represents one of the most advanced STEAM ecosystems globally, characterized by strong university-industry collaboration, substantial research funding, and world-class innovation institutions. The country's ability to translate research into commercial products and technologies is supported by robust venture capital systems, innovation hubs, and advanced digital infrastructure.

Lessons for Nigeria

The empirical evidence and case studies provide several important lessons for Nigeria's STEAM development agenda:

i. Increase investment in STEAM infrastructure to improve laboratory facilities and learning environments.
ii. Strengthen teacher training and continuous professional development in science and technology disciplines.
iii. Expand digital literacy programmes to ensure nationwide access to technological skills.
iv. Promote gender inclusion by encouraging greater participation of women in STEAM fields.
v. Strengthen university-industry partnerships to improve research commercialization and innovation outcomes.
vi. Increase funding for research and development to enhance innovation capacity.
vii. Integrate entrepreneurship education into STEAM curricula to support job creation and innovation.
viii. Establish innovation hubs, incubators, and technology parks within universities to foster practical learning and start-up development.

These lessons suggest that Nigeria must adopt a comprehensive and coordinated STEAM strategy that aligns education policy with national development objectives, industrial needs, and global technological trends.

Conclusion

This study examined the role of Science, Technology, Engineering, Arts, and Mathematics (STEAM) education in Africa, with particular emphasis on its relationship to innovation, human capital development, and sustainable economic transformation. The analysis demonstrates that STEAM education is a critical framework for equipping individuals with the interdisciplinary skills required to function effectively in a rapidly changing, technology-driven global economy. By integrating scientific knowledge with creativity, design thinking, and problem-solving competencies, STEAM provides a holistic approach to education that enhances innovation capacity and supports economic diversification. The findings of the study indicate that although several African countries have made notable progress in adopting STEM and STEAM-related reforms, the overall development of STEAM education across the continent remains uneven and constrained by structural challenges. These include inadequate funding, weak infrastructure, shortage of qualified teachers, limited digital access, gender disparities, and weak linkages between academic institutions and industry. Furthermore, low investment in research and development, coupled with limited

innovation ecosystems, continues to hinder Africa's ability to fully leverage its youthful population for technological advancement and industrial growth.

Comparative analysis reveals a significant gap between Africa and developed economies in terms of research output, digital infrastructure, innovation systems, and STEAM graduate employability. Developed countries benefit from well-established ecosystems that integrate universities, industries, governments, and research institutions, thereby facilitating seamless knowledge creation and commercialization. In contrast, many African countries are still in the early stages of building such systems. Despite these challenges, the study identifies significant opportunities for STEAM-driven transformation in Africa. The continent's large youth population, growing digital economy, expanding innovation hubs, and increasing policy attention to science and technology present strong foundations for future development. Case studies from Rwanda, South Africa, Finland, and the United States demonstrate that strategic investment in education, research, and innovation systems can significantly enhance national competitiveness and economic growth. In conclusion, STEAM education represents a strategic pathway for Africa's industrialization, technological advancement, and sustainable development. However, realizing its full potential requires deliberate policy interventions, sustained investment, institutional reforms, and strong collaboration among stakeholders. For Nigeria and other African countries, strengthening STEAM education is not optional but essential for achieving long-term economic resilience and global competitiveness.

Policy Recommendations

Based on the findings of this study, the following policy recommendations are proposed to strengthen STEAM education and enhance its contribution to sustainable development in Africa, particularly Nigeria:

I. **Increased and Sustained Investment in STEAM Education:** Governments should significantly increase budgetary allocations to education, with specific emphasis on science, technology, engineering, arts, and mathematics. Funding should prioritize the development of laboratories, digital learning infrastructure, research facilities, and innovation centres in secondary and tertiary institutions.

ii. **Strengthening Teacher Capacity and Professional Development:** There is an urgent need to invest in continuous training and retraining of teachers in STEAM disciplines. Teacher education programmes should be modernized to include digital pedagogy, inquiry-based learning, coding, robotics, and interdisciplinary teaching methods. Incentives should also be provided to attract and retain qualified STEAM educators.

iii. **Curriculum Reform and Integration of Practical Learning:** STEAM curricula should be restructured to emphasize experiential learning, problem-solving, creativity, and real-world application. Educational institutions should reduce excessive theoretical instruction and increase hands-on, project-based learning that reflects industry needs and global technological trends.

iv. **Expansion of Digital Infrastructure and Connectivity:** Governments should prioritize the development of reliable electricity supply, broadband internet access, and digital learning platforms, particularly in rural and underserved areas. Public-private partnerships should be encouraged to accelerate the deployment of educational technologies.

v. **Strengthening Research, Innovation, and Development Systems:** African countries should increase investment in research and development (R&D) and establish strong national innovation systems. Universities, research institutions, and industries should be linked through innovation hubs, incubators, and technology parks to promote knowledge transfer and commercialization of research outputs.
vi. **Promotion of Gender Inclusion in STEAM Fields:** Policies should be implemented to encourage the participation of women and girls in STEAM education through scholarships, mentorship programmes, awareness campaigns, and targeted support initiatives. Gender equality in STEAM is essential for maximizing human capital potential.
vii. **Enhancing University–Industry Collaboration:** Stronger partnerships between academia and industry should be established to ensure that graduates acquire skills that are relevant to labour market demands. Internship programmes, industrial attachments, joint research projects, and innovation partnerships should be institutionalized.
viii. **Integration of Entrepreneurship into STEAM Education:** Entrepreneurship education should be embedded within STEAM curricula to enable students to translate knowledge into business ideas, innovations, and job creation opportunities. This will help reduce unemployment and promote self-reliance among graduates.
ix. **Policy Stability and Long-Term Strategic Planning:** Governments should ensure policy consistency in education and innovation sectors to attract investment and sustain long-term development goals. STEAM development frameworks should be aligned with national development plans and continental strategies such as Agenda 2063 and the Sustainable Development Goals (SDGs).
x. **Strengthening Regional and International Collaboration:** African countries should deepen collaboration with global partners, development agencies, and international research institutions to access funding, technical expertise, and best practices in STEAM education. Regional cooperation within Africa should also be enhanced to share resources and build collective innovation capacity.

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Chapter 2

STEM EDUCATION IN AFRICA – THE PAST, PRESENT, AND FUTURE

STEMpedia, India

Abstract

Science, Technology, Engineering, and Mathematics (STEM) education has become a critical driver of innovation, economic growth, and sustainable development globally. In Africa, the evolution of STEM education reflects the continent's changing educational priorities, developmental aspirations, and responses to emerging technological advancements. This paper examines the past, present, and future of STEM education in Africa. It traces the historical development of STEM learning from the colonial era through post-independence educational reforms, highlighting achievements and persistent challenges. The paper further assesses the current state of STEM education, including issues of infrastructure deficits, inadequate funding, limited access to quality teaching resources, gender disparities, and skills gaps. Despite these challenges, growing investments in digital technologies, innovation hubs, policy reforms, and regional collaborations present significant opportunities for strengthening STEM capacity across the continent. Looking ahead, the study explores the prospects of STEM education in supporting Africa's industrialization, digital transformation, entrepreneurship, and participation in the global knowledge economy. The paper concludes that strategic investments, inclusive policies, and strengthened partnerships among governments, educational institutions, and the private sector are essential for positioning STEM education as a catalyst for sustainable development and economic competitiveness in Africa.

Keywords: *STEM Education, Africa, Science and Technology, Innovation, Digital Transformation, Human Capital Development, Sustainable Development.*

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Introduction

Although Africa holds nearly 17% of the world's population, its Science, Technology, Engineering & Math (STEM) capabilities fall behind the rest of the world. STEM education is a driver or economic performance, and this is essential for helping growing economies compete in the global market, create jobs (especially STEM jobs), and improve wealth. Despite lagging other regions in STEM, Africa has great untapped potential to transform its own and the global economy thanks to its unique demographic position, and African schools are a major part of this potential. Today, Africa has the world's largest population of young people. According to the United Nations World Population Prospects, over 60% of Africa's population is currently under 25, with Africa containing 19% of the global population of 15- to 24-year-olds. By 2035, sub-Saharan Africa will have a working population larger than the entire rest of the world combined. In contrast, other workforces in the world are aging.

Due to this demographic asset, Africa has immense potential to improve its local and global economies, if it can produce a generation of young professionals that can take charge of the development of their countries. This is why it is critical for education in Africa to reach new levels, particularly with skills that can promote more STEM jobs. Africa has the potential to contain some of the world's fastest-growing economies, but it can only compete with the rest of the world if it invests in STEM education for young people. Here is an in-depth look at the STEM education and STEM programs in Africa and what it can mean for Africa's future.

History and Context of STEM Education in Africa

Africa has historically fallen behind other regions of the world in STEM knowledge. Partly, this is due to the heavily documented lack of educational infrastructure. Staff shortages, lack of electricity and water supply, low student attendance in school, weak governance, and lack of materials are some of the challenges that have taken precedence over developing solid STEM programs. According to UNESCO's 2018 Global Education Monitoring Report, only 22% of primary African schools in sub-Saharan Africa have access to electricity. Plus, internet access is still a luxury in many regions. Due to the lack of basic and critical infrastructure, resources to allocate to higher-level STEM education have been scarce. Over the past several decades, it has become apparent that STEM is an important determinant of a country's economic development and security. Countries that have invested in STEM have experienced global prominence. Studies estimate that between 50 to 85 percent of U.S. GDP growth in the past 50 years can be attributed to advancements in science and engineering. While non-African countries dedicate up to 4% of their GDP to scientific research, African countries have allocated little to no funding to science, thus increasing the gap between Africa and other countries in STEM performance and therefore economic development.

The Current State of STEM Education in Africa

According to the African Development Bank, less than 25% of African higher education students are in STEM fields, with the majority of students studying social sciences and humanities. Unfortunately, most African schools do not specialize in STEM subjects, and since few students can afford to travel abroad for an education in STEM subjects, it is vital to focus on the education in Africa itself. Those that are skilled often emigrate to other continents to earn their livelihoods in a phenomenon known as “brain drain.” This is especially true when it comes to STEM skills. Each year, 70,000 skilled professionals make this exodus. Brain drain diminishes the development of industries like STEM which need highly educated nationals. Due to the lack of a domestic STEM workforce, most STEM jobs in Africa today are outsourced to other countries, including the U.S., China, and India. For example, because China has a large workforce of engineers, China has a strong presence in development projects in Africa. In 2014, 87 Chinese construction teams traveled to Kenya to construct the Standard Gauge Railway. Indeed, more than half of STEM funding comes from international players. Although this supports African development, it also means that

projects are not necessarily designed to support Africans so much as the countries providing the funding. A few organizations are taking steps. The government in South Africa, for example, now requires organizations to spend 1.5% of their payroll on training their workforce. In the Science and Technology Consolidated Plan of Action, the African Union urges members to spend 1% of its GDP on research and development to enhance STEM innovations.

The future for STEM Education in Africa

Over the next decade, STEM job openings requiring STEM literacy are expected to increase by the thousands. STEM education is a critical key to Africa's future, and governments and organizations are doing what they can. The 'African Unions Agenda 2063 is a long-term framework intended to transform the African continent over 50 years. The agenda aspires that, by 2063, Africa shall be a continent where "well educated and skilled citizens, underpinned by science, technology, and innovation for a knowledgeable society is the norm and no child misses' school due to poverty." To ensure the bright STEM future for Africa envisioned by the African Union's Agenda 2063, governments and organizations must step up and act. However, improving the state of STEM in Africa is a highly complex and challenging task requiring collaboration and effort across many sectors. STEM programs and initiatives supporting STEM skills still have a long way to go. Governments in Africa need to fully embrace STEM as a key point of focus and invest in educational resources. By producing highly qualified graduates, Africa can use its growing population of young people to improve economic development and leadership in its countries.

Additionally, governments must incentivize highly qualified professionals to stay and thrive in their home countries. The Revised Migration Policy Framework for Africa Plan of Action for 2018-2027 suggests African countries increase opportunities for local employment and professional development. It suggests encouraging nationals to contribute to their country of origin "through financial and human capital transfers, such as short- and long-term return migration [and] the transfer of skills, knowledge, and technology, [plus] maximize the contribution of skilled professionals to the continent by facilitating regional and continental mobility." STEM-related organizations and education in Africa and African schools should have African leadership, not just international leadership, and empower Africans to become involved to ensure that projects are sustainable for African nations long-term.

Finally, societal attitudes towards education in Africa and beyond must be revitalized. David Dodge, CEO of Codakid, says that "quality coding and STEM skill options are not available in many towns, cities, and even countries. This means that STEM jobs aren't being filled as well. Many parents and educators see the need and want to do something about it." Indeed, local businesses, communities, and families must work together to take charge of their youth's education. Since many of Africa's students are the first generation in their families to become formally educated, parents and communities may be unfamiliar with STEM skills and subjects and uninvolved in education. Therefore, it's important for families to motivate students to value learning, and for communities to create and encourage involvement in STEM programs such as coding for kids to expand education beyond schools.

Conclusion

Improving STEM education in Africa and resources in African schools will require the collaborative work of governments, organizations, communities, businesses, and individuals. Additionally, it will lead to more successful STEM job acquisition in the future. Although it currently falls behind other regions in STEM, Africa's demographic makeup and untapped potential give it an advantage moving forward. Africa is in a prime position to educate a new highly skilled workforce (particularly with STEM skills), develop its economy and compete with some of the world's biggest players.

First Published: https://thestempedia.com/blog/stem-education-in-africa-the-past-present-and-future/?srsltid=AfmBOoqbn1enDnbU4EJON1cMH aMVdN1AXcOjVic4p qADEA5EJjmR_tCZ

Chapter 3

POLICY, GOVERNANCE, AND INSTITUTIONAL FRAMEWORKS FOR STEAM IN NIGERIA

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Abstract
This chapter systematically analyzes policy, governance, and institutional frameworks shaping STEAM (Science, Technology, Engineering, Arts, and Mathematics) education in Nigeria. Despite global recognition of STEAM as a catalyst for innovation, Nigeria lacks a coherent national strategy for integrating arts into STEM curricula. Using qualitative policy analysis, the chapter evaluates the National Policy on Education and the roles of the Federal Ministry of Education, National Universities Commission, and National Board for Technical Education. It identifies structural, financial, and cultural barriers to STEAM implementation, including underfunding, inadequate teacher training, and socio-cultural bias against arts education. Emerging best practices from the African University of Science and Technology and the STEP-B initiative are documented. The chapter concludes that without deliberate policy revision, increased funding, teacher retraining, and examination reform, STEAM will remain marginal. Recommendations include a National STEAM Strategy, ring-fenced infrastructure funding, and public-private partnerships.

Keywords: *STEAM education, Nigeria, educational policy, governance, interdisciplinary learning, curriculum reform.*

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Introduction

In an era defined by rapid technological advancement and complex global challenges, the ability to think creatively while applying technical knowledge has become a cornerstone of economic competitiveness and innovation. Countries worldwide are reimagining their education systems to produce graduates who are not only proficient in science and technology but also equipped with the creativity, critical thinking, and adaptability that drive progress. One of the most promising educational paradigms to emerge from this reimagining is STEAM Science, Technology, Engineering, Arts, and Mathematics which integrates the analytical power of STEM with the creative and human-centered perspectives of the arts. STEAM education nurtures students who can solve problems, challenge established ideas, and innovate across disciplinary boundaries, skills that are indispensable for thriving in the 21st-century global economy. In many developed nations, STEAM has become an integral component of national education strategies. Countries such as the United States, United Kingdom, Finland, and South Korea have institutionalized STEAM through policy frameworks, dedicated funding streams, teacher retraining programs, and cross-sector partnerships between schools, universities, and creative industries. These investments reflect a growing recognition that the complex challenges of the modern world from climate change to public health crises to digital transformation require solutions that blend technical rigor with creative insight. Consequently, STEAM-educated graduates are increasingly valued across sectors ranging from technology and engineering to design, entertainment, and social entrepreneurship.

Nigeria, however, presents a markedly different picture. Despite being Africa's largest economy and most populous nation, with a vibrant creative industry (Nollywood, music, fashion, and digital arts) that contributes significantly to GDP, the country's education system remains stubbornly siloed along traditional disciplinary lines. The National Policy on Education (NPE), while revised multiple times since its inception in 1977, continues to emphasize STEM subjects without explicitly mandating or even encouraging the integration of the arts into science and technology curricula. As a result, Nigerian students are often trained to excel within narrow disciplinary boundaries, leaving them ill-prepared for the interdisciplinary, collaborative, and creatively demanding nature of contemporary work environments. Despite the global momentum toward STEAM and the demonstrated benefits of interdisciplinary learning, there exists a critical gap in both Nigerian educational policy and the scholarly literature. While individual studies have examined STEM education challenges in Nigeria (Umar, 2020; Adeniran, 2019), and others have explored arts education in isolation (Ogunyemi, 2019), no comprehensive policy analysis has systematically examined the structural, financial, governance, and cultural barriers specifically impeding STEAM adoption in Nigeria. Furthermore, the roles and limitations of key governance institutions the Federal Ministry of Education (FME), National Universities Commission (NUC), and National Board for Technical Education (NBTE) in facilitating or hindering STEAM integration have not been critically evaluated. This absence of a holistic policy and governance analysis leaves policymakers, educators, and development partners without a clear evidence base for designing effective STEAM interventions.

Understanding STEAM

The shift from STEM to STEAM represents a complete transformation in approaching education and learning. While STEM has long focused on logical reasoning, data analysis, and problem-solving, it sometimes misses a crucial element: creativity. Students trained in STEM often excel at well-defined problems, calculations, and applying formulas. However, when dealing with ambiguity, working collaboratively, or thinking creatively, they may find themselves disadvantaged. This is where the arts step in.

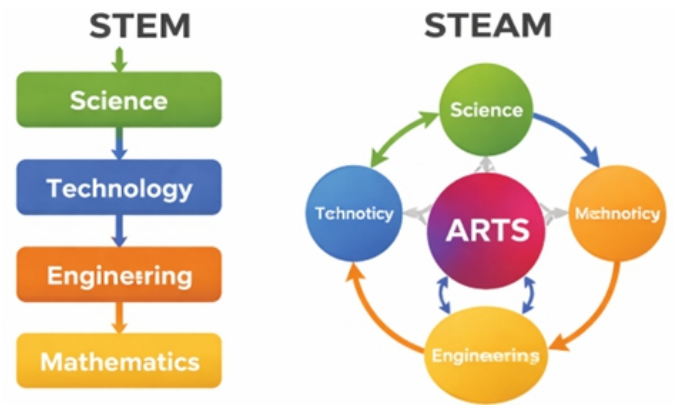

Figure 1.1 diagram illustrating the difference between STEM and STEAM showing STEM as a linear progression (Science → Technology → Engineering → Mathematics) and STEAM as an interconnected, creative cycle that integrates the arts with STEM.

The inclusion of arts whether visual arts, music, theater, design, literature, or humanities brings a transformative shift in problem-solving approaches. Unlike traditional STEM, which often follows a linear, step-by-step approach, arts introduce a more fluid and dynamic thinking method. This approach is associative, allowing connections between seemingly unrelated ideas; iterative, encouraging ongoing exploration and refinement; and emotionally intelligent, recognizing empathy and human connection in creating solutions. By blending creative skills with technical knowledge, STEAM nurtures individuals who are not just experts in their fields but also innovative thinkers, collaborators, and adaptable problem-solvers.

For instance, a student merging mathematics with visual arts can design an architectural model drawing inspiration from local culture, blending beauty and functionality. A learner combining technology with literature can create digital tools simplifying complex biological concepts, making science more accessible and engaging. An engineer developing low-cost prosthetics by integrating engineering with industrial design ensures the final product is functional, user-friendly, comfortable, and aesthetically pleasing. These real-world examples demonstrate how arts enrich STEM disciplines by fostering creativity, empathy, and innovative thinking qualities crucial in a rapidly changing world.

Policy and Governance in Education

Policy's role in shaping STEAM education is crucial. Policies serve as foundations for educational systems, providing legal frameworks and institutional guidelines driving

program implementation. In Nigeria, educational policies blueprint how STEAM can be introduced, developed, and scaled across schools and universities. Nigeria's education governance is a complex network of institutions, each with its role in setting and enforcing educational standards. Key players include the Federal Ministry of Education (FME), National Universities Commission (NUC), and National Board for Technical Education (NBTE). Together, these bodies determine education direction, influence curriculum design, and promote new educational models like STEAM. The FME is the central authority overseeing the entire education system from primary to tertiary levels, formulating broad policy frameworks and allocating resources to meet national educational goals. The NUC regulates university education, ensuring institutions meet national standards and fostering new educational strategy development. The NBTE focuses on technical and vocational education, ensuring the workforce acquires skills necessary for industrial growth and innovation.

However, governance in Nigeria's education system extends beyond these central bodies. Effective education governance requires collaboration across federal, state, and local authorities, each responsible for implementing policies at respective levels. Private sector involvement also plays a significant role, particularly in developing vocational training programs and promoting innovation through partnerships with universities and technical institutions. Effective governance is not just about formulating policies but ensuring efficient execution. Educational policy execution, particularly promoting STEAM, requires significant investments in qualified teachers, infrastructure, and digital tools. Furthermore, it calls for ongoing public and private sector support to address gaps in funding, professional development, and community engagement. Without this, policies risk becoming mere documents without impact. Governance must be inclusive, ensuring all stakeholders including educators, students, industry leaders, and policymakers actively engage in shaping education direction.

Historical Overview of Nigerian Educational Policies

Since Nigeria gained independence in 1960, the country has developed various educational policies aimed at addressing its rapidly growing population's needs. These policies have been crucial in shaping the nation's education system structure from primary through tertiary levels and have sought to align educational practices with national development goals. The most significant policy is the National Policy on Education (NPE), which serves as the foundational framework for the country's education system. The NPE was first formulated in 1977 to provide a comprehensive roadmap for educational development in Nigeria, setting goals, structure, and strategies for delivering education at all levels. Over the years, the NPE has been revised multiple times, with notable revisions in 1981, 1998, and 2004. Each revision sought to adapt the policy to evolving country needs and address emerging challenges such as population growth, economic development, and global educational trends.

The 1977 NPE focused heavily on expanding access to education, particularly at primary and secondary levels, responding to the need to increase literacy rates and provide foundational education to Nigeria's diverse population. As the country faced rapid urbanization and population growth, education demand expanded exponentially, and the NPE aimed to ensure education reached all society segments, particularly in rural and underserved areas.

Challenges in STEAM Integration

While the NPE has largely succeeded in expanding education access, it has struggled to integrate STEAM disciplines into the educational framework. Arts integration into traditional STEM subjects has been particularly slow. The NPE's original focus was largely on quantitative sciences and technical education, with little emphasis on creativity and arts. In the 2004 NPE revision, there was an attempt to diversify Nigeria's educational approach, placing greater emphasis on technical and vocational education (TVET) alongside general education. This aimed to equip students with academic knowledge and practical skills preparing them for the workforce. However, while these reforms sought to broaden the educational system's scope, arts education integration alongside technical and scientific disciplines remained largely underdeveloped.

Barriers to Effective Implementation

Despite these intentions, the revised NPE implementation has faced numerous obstacles. Insufficient funding is one significant challenge. Nigeria's education sector has consistently received less than 5% of the national budget, well below UNESCO's recommended 15-20% allocation for education. This underfunding has hindered the education system's ability to develop infrastructure, teaching resources, and programs necessary for delivering STEAM education. Another challenge is the lack of well-trained teachers, particularly in fields integrating arts with STEM. Many teachers are still trained in traditional, siloed disciplines and are not equipped to teach interdisciplinary subjects combining arts and sciences. This teacher training gap, coupled with outdated infrastructure in many schools, has made realizing a diversified, STEAM-oriented education system difficult.

Moreover, policy execution has been inconsistent. While the policy has laid out clear goals, bringing these goals to fruition at grassroots level has often faltered due to weak coordination between federal, state, and local government bodies, as well as limited private sector involvement in supporting educational reforms. In essence, Nigeria's educational policies, particularly the NPE, have made significant strides in expanding education access and promoting vocational training. However, STEAM disciplines integration especially incorporating arts into STEM education has remained challenging. The barriers of inadequate funding, teacher training, and infrastructure, combined with inconsistent policy implementation, have slowed progress toward a truly integrated educational system.

Policy Gaps and Need for STEAM Integration

A key gap in Nigeria's NPE is its insufficient emphasis on integrating arts into STEM education. While the policy has made significant strides in expanding education access and promoting scientific and technical fields, it fails to adequately address how arts education can complement and enhance disciplines like science, technology, engineering, and mathematics. This oversight limits the education system's ability to foster well-rounded individuals possessing both technical expertise and creativity necessary for driving innovation in today's global economy. Arts integration into STEM has gained significant traction globally as part of the STEAM movement, emphasizing synergy between creative thinking and technical skills. However, Nigeria's educational framework has yet to embrace this holistic approach nationally. The policy's failure to explicitly include arts in its goals and

strategies for educational development has resulted in a system that continues to prioritize technical and scientific knowledge at the expense of creative and innovative thinking.

Without a formal STEAM policy, Nigerian educational institutions face considerable challenges in developing and implementing interdisciplinary curriculum effectively integrating arts with sciences. This gap is particularly evident in higher education institutions, where technical courses often operate in isolation from arts, making it difficult to cultivate critical thinking, problem-solving, and collaboration skills essential for addressing modern world challenges. The absence of clear STEAM directives also limits teachers' capacity to design courses bridging these disciplines. Many teachers are trained in isolated subject areas and often lack tools or knowledge to teach across disciplines. Consequently, students often receive narrow focus on either technical or artistic sides of their education rather than an integrated approach nurturing both. To address this gap, Nigeria needs a formal STEAM education policy promoting interdisciplinary curriculum and providing framework, resources, and support needed to make integration a reality. Such a policy would recognize arts value in enhancing technical education and ensure students acquire diverse skillsets required to thrive in an increasingly interconnected and creative global economy.

Incorporating arts into STEM education is not just about creating more creative professionals but about fostering innovative thinkers, collaborative leaders, and problem-solvers who can approach challenges from multiple perspectives. The STEAM approach encourages critical inquiry, creativity, and entrepreneurial thinking, all essential for navigating 21st-century challenges.

The Federal Ministry of Education (FME)

The FME is the central body responsible for formulating and implementing educational policies in Nigeria. It plays a critical role in overseeing curriculum development, accrediting educational institutions, and allocating federal resources to support education across the country (Federal Ministry of Education [FME], 2004). As the key education sector policymaker, the FME's decisions shape education direction and quality at all levels from primary through tertiary (Ogunyemi, 2015). Despite its pivotal role, the FME's policies have faced significant criticism. One major concern has been inconsistent policy formulation and implementation. The education system has often been described as fragmented, with policies inconsistently applied or periodically revised without addressing foundational issues (Ibitoye, 2017). Additionally, the FME has been criticized for weak enforcement mechanisms hindering effective educational reform implementation (Adetunji & Ibrahim, 2018).

Furthermore, while the FME has made strides in promoting science and technology education, it has yet to integrate STEAM into the broader educational framework. This gap represents a missed opportunity to create a more holistic education approach focusing not only on technical skills but also nurturing creativity, problem-solving, and interdisciplinary thinking (Umar, 2020).

In recent years, the FME has launched several initiatives aimed at enhancing science and technology education, including partnerships with international organizations to improve STEM teacher training, providing educators with tools and skills necessary to meet evolving global economy demands (FME, 2004). Despite these efforts, these initiatives have not sufficiently addressed arts education integration within the curriculum. Consequently, Nigeria's educational system continues to miss comprehensive STEAM approach benefits that could better equip students with creativity and critical thinking skills necessary to thrive in an increasingly complex world (Adeniran, 2019).

The National Universities Commission (NUC)

The NUC is the primary body responsible for overseeing university education in Nigeria, playing a central role in setting academic standards, developing university curricula, and ensuring universities comply with national educational goals (National Universities Commission [NUC], 2019). As the regulatory body for university education, the NUC's decisions significantly shape Nigerian universities' academic structure and influence higher education direction. The NUC has made strides in improving Nigerian university education quality, particularly in strengthening accreditation procedures and aligning curricula with global standards (Ogunyemi, 2020). However, one significant challenge has been slow arts integration into STEM education. Despite growing international trends toward STEAM, the NUC has not yet developed a comprehensive policy mandating arts inclusion in STEM programs. Consequently, STEAM education integration remains largely optional, with individual universities deciding whether to include arts within their curricula.

This lack of clear national STEAM guidance has led to a fragmented interdisciplinary education approach in Nigerian universities. Some institutions have taken initiative to blend science and technology with arts, while others continue following traditional STEM-focused models. For example, the African University of Science and Technology (AUST) in Abuja has pioneered efforts to incorporate arts into its academic programs, adopting a more interdisciplinary learning approach encouraging creative thinking and innovative problem-solving (AUST, 2018). However, such initiatives are currently exceptional rather than routine. Without a national NUC policy enforcing arts integration into STEM disciplines, many Nigerian universities continue focusing on STEM subjects in isolation, missing holistic education model benefits that could better prepare students for 21st-century challenges (Adeniran, 2020).

The National Board for Technical Education (NBTE)

The NBTE is the governing body responsible for regulating technical education and vocational training in Nigeria. Its primary role is ensuring technical institutions across the country meet national standards, producing graduates possessing practical skills industries need (National Board for Technical Education [NBTE], 2017). It plays a vital role in shaping the country's workforce, focusing on equipping students with skills critical for industrial growth and national development. The NBTE has made significant strides in improving Nigerian technical education quality, including overseeing polytechnics and vocational institution accreditation and ensuring curricula align with industry needs (Ogunyemi, 2019). Despite these efforts, the NBTE's policies have often been disconnected from the broader educational policy framework, particularly regarding arts education integration.

While the focus has been on providing technical skills necessary for industrial development, creative and critical thinking aspects of STEAM crucial for fostering innovation have been largely overlooked.

Consequently, the NBTE's policies have been more geared toward training individuals in technical competencies such as engineering, construction, and manufacturing, with limited emphasis on arts integration. Current policies insufficiently incorporate interdisciplinary learning central to STEAM education, which links technical disciplines with creative problem-solving and innovation (Adetunji, 2020). This integration lack restricts students' ability to develop well-rounded skills blending technical proficiency with creativity key for addressing today's multifaceted global challenges. However, there have been recent NBTE attempts to encourage more interdisciplinary programs blending technical skills with creativity. For instance, pilot programs in some technical colleges and polytechnics attempt to bridge gaps between technical training and creative fields like industrial design and digital media (NBTE, 2020). These initiatives, while promising, remain small-scale, and broader nationwide implementation remains uncertain. Lack of a coherent national policy integrating arts into technical education has made widespread traction difficult for these programs. For STEAM to truly flourish in Nigeria, the NBTE must take a more active role in promoting creative disciplines alongside technical education. This would involve encouraging more cross-disciplinary programs and aligning vocational training with a holistic educational framework preparing students for modern workforce's evolving demands.

Inadequate Funding and Infrastructure

One significant barrier to STEAM education implementation in Nigeria is insufficient education sector funding. Despite growing global STEAM emphasis and its potential to drive innovation, Nigerian educational institutions particularly public universities and technical colleges often lack essential resources needed to build and maintain infrastructure required for modern STEAM education. This includes adequate laboratory facilities, computer and internet access, and up-to-date teaching materials facilitating interactive, technology-enhanced learning (Ogunyemi, 2020). Without these critical resources, institutions cannot provide students with hands-on experiences vital to STEAM learning, limiting their ability to apply theoretical knowledge to real-world challenges. Underfunding extends to both capital investment and operational budgets for educational institutions. For instance, public universities in Nigeria often operate under severe financial constraints, hindering their ability to purchase necessary equipment or upgrade outdated facilities (Umar, 2021). Consequently, students in these institutions may lack access to latest technology or tools central to STEAM education.

Moreover, many educational institutions still rely on outdated infrastructure, impeding education quality and limiting teaching method effectiveness, particularly in fields requiring practical and experimental learning. Additionally, overall education funding is often inadequate to meet Nigeria's rapidly growing population's needs. According to UNESCO, Nigeria's education sector consistently receives less than 5% of the national budget, far below the internationally recommended 15-20% allocation (UNESCO, 2020). This financial shortfall hampers reform implementation and educational program

expansion, including STEAM-focused programs. Lack of sufficient funding limits educational institutions' ability to train qualified teachers, purchase modern educational resources, and invest in necessary infrastructure supporting effective STEAM curriculum. As Nigeria faces increasing demand for a workforce equipped with both technical and creative skills, adequate STEAM education investment becomes even more critical. Without proper funding, the country risks falling behind in a global economy increasingly valuing interdisciplinary learning and innovation. Ensuring the education sector receives necessary financial support is crucial for fostering the creative, skilled workforce that can address 21st-century challenges.

Teacher Training and Professional Development

Another major challenge facing STEAM education implementation in Nigeria is the lack of adequately trained teachers capable of effectively teaching interdisciplinary subjects, particularly in rural and underserved areas. Teachers in these regions often lack necessary skills and training to integrate arts into STEM subjects. Furthermore, many educators are unfamiliar with project-based learning or other interdisciplinary teaching methods central to STEAM (Adeniran, 2020). This teacher preparation gap is particularly concerning given STEAM teaching complexity, requiring technical proficiency and creative teaching strategy blends. In Nigeria, teacher training programs have traditionally focused on disciplinary silos, with teachers trained to specialize in individual subjects such as mathematics, physics, or literature without receiving cross-disciplinary training required for effective STEAM teaching. While specialization benefits foundational learning in individual subjects, it limits educators' ability to develop interdisciplinary curricula combining arts with sciences and technology (Umar, 2021). This issue is exacerbated by the fact that curricular frameworks across Nigerian schools have not been fully adapted to promote interdisciplinary learning as envisioned in the STEAM model. Despite FME efforts to improve teacher quality through various training initiatives, there remains significant absence of a focused STEAM education strategy in teacher professional development programs.

While initiatives have enhanced teacher capabilities in STEM subjects, these efforts have often neglected arts integration critical for fostering creativity and critical thinking. Consequently, many educators continue relying on traditional teaching methods that do not sufficiently encourage creative exploration or collaborative learning (Ogunyemi, 2020). One notable institution working to improve teacher quality is the National Teachers Institute (NTI), which has made strides in providing professional development programs for teachers nationwide. The NTI offers training aimed at improving teaching techniques and enhancing teachers' ability to handle modern education challenges. However, much remains to ensure teachers acquire necessary skills for interdisciplinary teaching, particularly in STEAM disciplines. To realize STEAM education's potential, more comprehensive and targeted professional development programs are required programs that not only improve teaching in individual subject areas but also provide practical tools for integrating arts into STEM education. As Nigeria moves toward adopting a STEAM-oriented education system, concerted effort must be made to retrain and empower educators, ensuring they have tools and skills to deliver interdisciplinary curriculum fostering innovation, creativity, and problem-solving. This requires shifting from traditional teacher training approaches and

emphasizing equipping teachers to teach across disciplines and encourage arts-sciences collaboration.

Socio-Cultural Barriers

Cultural attitudes toward arts and sciences in Nigeria also present significant barriers to successful STEAM education integration. In many Nigerian communities, arts are often regarded as secondary to science and technology. This cultural bias, with deep historical and societal roots, continues influencing how students, parents, and educators perceive arts value in education. While science and technology are viewed as practical and essential for national development, arts are frequently dismissed as less important or as a luxury rather than a critical component of well-rounded education (Ogunyemi, 2019). This cultural perception creates challenges in promoting arts integration into STEM education, leading to undervaluing creativity's role in problem-solving and innovation. The belief that arts education lacks practical applications or is less valuable in the workforce undermines efforts to incorporate creative disciplines into educational curricula. Consequently, students may not fully appreciate arts' role in fostering critical thinking, creativity, and innovative problem-solving skills crucial for addressing 21st-century challenges (Adetunji, 2020).

This socio-cultural bias also reflects in parent and educator attitudes, who may prioritize STEM subjects over arts when making educational decisions for children or designing curricula. In many families, pursuing arts careers is often seen as less financially viable or prestigious compared to engineering, medicine, or technology careers. This perception further reinforces the STEM-arts gap, making it difficult to foster an education system truly embracing a STEAM model (Umar, 2021). Furthermore, media and societal narratives often contribute to this imbalance by focusing on scientific and technical field achievements while sidelining artists, designers, and other creative professionals' contributions. This cultural narrative limits arts recognition as an essential national development pillar, hindering efforts to shift toward more interdisciplinary education approaches. However, this cultural bias is not insurmountable. Advocacy and awareness campaigns, particularly by educational institutions and government agencies, are critical for changing public arts perceptions. STEAM education must be promoted as a valuable integrated approach preparing students for wide-ranging technical and creative industry careers. By highlighting science-creativity intersections and showcasing successful STEAM professionals using both technical and artistic skills, shifting cultural mindsets toward more holistic education views is possible (Adeniran, 2020).

The African University of Science and Technology (AUST)

AUST, located in Abuja, stands as one of few Nigerian institutions fully embracing the STEAM model. As an innovation-focused institution, AUST offers interdisciplinary programs integrating engineering, technology, and arts, preparing students for technical fields, entrepreneurship, and creative industries (AUST, 2020). By blending traditionally separate disciplines, AUST provides students with a more holistic education equipping them with technical expertise and creative thinking necessary to navigate modern world's increasingly complex challenges. AUST's education approach builds on the premise that professionals must be well-rounded and capable of applying both scientific knowledge and artistic creativity to solve problems. The university's curriculum encourages

interdisciplinary thinking, moving beyond traditional discipline silos. For example, students may engage in projects requiring both engineering design and artistic expression, enabling them to tackle problems with more innovative mindsets. This approach benefits personal development and aligns with global shifts toward fostering creative industries combining artistic and technical expertise (Adeniran, 2021).

AUST's commitment to STEAM education has earned recognition as a model institution for arts integration into STEM framework in Nigeria. The university's interdisciplinary programs have become a blueprint for other institutions beginning to explore arts-science integration, particularly in fields like industrial design, digital media, and technology-based entrepreneurship (AUST, 2020). Despite being a pioneering STEAM integration institution, AUST's approach faces several challenges typical of early new educational model adopters, including difficulty convincing other institutions to adopt similar interdisciplinary curricula and securing adequate funding to support such broad and innovative initiatives. Nevertheless, AUST's example paves the way for more Nigerian universities to embrace STEAM philosophy, showing that when applied effectively, interdisciplinary education can bridge creativity-technology gaps, ultimately preparing students to thrive in an ever-evolving global economy.

Science and Technology Education Post-Basic (STEP-B)

The STEP-B initiative, supported by the World Bank, aims to significantly enhance science and technology education quality at Nigeria's secondary school level. The program was designed to address growing demand for skilled scientists and technologists by improving STEM subject teaching and learning in secondary schools nationwide (World Bank, 2017). STEP-B focuses on providing secondary school students access to modern scientific tools, resources, and high-quality teaching in physics, chemistry, biology, and mathematics. Its goal is equipping students with foundational knowledge and skills needed to pursue higher education and careers in science and technology. While STEP-B has made significant progress in improving science education access, particularly in rural and underserved areas, the initiative has not yet fully embraced arts integration into its framework. The program's primary focus remains on STEM education, with limited attention to creative learning aspects central to comprehensive STEAM approaches. This absence of strong arts education emphasis has resulted in missed opportunities to promote interdisciplinary curriculum incorporating creativity and critical thinking necessary for holistic problem-solving and innovation (Adeniran, 2020).

Arts integration into STEP-B could be a powerful means of fostering creativity, collaboration, and innovative thinking vital components of modern educational landscapes. By bridging science-arts gaps, STEP-B could create an educational framework that not only emphasizes technical skills but also nurtures creative problem-solving qualities highly valued in today's rapidly evolving workforce (Adetunji, 2021). While STEP-B has certainly improved science education infrastructure and resources available in Nigeria, the initiative would benefit from a more inclusive approach incorporating arts alongside science and technology education. This integration would better prepare students to tackle complex challenges requiring both technical knowledge and creative thinking.

Summary

This chapter explored policy, governance, and institutional frameworks surrounding STEAM education in Nigeria. It highlighted educational policies' critical role in shaping learning direction, particularly focusing on Science, Technology, Engineering, Arts, and Mathematics integration. The chapter critically examined how national policies such as the NPE have evolved over time to accommodate Nigeria's educational system and workforce growing needs, while noting arts integration gaps into STEM. The chapter underscored key institutions' roles including FME, NUC, and NBTE in guiding Nigerian educational development. Despite their efforts to enhance STEM education, these institutions have yet to fully embrace a STEAM model fostering interdisciplinary education approaches. The chapter discussed how insufficient funding, outdated infrastructure, and teacher training deficiencies further hinder effective arts integration into education. Additionally, socio-cultural barriers such as arts undervaluation in Nigerian society limit successful STEAM initiative implementation. The chapter also highlighted innovative examples of pioneering STEAM integration institutions, such as AUST and STEP-B initiatives, offering insights into how interdisciplinary learning can be successfully implemented. However, challenges such as inconsistent policy enforcement and lack of comprehensive arts integration strategies persist. Finally, the chapter emphasized need for policy reform promoting STEAM education across all Nigerian education system levels. It argued that a comprehensive STEAM policy is essential for preparing Nigeria's students to meet increasingly complex global economy demands, where creativity, innovation, and technical expertise are equally valued.

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Chapter 4

HARNESSING STEAM FOR INDIGENOUS CONSTRUCTION MATERIALS DEVELOPMENT AS A PATHWAY TO SUSTAINABLE INFRASTRUCTURE AND HOUSING IN NIGERIA

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Abstract
The African construction industry has, over the years, remained dependent on foreign expertise and materials, leading to capital flight, currency exchange rate instability, and limited access to affordable housing. Despite the abundance of natural and human resources, African nations, especially Nigeria, have not maximised the benefits of Science, Technology, Engineering, Arts, and Mathematics (STEAM) in indigenous technological development in the construction industry. This chapter explores the nexus among STEAM education, indigenous content development, and construction materials development in the context of sustainable infrastructure development in Nigeria. This chapter draws from contemporary issues in STEAM education, indigenous content development, and construction materials development, including empirical data and contemporary research in the field, to demonstrate that the 70-80% dependency rate of the Nigerian construction industry on imported materials is not just an economic weakness but also an opportunity for the application of STEAM education in indigenous problem-solving in the construction industry. Using the construction materials value chain in Nigeria, contemporary issues in indigenous content development, and the National Building Materials Manufacturing Hubs initiative, the chapter proposes an overarching framework for the application of STEAM education in the context of indigenous content development in the construction industry in Nigeria, addressing the deficit in the 28 million housing units required in the country, while at the same time promoting industrialisation, employment creation, and sustainability in the construction industry. The chapter's findings will also inform the discussion on the decolonisation of the African construction industry, as well as on STEAM education and indigenous content development.

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Keywords: *STEAM education, indigenous construction materials, local content development, housing deficit, Nigeria, sustainable construction, technology transfer, innovation systems*

Introduction

The connection between a society's technological abilities and its capacity to shape its built environment is arguably one of the most essential forms of development independence. However, in Africa, this connection has been characterized by dependency rather than self-reliance. No country in Africa better exemplifies this than Nigeria, where, despite a long history of independence, abundant natural resources, and strong economic growth, its construction industry remains largely reliant on imports. This dependency, however, goes beyond construction costs, carrying significant economic, social, and technological consequences. The modern Nigerian construction industry is expanding, with projections indicating an 8 percent annual growth rate, aiming to reach NGN 25.72 trillion by 2025, after achieving a compound annual growth rate of 12.1 percent between 2020 and 2024. However, despite these positive growth indicators, the industry faces significant weaknesses. For example, 70-80 percent of its construction materials are imported, a situation described by experts as unsustainable. With the exception of cement, which is locally produced by companies like Dangote and BUA, almost all other construction materials, including electrical wiring, sanitary ware, finishes, and processed timber, are imported.

This reliance on imports has several implications for the Nigerian economy. First, it puts continuous pressure on the Naira's value. The demand for construction materials is a key factor driving imports. Second, it pushes inflation upward. Fluctuations in prices and currency exchange rates are quickly reflected in the costs of construction services. Perhaps most concerning, it leads to the export of potential construction jobs to China, Europe, and other countries, while simultaneously preventing these nations from developing their own industries that could meet these demand needs. The human toll of this technological dependency is significant. Nigeria faces an estimated housing shortfall of 17 to 28 million units. The country's annual construction output is only 200,000 units—far below the one million units experts say are needed to start addressing the deficit. For the average Nigerian, the biggest issue is the high cost of housing. Recent studies show that 72 percent of workers in Nigeria spend 40 percent of their salaries on housing, which amounts to four to six months of income each year. When construction materials are priced in foreign currency and transported through inefficient supply chains, housing becomes unaffordable for everyone except the wealthy. The main argument of this chapter is that these challenges can be tackled through Science, Technology, Engineering, Arts, and Mathematics (STEAM).

By combining knowledge with creativity and innovation, STEAM enables Nigeria's construction industry to shift from reliance on external technological solutions to developing its own. STEAM's role in creating indigenous construction materials technologies is not just an option—it's a vital part of Nigeria's development. This chapter is divided into six sections. After this introduction, Section 2 explores STEAM's conceptual foundations and its link to local content development, offering a new view on technological capabilities that include the development of construction materials. Section 3 provides a detailed analysis of Nigeria's reliance on importing construction materials, using data to show the extent, structure, and

impacts of this dependence. Section 4 investigates Nigeria's unused opportunities in developing construction materials, focusing on their scientific, technical, and economic aspects, including laterite, bamboo, timber, and agricultural wastes as potential building materials. Section 5 proposes a STEAM model to advance Nigeria's construction materials sector, encompassing education, research, standardization, and commercialization. Section 6 wraps up with recommendations and ideas for future research.

STEAM and Local Content: Conceptual Foundations

From STEM to STEAM: Evolution of an Educational Paradigm

The conceptual evolution from STEM to STEAM is not merely the addition of the arts to an existing acronym. It is a fundamental acknowledgment that technological innovation is not just about technical skills but also about creativity and context. The STEM movement was popularized in the second half of the twentieth century to acknowledge the importance of science, technology, engineering, and mathematics for economic competitiveness in a highly technological world. However, a number of scholars pointed out that, in its traditional sense, STEM education was failing to produce graduates who could creatively solve problems. The integration of the arts into STEM education, known as STEAM, addresses this limitation by intentionally incorporating design, creativity, and human-centred approaches. STEAM, as described in the STEMTastic Adventures! The Africa 2025 Symposium is "not just a curriculum; it is the engine of our transformation" in a world driven by AI, climate change, and digital economies.

This new approach recognizes that solving complex issues such as housing affordability, sustainable construction practices, and innovative building materials requires not only knowledge but also the ability to think creatively, develop new solutions, consider user needs, and incorporate diverse perspectives. STEAM education offers hope for Africa, which has a young population that needs development to meet the continent's growth challenges. Africa has the youngest population in the world, with projections showing that by 2050, a quarter of all youths worldwide will be from Africa. This presents a strategic opportunity for Africa to position itself as a leader in solving everyday problems through innovation.

Local Content as Technological Capability

The idea of local content has significantly changed from its original meaning in the oil industry. According to Professor Uche Okorie, Registrar of Nigeria's Council for the Regulation of Engineering in Nigeria (COREN), local content means "the quantum composite value added or created in the Nigerian economy through utilization of Nigeria's human and material resources for the provision of goods and services." Key aspects of local content include the use of local labour, local procurement, value-added manufacturing, capacity building, and technology transfer. However, as Okorie highlights, "local content is not nationalism for its own sake; it must meet quality, safety, environment standards".

Although the term originated in the oil and gas industry, it is now used broadly across the agricultural, manufacturing, ICT, and construction sectors, among others. To Nigerians, local content means "moving from being mainly a consumer/importer of goods and services to becoming a producer, processor, and exporter." This emphasizes that it is not just about mandates but also about building the technological capabilities that can shift the economy

from a state of consumption to one of production. In the expanded sense, local content is mainly about technological capability rather than just local participation. It involves creating the so-called "technological capabilities," including skills, knowledge, and organizational structures that enable effective use of technology and, over time, its improvement. These technological capabilities exist at the individual, organizational, and systemic levels.

The STEAM-Local Content Nexus in Construction

The construction industry has unique features that shape the connection between STEAM skills and local content development. Unlike manufacturing, where products are made in factories and shipped to consumers, the construction industry is site-specific: materials and equipment are assembled on-site to create a structure that reflects the community's needs and desires. The difficulty lies in the advanced nature of construction technology. Modern buildings incorporate various materials and techniques, including the structural frame, building envelope, finishes, services, and electrical systems. These components are supported by different supply chains and require diverse technical knowledge. Heavy reliance on imports in construction highlights a lack of capabilities across multiple technologies simultaneously, such as producing specialized glass, manufacturing specific fittings, processing various materials, and utilizing alternative materials. The site-specific nature of the construction sector also offers an opportunity. Building responds to local climate, soil conditions, culture, and economy. These are areas where local knowledge and skills are inherently strong. Local building traditions, developed over centuries, are a sophisticated reflection of local materials and environmental conditions.

The challenge is how to connect these traditions with modern technical capabilities in a way that enhances the technologies without sacrificing their relevance and affordability. This is exactly what a well-designed STEAM approach can achieve. The fields of science, technology, engineering, and mathematics offer insights into the material properties of construction technologies. The arts component can encourage design thinking and the development of innovative solutions that are both technically advanced and culturally relevant. These form the core of "indigenous innovation": improving technologies through creative adaptation to the local context. The vision of the African Export-Import Bank (Afreximbank) in this regard has been clearly expressed. Kanayo Awani, the bank's Executive Vice President, stated at the Intra-African Trade Fair in 2025 that "The future of Africa's development cannot be outsourced. We have the expertise, and above all, the collective will to ensure that Africa's infrastructure dreams are realized and placed in our hands." This confidence in African potential is not just empty talk. It is backed by evidence of success in construction and engineering. This includes Afreximbank's facilitation of over $12.1 billion in contracts for African engineering, procurement, and construction companies over five years. It features major projects in the region, such as the Julius Nyerere Hydropower Plant in Tanzania, which was completed entirely by African contractors and financed within Africa.

Nigeria's Construction Materials Import Dependence: Magnitude and Implications

The Scale of Import Dependence

To understand the extent of import dependence in Nigeria, it is important to consider both direct and indirect imports of construction materials. It is also crucial to examine the import dependence for various categories of building materials. The most commonly cited figure for

import dependence in the Nigerian construction industry is that 70-80 percent of building materials are imported. This figure appears in several sources and suggests that it is a reasonable estimate of the country's reliance on imports. One category of building materials with lower import dependence than others is cement. Industry expert John-Bede Anthonio states, "The only thing that's not imported is cement, thanks to companies like Dangote and Bua." The success of Nigeria's cement industry suggests that this sector could reduce its reliance on imports. Aside from cement, however, import dependence is widespread. Reinforcing steel, despite the availability of scrap metal and iron ore, is mainly imported, with prices more than doubling from 2023 to 2025 due to currency depreciation and global price swings.

Electrical wiring, fittings, sanitary ware, tiles, paints, finishes, and even timber products despite Nigeria being the largest producer of sawn timber in Africa are mostly imported. Perhaps the most surprising reliance on imports is in timber products, given that Nigeria produces over 2,130,000 cubic meters of industrial roundwood annually, including high-value species like mahogany, iroko, and obeche, yet most of these are exported, while imported products are used in construction. Not only are materials imported, but technical expertise and project implementation are sourced from abroad as well. As Afreximbank has shown, most of the $90 billion African countries spend annually on infrastructure development is allocated to projects undertaken by foreign engineering, procurement, and construction companies. Foreign contractors offer financing options that their African counterparts lack, given the financial conditions in most African countries. This creates a vicious cycle of dependence. This phenomenon is also seen in Nigeria, where most major infrastructure projects undertaken by foreign contractors Chinese, European, or Turkish relegate indigenous players to subcontractor roles or completely shut them out of the process.

Economic Consequences

The economic impacts of import dependence in the construction sector are extensive and diverse. The primary economic consequence of import reliance in Nigeria's construction industry is its negative effect on the balance of payments and the value of the national currency. Importing construction materials accounts for a significant share of Nigeria's balance of payments. This creates a steady demand for foreign exchange driven by the sector's import dependence. Ultimately, this demand contributes to the depreciation of the national currency. The Naira's depreciation over the past few years has been significant. As the Naira depreciates, the cost of imported materials increases proportionally. Consequently, the prices of building materials rise in tandem with the Naira's depreciation. This leads to a ripple effect, increasing house prices nationwide. The ripple effect of import dependence in Nigeria's construction sector, combined with the depreciation of the Naira, is clear in the rising prices of building materials over recent years. In Lagos State, the costs of essential building materials increased significantly between 2023 and 2025. The price of reinforcement steel measuring between 10 and 16 millimetres surged during this period. For instance, this product's price jumped from about NGN 800,000 per ton in 2023 to over NGN 1,600,000 in 2024. Other building materials experienced similar increases. A 12mm iron rod's price rose from NGN 8,000 in May 2023 to NGN 19,000 in May 2024. Similarly, a 10mm rod's price increased from NGN 3,600 to NGN 9,500, and an 8mm rod from NGN 2,500 to NGN 6,500 in the same period.

Import dependence in Nigeria's construction sector contributes to inflation. The prices of building materials influence house prices. Housing is a major part of the typical Nigerian worker's expenses. The fact that 72 percent of workers in Nigeria spend about 40 percent of their income on rent highlights the importance of this sector in the economy. The employment impacts of import dependence are just as significant. The construction industry is the second-largest employer in Nigeria. However, if these materials are imported rather than produced locally, the jobs involved in their manufacture will go to people in other countries, not in Nigeria. Local production of these materials will create jobs in various sectors, including raw material extraction, manufacturing, logistics, and retail. As Anthonio says, "If we can produce materials locally, we will employ many people, which will have a multiplier effect on other sectors". But most importantly, reliance on imports hinders the growth of the local industry. As long as these materials are imported, the necessary technological skills for long-term industrial growth are never developed. Local industry, if properly guided, could build the capacity to produce quality materials, but remains stuck in trading them, adding little value. These technological skills are never gained. The cycle of import reliance continues.

Housing Deficit and Affordability Crisis

The ultimate consequence of import dependence in the construction industry is the housing shortage crisis affecting millions of Nigerians. Nigeria's housing deficit is estimated differently by various sources. However, regardless of the specific number, it is widely agreed that the housing deficit in Nigeria is at crisis levels. The Federal Government of Nigeria has cited the housing deficit at 17 million units, while other estimates suggest it could be as high as 28 million units. Nigeria's annual construction output of 200,000 units falls far short of the one million units needed each year to close the gap. This deficit directly impacts the affordability challenges Nigerians face. The discovery that 72 percent of workers spend 40 percent of their income on rent shows that many Nigerians cannot afford basic housing. Most Nigerians can only dream of owning a home. The high cost of construction materials, limited access to mortgages, and rapid urbanization mean that demand for housing consistently exceeds supply. The affordability challenges Nigerians face is having a devastating effect on low- and informal-sector workers. These are the majority of Nigeria's urban residents. These workers cannot access formal housing markets and are forced to live in informal settlements with poor housing standards. The physical housing deficit Nigeria faces is visible in informal settlements springing up on the outskirts of cities. These settlements are built from materials imported into Nigeria but assembled with skills limited by resource availability.

Policy Responses and Their Limitations

The Nigerian government has recognized the challenges caused by reliance on imported construction materials. It has introduced several policies to address these issues. The most promising policy is the Federal Government's plan to establish manufacturing hubs for building materials across the six geopolitical zones. This plan was announced by the Minister of Housing and Urban Development, Architect Ahmed Musa Dangiwa. Each hub is expected to house factories producing cement, steel, tiles, sanitary ware, paints, and doors within a single economic zone. When operational, these hubs are projected to create over 50,000 jobs, strengthen the Naira by reducing import costs, and position Nigeria as an export hub for construction materials in the region.

This initiative recognizes that housing can serve as a key driver of economic development, "turning construction into a complete economic ecosystem". Other initiatives to support these efforts include promoting the use of local materials through research, standardization, and demonstration. For example, the Sustainable Building 2025 conference highlighted the potential of laterite, bamboo, and local timber as construction materials, providing alternatives to imported materials. Such options could be effective for developers to adopt. It is reported that, with proper treatment, bamboo's tensile strength is comparable to steel and offers the additional benefits of re-growing after 18 months and of absorbing carbon. However, many challenges may arise during implementation. It is reported that previous government initiatives in Nigeria have been hindered by implementation problems. Experts suggest establishing independent agencies to oversee initiatives like this to prevent government interference. There are also challenges related to financing, infrastructure especially electricity and security issues that may occur during implementation. Additionally, navigating the numerous incentives involved, including competition from established import chains and opposition from those resistant to change due to the current system, presents another challenge.

Indigenous Construction Materials: Potential and Challenges

The Resource Endowment

The country also benefits from a wealth of natural resources that can serve as inputs for local construction materials. Its geological diversity means it has plentiful mineral resources, such as limestone for cement production—already widely used—clay for bricks and tiles, laterite for earth construction, granite for aggregate, and kaolin for ceramics. The country's climate also fosters the growth of various timbers with excellent construction qualities, including mahogany, iroko, obeche, and African walnut. Agricultural by-products such as rice husk, cassava peels, palm kernel shells, and sugarcane bagasse can also be used to produce composite materials. The availability of these natural resources varies across the country, reflecting its ecological and geographical diversity. The mangrove swamp and rainforest in the southern region provide timber and bamboo; the derived savanna and Guinea savanna in the middle region supply clay and agricultural residues; the Jos Plateau in the north offers kaolin and tin by-products; and the sedimentary basin in the Niger Delta's delta region provides clays and sands.

Laterite and Earth-Based Construction

Laterite is a tropical soil widely used in West African construction for centuries. Traditional methods, such as sun-dried blocks, earth construction, and wattle and daub, produced buildings that were thermally comfortable and culturally suitable, using readily available materials with minimal processing. Many of these buildings, when properly maintained, have proven to be extremely durable. It is clear that modern earth construction has surpassed these traditional techniques. Research shows that laterite blocks can be stabilized with small amounts of cement or lime to create compressed earth blocks (CEBs), which are stronger and more water-resistant. CEBs can be produced with either manual or motorized presses, allowing for small-scale production with minimal capital investment. When properly designed and compacted, earth blocks can meet or even exceed the standards of conventional masonry for low-rise buildings.

Besides availability, laterite construction has other benefits. One of these is that earth construction provides good thermal mass, which helps regulate indoor temperatures and lowers cooling needs.

This is especially important for Nigeria because of its tropical climate. Earth construction also supports local industries since it can be painted with locally made paint. Lastly, earth construction is visually attractive, bridging modern architecture with its historical roots. To fully utilize laterite construction, however, several challenges must be addressed. First, laterite varies significantly depending on the source. Second, although stabilizing with cement is more costly than natural stabilization with lime, it remains much cheaper than producing bricks or blocks. Third, earth construction is still often associated with poverty and underdevelopment, and this association must be challenged to promote laterite use. Finally, there is a continuing lack of technical expertise in earth construction among architects, engineers, and artisans due to its limited current use.

Bamboo: The "Plant Steel".

Bamboo is increasingly recognized as a sustainable building material with promising prospects. As Sanmi Olowosile, the chairman of the Sustainable Green Environment Initiative, states: "Bamboo is a plant steel material which, when treated properly, has the same tensile strength as steel." Bamboo grows quickly and reaches maturity in three to five years, unlike timber, which takes decades. It also reproduces itself without replanting. Bamboo absorbs a significant amount of carbon dioxide during its growth cycle. Additionally, bamboo can grow on poor soil and does not compete with food crops. The uses of bamboo in construction are many. Chemically treated bamboo poles can be used in building projects. Bamboo can also be made into panels for floors, walls, and furniture. Engineered bamboo is suitable for modern buildings. Bamboo fibres are used in creating composite materials that could replace synthetic fibres. Nigeria has abundant bamboo resources that are currently underused. The country has numerous bamboo forests, both natural and planted. However, most bamboo used in construction is untreated, which raises durability concerns. Bamboo is also imported in processed form. Developing Nigeria's bamboo value chain will require investment in treatment facilities, which may include chemical treatments or traditional methods such as smoking and soaking. Additionally, research is needed to explore how bamboo can be effectively used in Nigerian construction.

Timber: From Export to Domestic Use

Nigeria's position as Africa's largest producer of sawn timber is both an opportunity and a paradox. It offers an opportunity because of the abundance and diversity of timber resources available. However, it presents a paradox because, despite its production potential, Nigerian construction primarily uses imported timber products, while logs are exported for processing elsewhere. This paradox stems from the nature of the timber value chain. Nigeria's timber industry has long been export-focused. Logs are shipped to countries like China, the US, Germany, Indonesia, Finland, Poland, and Brazil for processing. Nigeria has limited capacity for local timber processing. The timber products available in the local market are either imported or processed from locally grown logs that lack consistent quality and finish. Recently, the government implemented a policy banning log exports, though it was unpopular among log producers and exporters. This policy aims to develop a domestic

timber-processing industry and add value locally. For the potential of Nigerian timber for domestic construction to be realized, several constraints must be addressed. There is a need to upgrade capacity and quality in the processing industry to produce timber products of acceptable quality for construction use. These timber products must meet requirements for strength grading, moisture content, and dimensional stability. Additionally, treatment facilities are necessary to protect timber from termite and fungal attacks, which are major factors affecting timber durability in tropical countries.

Agricultural Wastes and Composite Materials

In Nigeria, the agricultural sector generates substantial waste that can be used as a resource in the construction industry. Rice husks, found in rice-growing states, can be burned to produce rice husk ash, a pozzolana that can replace cement in concrete and blocks. Cassava peels and palm kernel shells can be used to make lightweight aggregates. Sugarcane bagasse can be used to manufacture fibreboard. The use of composite materials made from agricultural waste provides opportunities for STEAM applications. Refining the proportions of materials mixed together, improving the mechanical properties and durability of the composites, developing suitable manufacturing processes, and testing their performance require scientific and engineering expertise. The arts and design components of STEAM help develop materials that not only perform well but also look attractive and appeal to the senses.

Barriers to Indigenous Materials Adoption

Despite the potential of indigenous materials, significant barriers prevent their adoption by the mainstream construction industry. Understanding these barriers is essential for designing suitable solutions. Technical obstacles to adopting indigenous materials include variability in performance, limited data on their characteristics, and a lack of standardized testing and quality assurance procedures. Unlike factory-produced materials with consistent traits, indigenous materials vary greatly depending on factors such as source, processing methods, and environmental conditions. Architects, engineers, and builders cannot specify indigenous materials without reliable data on their performance and quality assurance procedures that could be used to standardize their use. Regulatory barriers stem from building codes and standards crafted with conventional materials in mind, which may not accommodate indigenous materials. Nigerian building codes, like those of other nations, are mainly based on international models and assume the use of industrially manufactured materials. Integrating indigenous materials will require either meeting performance criteria which can be challenging without testing protocols or developing specific standards for these materials.

Capacity barriers exist due to limited knowledge and experience among construction practitioners in working with indigenous materials. This is because architecture and engineering education in Nigeria has predominantly focused on conventional materials and construction methods, with little emphasis on indigenous alternatives. As a result, it is unlikely that construction practitioners, who were not trained to work with indigenous materials, would specify their use, even if they have advantages. Economic barriers relate to incentives for construction practitioners who use either imported or local materials. Imported materials, although they come with a high foreign exchange cost, have a well-established system, which makes their use easier than local materials that require additional

effort in sourcing, testing, and quality assurance. Cultural barriers involve perceptions or attitudes toward indigenous materials. In some societies, earth and bamboo construction are seen as traditional or inexpensive, while concrete, glass, and steel construction are viewed as modern or advanced. To shift this perception, demonstration projects are needed to highlight the potential of using indigenous materials in contemporary construction.

Leveraging STEAM Across the Materials Value Chain
A Framework for STEAM-Enabled Materials Innovation

Overcoming the challenges to indigenous materials development and realizing the potential of Nigeria's resource endowment requires an integrated approach that leverages STEAM capabilities across the entire value chain of materials development. This value chain includes processes from resource identification and characterization to materials development and improvement, product design and testing, standardization and certification, commercialization, and ultimately, professional education and capacity building. Each stage offers unique opportunities for STEAM application and involves a distinctive mix of scientific, technical, and creative skills. The proposed framework recognizes that developing indigenous materials is more than just "rediscovering" traditional skills. Instead, it involves the creative use of traditional knowledge combined with modern scientific understanding and technical abilities. While traditional builders, through generations of experience, knew which laterite deposits produced good blocks, which bamboo species resisted termites, and which wood species seasoned well, modern STEAM capabilities can enhance this traditional knowledge with scientific insights into the underlying processes.

Resource Identification and Characterization

At the core of developing indigenous materials is the identification and characterization of resources. It involves systematically identifying and describing Nigeria's construction materials resources, including laterite deposits with varying clay, silt, and iron oxide content; clay deposits with different levels of clay suitable for brick and tile production; bamboo with diverse species composition and growth stages; timber with various species; and agricultural wastes with different quantities and qualities. This characterization work is primarily a scientific exercise that also requires engineering science to understand the relationship between the material's properties and its potential applications. Additionally, there is a need for design thinking to understand how the characterized material could be transformed into a useful product. There is also potential to use geographic information systems and remote sensing techniques for mapping resources, along with lab-based characterization in accordance with established standards. Universities and research institutions play a vital role in characterization efforts. Nigeria has federal and state universities, polytechnics, and research institutions with scientists and engineers possessing the right expertise. However, realizing these opportunities requires adequate research interests, funding mechanisms, and collaboration frameworks.

Materials Processing and Improvement

After characterising resources, the next step is to design and improve suitable materials-processing techniques that transform raw materials into usable construction products. This process is inherently interdisciplinary, involving materials science to understand how processing affects materials, mechanical engineering to develop and optimize processing

machinery, chemical engineering to create appropriate treatment and stabilization methods, and industrial design to produce products that meet users' needs and preferences. For laterite-based materials, research will focus on stabilization what type and amount of stabilizer offers the best balance of strength, durability, and cost? What pressures and moisture levels will achieve optimal density? How will these factors vary depending on the composition of laterite? For bamboo materials, processing will address questions about treatment methods that deliver maximum durability without high costs or environmental impacts, as well as methods for producing engineered bamboo with consistent properties. Regarding agricultural wastes, research will consider suitable treatment methods, ideal particle size, binders, and forming processes. This research on processing will need facilities for materials testing in a laboratory, pilot-scale facilities for process development and testing, and demonstration facilities for performance validation. It will also require collaboration between researchers and industry players who can provide the necessary input and guidance and ultimately implement the innovations successfully. The proposed building materials manufacturing hubs could serve as a potential area for collaboration in developing indigenous building materials processing.

Product Development and Testing

The processed materials will then be further developed into products that meet market and regulatory standards. This product development process involves many considerations to meet user needs and ensure compliance with the building industry's requirements. For example, a laterite block product must not only meet strength and durability standards but also conform to specifications for dimensions, plastering and painting surface finish, and cost competitiveness. The testing process for building products requires careful attention to ensure they meet performance standards. This includes verifying that the products satisfy mechanical requirements such as compression, tension, and modulus of elasticity. It also involves confirming that the products fulfil durability, water resistance, and freeze-thaw resistance criteria. Additionally, for bio-based products, termite resistance may also need to be evaluated. The engineering disciplines within STEAM play a vital role in this process. The arts and design disciplines in STEAM are equally important. Ultimately, the product must meet both the performance expectations and the aesthetic preferences of users.

Standardisation and Certification

The lack of standards for indigenous materials is a major obstacle to their mainstreaming. Architects and engineers cannot specify indigenous materials without established standards. Builders will not use these materials unless they are confident in their quality. Regulators will not approve indigenous materials for use unless there is proof of compliance with the relevant standards. Therefore, it is essential to develop standards for indigenous materials to enable their mainstream adoption. Creating standards requires collaboration among researchers (who provide data for standards), standards organizations (such as the Standards Organisation of Nigeria), professional institutions (such as the Nigerian Society of Engineers and the Nigerian Institute of Architects), and industry stakeholders. In addition to developing standards, it is crucial to establish certification mechanisms that ensure indigenous materials products meet specific requirements. These mechanisms can include product certification, in which individual products are tested, or system certification, in which processes are audited.

Commercialisation and Scaling
It is essential to develop technically sound indigenous materials, but it is equally important that these products be commercially viable so they can compete favourably with established materials.

Manufacturing Economics
Manufacturing economics involves optimizing processes to maintain cost competitiveness. In some cases, small-scale production of local materials for regional markets may be cost-effective, but for broader impact, larger-scale facilities might be needed, which require capital investment. Manufacturing hubs for building materials could benefit from economies of scale, ensuring cost competitiveness for local materials.

Development of the Supply Chain
The development of the supply chain involves sourcing raw materials, distributing finished products, and ensuring the availability of installation skills. For indigenous materials, a new supply chain must be developed, which requires investing in supply chain infrastructure. Government procurement could play a key role in generating initial demand for indigenous materials, thereby justifying investment in supply chain infrastructure.

Marketing and Branding
Marketing and branding need to overcome perception barriers for indigenous materials. Instead of portraying indigenous materials as a "low-cost alternative," marketing strategies should highlight their unique advantages, such as positive environmental effects, thermal performance, appearance, and contributions to local economic growth.
Demonstration projects that showcase indigenous materials in high-profile construction projects would also be effective in changing perceptions.

Business Model Innovation
Innovation in business models is crucial for developing indigenous materials, as models that combine material production with construction services, offer performance guarantees, or provide financing for material purchases, can help overcome perception barriers to indigenous materials.

Professional Education and Capacity Building
Ultimately, the success of indigenous materials development relies on people: the architects who specify materials, the engineers who design with them, the builders who construct with them, and the entrepreneurs who produce them. Building this capacity among people requires incorporating indigenous materials into professional education curricula. In the university and polytechnic sectors, there should be greater emphasis on indigenous materials in the curriculum than on conventional ones. This should be done not only at the theoretical level but also practically. Design studios should encourage and reward designs that creatively incorporate indigenous materials, showcasing their potential for future designers. For professionals, there should be training programs on the specification and application of indigenous materials, especially as part of ongoing professional development. Professional organizations such as the Nigerian Society of Engineers and the Nigerian Institute of Architects play important roles in developing and conducting such training programs. For

artisans and crafters, training in the use of indigenous materials is essential. The proposed Construction Artisan Training School, which aims to train 1 million artisans by 2035, could include indigenous materials in its curriculum. This not only improves skills but also creates jobs.

The Role of STEAM Centres and Partnerships

Implementing the full range of the proposed concept requires an institutional framework that brings together various skills needed for innovation with indigenous materials. STEAM centres, like the one recently launched at the Botswana International University of Science and Technology (BIUST), show promise. These centres create a learning environment that offers hands-on engineering and science lab experiences, enabling students to work with the latest scientific and engineering tools in a safe, supportive setting under the guidance of experienced mentors. As noted by Professor Otlogetswe Totolo, Vice Chancellor of BIUST, in his remarks during the launch of the centre, "such facilities signify an investment in human capability, creativity, and national progress. They signify the potential outcomes when international collaborators join forces with local organizations to equip the upcoming generation of scientists, engineers, and innovators." The same can be said of the potential of establishing STEAM centres in Nigeria focused on construction materials innovation. Partnerships are essential in this model. Collaborations with other countries can offer expertise, technology, and resources, as seen with BIUST and STEM power Corporation. Industry partnerships ensure that research, development, education, and training remain relevant and that innovations can be scaled up. Government partnerships guarantee that solutions are informed and facilitate the adoption of innovations through government procurement. Community partnerships make sure solutions are suitable and can be shared fairly.

Conclusion and Policy Recommendations

Synthesis of Arguments

In this chapter, we have demonstrated that Nigeria's import dependence on construction materials, along with the attendant economic costs and contribution to the housing deficit, can be addressed through the strategic use of STEAM capabilities. The argument has been developed through several related claims.

Firstly, we have demonstrated that import dependence in Nigeria's construction materials sector is not merely an issue of import dependence. It is an issue of technological capabilities. We have shown that Nigeria imports construction materials not because it lacks the natural resources for their production. We import because we lack the technological capabilities to produce them.

Secondly, the development of technological capability requires an educational and innovation model that integrates technical skills with creativity and contextual understanding. Such an educational model is STEAM – science, technology, engineering, mathematics, arts, and design. This model not only imparts technical skills in the relevant fields of science, technology, engineering, and mathematics but also the creative application of such skills to address new problems. Such a capability is required in the development of indigenous construction materials.

Thirdly, Nigeria is a country rich in natural resources that could provide raw materials for the development of indigenous construction materials. Laterite, bamboo, timber, and agricultural wastes are among these resources that could be developed into construction materials through the application of appropriate technology. Such construction materials could be technically appropriate, economically viable, and culturally acceptable.

Fourthly, the development of indigenous construction materials in Nigeria would require a concerted effort along the entire value chain from natural resource characterisation through processing and development into construction materials to standardisation and commercialisation.

Policy Recommendations

Based on the analysis in the foregoing sections, the following policy recommendations are made regarding the utilisation of STEAM capabilities to develop indigenous construction materials in Nigeria. A National Construction Materials Innovation Programme should be set up. Such a programme should be housed in an appropriate agency in the Federal Republic of Nigeria, such as the Federal Ministry of Science and Technology or the National Agency for Science and Engineering Infrastructure. Integrate Indigenous Materials into Professional Curricula. The National Universities Commission, with input from various professional bodies, should ensure that courses offered in various universities, especially in architecture, engineering, and construction, include materials science, testing methods, specification practices, and design applications related to indigenous materials. Similar considerations should be applied to courses offered across various polytechnics and vocational institutions. Establish STEAM-Centred Facilities for Construction Materials Research. Building on the model established by the BIUST STEAM Centre, Nigeria can develop STEAM-centred facilities dedicated to research and education on construction materials. These facilities can be established within existing universities or research institutions. These facilities can be used for materials characterization and processing research, as well as for educational purposes for students from various disciplines and industry players. Accelerate Standards Development for Indigenous Materials.

The Standards Organisation of Nigeria, in collaboration with research institutions and professional bodies, should accelerate the development of standards for indigenous materials. The standards should be informed by research results and include input from industry players. The first set of standards should be developed for promising materials, such as stabilized earth blocks, treated bamboo, and timber. Integrate Indigenous Materials Development into Building Materials Manufacturing Hubs. The proposed hubs for building materials manufacturing should incorporate the development of indigenous materials into their operations. This can be achieved by allocating space within these hubs for indigenous materials manufacturers. Leverage Public Procurement to Create Demand. Government construction projects, including public housing, schools, and health facilities, should specify the use of indigenous materials where they meet performance requirements. This will provide the demand required for indigenous materials producers to gain economies of scale and provide proof of concept for indigenous materials. Establish a Construction Materials Innovation Fund. A fund should be established to support indigenous materials enterprises, including funding for pilot plant development, equipment procurement, product testing,

and certification. It should be designed to leverage private sector co-investment. It should be targeted at enterprises most likely to commercialise. Foster Regional Cooperation on Materials Research. Given the similarities in resource endowments and construction needs across West Africa, regional cooperation in materials research could be an important catalyst for progress and help share the costs. Nigeria should cooperate with other countries in the region, including the Economic Community of West African States (ECOWAS), to establish collaborative research initiatives.

Directions for Future Research

The above analysis also provides many avenues for future research, including:

i. Further mapping of Nigeria's laterite resources, including the development of predictive models correlating geological setting with engineering properties.
ii. Further optimisation of stabilisation techniques for earth-based materials, including the evaluation of alternative stabilisers to cement that are more environmentally benign.
iii. Further development of treatment techniques for bamboo that are effective against termite damage as well as fungal degradation, yet are cost-effective, as well as environmentally benign.
iv. Characterisation of Nigerian timber species for structural uses, including the development of strength grading rules and design values
v. Research into the use of agricultural waste materials for partial substitution of traditional construction inputs, including life cycle assessment of environmental impacts
vi. Research into the factors influencing the adoption of indigenous materials from the perspective of different stakeholder groups, such as architects, builders, developers, and home owners
vii. Research into the success of indigenous materials projects in other countries, with particular emphasis on the lessons that can be learned for Nigeria
viii. Developing business models that support sustainable indigenous material enterprises for low-income markets.

Concluding Reflections

The discussion in the chapter has implications for the broader discourses on African development. The dependency that characterises the construction industry in Nigeria is not unique; it is replicated in other sectors across the African continent. To escape dependency, it is not just a matter of changing how the industry operates; it also requires fundamental changes in the country's technological development. STEAM education is a way to achieve that. The implications of the discussion go beyond the economy; they go to the heart of a society's ability to control its destiny. A society that is not capable of constructing its spaces in ways that it desires, using its own materials and its own capabilities, is not in control of its destiny in the way that it should be. The materials that dominate the construction industry in Nigeria, for instance, not only impose costs in terms of exchange rates but also in terms of design, standards, and aesthetics that are not indigenous to the country. They construct spaces that may not be in the best interests of the people of Nigeria, nor spaces that express their aspirations. Indigenous materials development, by contrast, has the potential to deliver

a built environment that is not only more affordable and more sustainable but also more authentic in its Nigerian-ness.

Materials such as laterite blocks, bamboo poles, and indigenous timbers offer a connection to indigenous traditions in the construction process, while, when applied with STEAM innovations, they can also deliver modern construction standards. They offer the opportunity to develop spaces that can address the needs of the local context in terms of climate, culture, and economy, spaces that embody capability, not dependency. The realization of the potential of indigenous materials development will, however, require commitment, investment, and patience from a variety of stakeholders. It will demand investment in education, research, infrastructure, and enterprise development, as well as investment in standards and quality assurance. It will demand patience, too, as technological capability development is a slow process that can only be achieved through learning and experience. But the alternative to achieving indigenous materials development through the application of STEAM innovations is not an option at all; it is not only an opportunity but an imperative.

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Chapter 5

ENTREPRENEURSHIP AND HUMAN CAPITAL DEVELOPMENT: PATHWAYS TO POVERTY REDUCTION IN AFRICA

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Abstract
Entrepreneurship plays a pivotal role in driving economic growth and reducing poverty in Africa. This study examines the impact of entrepreneurship on human capital development and poverty reduction in sub-Saharan Africa. Using a quantitative approach, data from 4 African countries were analyzed to assess how entrepreneurship contributes to education, skills acquisition, and health improvements, ultimately reducing poverty. Specifically, this study proposes a comprehensive framework—the Entrepreneurial Human Capital (EHC) Model that integrates education, vocational training, health interventions, and mentorship into the entrepreneurial ecosystem. Empirical evidence from four African case studies (Kenya's Uwezo youth entrepreneurship program, Nigeria's Tech Start incubator, Ghana's Skill Bridge apprenticeship scheme, and Ethiopia's Agri-Innovate farmer enterprise project) illustrates how targeted human capital investments amplify entrepreneurial outcomes. Results indicate that entrepreneurship significantly enhances human capital development, leading to improved poverty outcomes. The study concludes that fostering entrepreneurship is crucial for sustainable development in Africa, and policymakers should prioritize creating supportive environments for entrepreneurial activities.

Keywords: *Entrepreneurship, Human Capital Development, Poverty Reduction, Skills Acquisition, Capability approach*

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Introduction

Africa faces significant development challenges, with poverty remaining a pervasive issue across many countries. Despite progress in economic growth, the continent's poverty rates are among the highest globally, with over 40% of the population living below the poverty line (World Bank, 2020). Human capital development is critical for sustainable development and poverty reduction, and entrepreneurship is increasingly recognized as a key driver of this process. Entrepreneurship contributes to economic growth by creating jobs, fostering innovation, and improving productivity. In Africa, where formal employment opportunities are limited, entrepreneurship can play a vital role in reducing poverty and improving livelihoods. Human capital, encompassing education, skills, and health, is essential for entrepreneurial success and sustainable development. The relationship between entrepreneurship, human capital development, and poverty reduction is complex. Entrepreneurship can enhance human capital by providing opportunities for skills development, education, and health improvements. Conversely, investments in human capital can foster entrepreneurship by equipping individuals with the necessary skills and knowledge to start and grow businesses.

In sub-Saharan Africa, where poverty is most prevalent, understanding the interplay between entrepreneurship and human capital development is crucial for designing effective poverty reduction strategies. Policymakers and development practitioners need to create environments that support entrepreneurship and invest in human capital to achieve sustainable development goals. This chapter examines the role of entrepreneurship in human capital development and poverty reduction in Africa, focusing on sub-Saharan Africa. It analyzes how entrepreneurship contributes to human capital development through education, skills acquisition, and health improvements, ultimately reducing poverty. It reviews the theoretical foundations that link human capital to entrepreneurial performance, culminating in the Entrepreneurial Human Capital (EHC) Model. The model is then operationalized through four illustrative case studies, each highlighting a distinct pathway through which human capital interventions enhance entrepreneurial impact. By exploring these pathways, the chapter provides insights into how entrepreneurship can be leveraged for human capital development and poverty reduction in Africa.

Literature Review

Understanding Poverty in Africa: A Multidimensional Perspective

Poverty in Africa is multidimensional, involving income, health, education, and living standards (Alkire & Santos, 2014). The Multidimensional Poverty Index (MPI) highlights deprivations in health, education, and living standards (OPHI, 2020). Addressing poverty requires interventions in multiple areas like education, health, and economic opportunities (UNDP, 2019).

Entrepreneurship and Economic Development

Entrepreneurship is widely recognized as a driver of economic growth and development (Schumpeter, 1934; Audretsch & Keilbach, 2004). Entrepreneurs contribute to economic development by creating jobs, fostering innovation, and improving productivity (Acs & Audretsch, 2003). In Africa, entrepreneurship is seen as a pathway to economic diversification and poverty reduction (Nwankwo & Gbadamosi, 2013). The entrepreneurial

process involves identifying opportunities, mobilizing resources, and creating value (Shane & Venkataraman, 2000). In Africa, entrepreneurs often operate in challenging environments with limited access to finance, infrastructure, and markets (George et al., 2016). Entrepreneurship can drive structural transformation in African economies by promoting diversification and industrialization (UNECA, 2017). For example, Kenya's tech sector has grown rapidly, creating jobs and driving innovation (Hafkin, 2017). However, entrepreneurship in Africa faces challenges like limited access to finance, corruption, and inadequate infrastructure (World Bank, 2020). Entrepreneurship's impact on economic development is influenced by institutional factors like regulatory frameworks and governance (Acs et al., 2018). In Africa, improving institutions can enhance entrepreneurship's contribution to economic growth (Fosu, 2013).

Human Capital Development and Poverty Reduction

Human capital development is critical for economic growth and poverty reduction (Becker, 1964; Schultz, 1961). Investments in education, skills, and health enhance individuals' productivity and economic prospects (Psacharopoulos & Patrinos, 2004). In Africa, human capital development is linked to improved economic outcomes and poverty reduction (Sachs, 2005). Human capital development enables individuals to participate in more productive economic activities, increasing incomes and reducing poverty (World Bank, 2018). Education and skills training are key components of human capital development, enhancing employability and entrepreneurial capabilities (Hanushek & Woessmann, 2012). In Africa, challenges like limited access to quality education and healthcare hinder human capital development (UNDP, 2019). Addressing these challenges can enhance poverty reduction outcomes.

Entrepreneurship and Human Capital Development

Entrepreneurship enhances human capital development through skills acquisition, education, and experience (Unger et al., 2011). Entrepreneurs invest in human capital to improve business performance and competitiveness (Marvel & Lumpkin, 2007). In Africa, entrepreneurship contributes to human capital development through informal training and skills transfer (King & McCreery, 2013). Entrepreneurship provides opportunities for experiential learning and skills development, particularly in contexts with limited formal education (Glaub et al., 2014). Entrepreneurs in Africa often rely on networks and informal learning to develop skills (Nwankwo & Gbadamosi, 2013).

Pathways to Poverty Reduction

Entrepreneurship reduces poverty through job creation, income generation, and economic growth (Nwankwo & Gbadamosi, 2013). Human capital development enables individuals to engage in more productive entrepreneurial activities, enhancing poverty outcomes (Sachs, 2005). Entrepreneurship can address poverty through inclusive business models targeting low-income populations (Prahalad, 2005). In Africa, entrepreneurship has potential to reduce poverty in rural and marginalized areas (Fafchamps & Shilpi, 2009).

Contextual Factors in Africa

Africa's entrepreneurial context is shaped by institutional, cultural, and economic factors (George et al., 2016). Informal entrepreneurship is prevalent, and access to finance, education, and markets affects entrepreneurial outcomes (Nwankwo & Gbadamosi, 2013).

Theoretical Foundations: Entrepreneurship, Human Capital Development, and Poverty Reduction in Africa

The theoretical foundations for this topic draw on several frameworks:

i. **Human Capital Theory (Becker, 1964; Schultz, 1961):** Human Capital Theory posits that investments in education, skills, and health enhance individuals' productivity and economic outcomes. Becker (1964) emphasizes education and training as key investments in human capital. Schultz (1961) highlights the role of human capital in economic growth. In Africa, human capital development is critical for entrepreneurship and poverty reduction. Educated and skilled individuals are more likely to engage in entrepreneurial activities, innovate, and contribute to economic growth. Human capital also enhances adaptability to changing economic conditions. Policymakers should prioritize investments in education and skills training to foster entrepreneurship and reduce poverty.

ii. **Entrepreneurship Theory (Schumpeter, 1934; Kirzner, 1973):** Entrepreneurship Theory, led by Schumpeter (1934) and Kirzner (1973), emphasizes entrepreneurs' role in driving innovation, creating jobs, and contributing to economic growth. Schumpeter's "creative destruction" highlights entrepreneurs' role in innovating and disrupting existing economic structures. Kirzner's focus is on entrepreneurs identifying opportunities. In Africa, entrepreneurship can reduce poverty through job creation and income generation. Entrepreneurs address market gaps, provide services, and drive structural transformation. Supportive ecosystems can enhance entrepreneurship's impact on poverty reduction.

iii. **Institutional Theory (North, 1990; Acemoglu & Robinson, 2012):** Institutional Theory emphasizes institutions' role in shaping economic outcomes and entrepreneurship. North (1990) highlights institutions' impact on economic performance. Acemoglu & Robinson (2012) link institutions to prosperity and poverty. In Africa, institutional constraints like regulatory barriers, corruption, and weak property rights affect entrepreneurship and human capital development. Improving institutions can enhance entrepreneurship's contribution to poverty reduction. Policymakers should focus on institutional reforms to support entrepreneurship.

iv. **Poverty as Multidimensional Deprivation (Sen, 1999; Alkire & Santos, 2014):** Poverty involves multiple deprivations (income, health, education) as emphasized by Sen (1999) and measured by Alkire & Santos (2014) via the Multidimensional Poverty Index. Addressing poverty requires interventions in multiple areas like education, health, and economic opportunities. In Africa, multidimensional poverty requires holistic approaches combining human capital development and entrepreneurship. Policymakers should address multiple dimensions to reduce poverty effectively.

v. **Resource-Based View (Barney, 1991):** The Resource-Based View (RBV) emphasizes firms leveraging resources for competitive advantage (Barney, 1991). Entrepreneurs in Africa can leverage human capital (skills, knowledge) for business success. RBV highlights strategic resource use for entrepreneurship success. Human capital is a key resource for entrepreneurs to innovate and compete. Policymakers should support building entrepreneurial resources.

Key Theoretical Linkages

i. Entrepreneurship → Human Capital Development: Entrepreneurship enhances skills and knowledge.
ii. Human Capital → Entrepreneurship: Human capital enables entrepreneurial success.
iii. -Entrepreneurship & Human Capital → Poverty Reduction: Both contribute to income generation and economic growth.

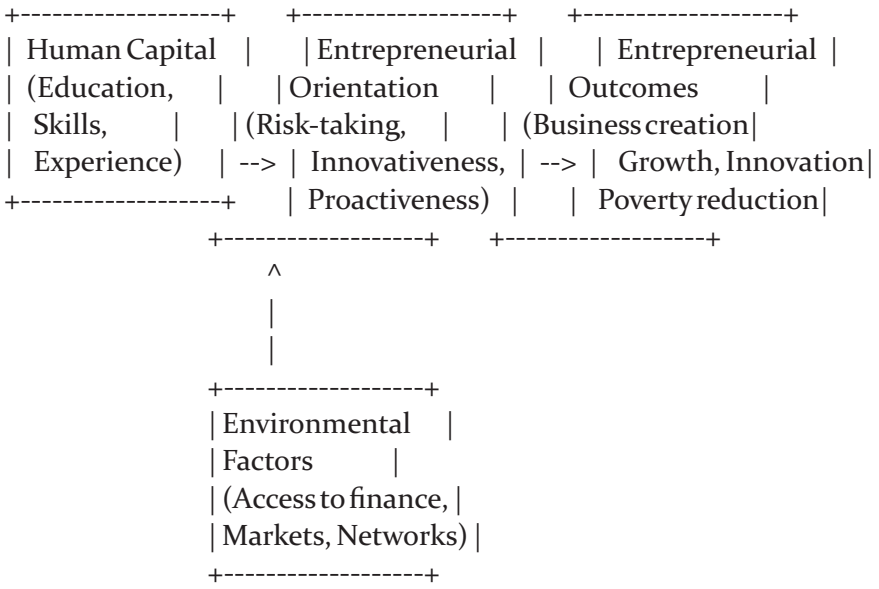
The Entrepreneurial Human Capital (EHC) Model

The Entrepreneurial Human Capital (EHC) Model integrates human capital theory with entrepreneurship to explain how entrepreneurs leverage their skills, knowledge, and abilities to create and grow businesses. The EHC model emphasizes the role of human capital in entrepreneurial success, highlighting the interplay between individual characteristics, skills, and environmental factors.

Components of the EHC Model

i. Human Capital: Education, skills, experience, and knowledge that entrepreneurs possess. Human capital is a critical resource for entrepreneurs, enabling them to identify opportunities, mobilize resources, and create value.
ii. Entrepreneurial Orientation: Risk-taking, innovativeness, proactiveness, and competitive aggressiveness. Entrepreneurial orientation influences how entrepreneurs leverage human capital to achieve business goals.
iii. Environmental Factors: Access to finance, markets, networks, and institutional support. Environmental factors shape opportunities and constraints for entrepreneurs.
iv. Entrepreneurial Outcomes: Business creation, growth, innovation, and poverty reduction. The EHC model suggests that entrepreneurs with strong human capital and orientation, operating in supportive environments, are more likely to achieve positive outcomes.

Diagrammatic Overview of the EHC Model



Explanation and Application

i. **Human Capital:** Provides the foundation for entrepreneurial success. Entrepreneurs with strong human capital are better equipped to identify opportunities and manage resources.
ii. **Entrepreneurial Orientation:** Influences how entrepreneurs leverage human capital. For example, entrepreneurs with high innovativeness are more likely to create new products or services.
iii. **Environmental Factors:** Shape opportunities and constraints. Access to finance, for instance, can enable or hinder business growth.
iv. **Entrepreneurial Outcomes:** Result from the interplay of human capital, orientation, and environment. The EHC model can guide policymakers in designing interventions that support entrepreneurship and poverty reduction in Africa.

Implications for Africa

In Africa, the EHC model highlights the importance of investing in human capital development (education, skills training) and creating supportive environments for entrepreneurship. By enhancing human capital and addressing environmental constraints, African entrepreneurs can contribute more effectively to economic growth and poverty reduction. Empirical evidence shows that human capital has a positive impact on entrepreneurship outcomes in Africa, particularly in countries like South Africa, Malawi, Kenya, and Nigeria.

Key Findings:

i. **Human Capital and Economic Growth:** Studies have found that investing in education and health significantly contributes to economic growth in Africa. For instance, a study on 48 African countries from 2000 to 2019 revealed that human capital development has a positive impact on economic growth.
ii. **Education and Skills:** Research in Nigeria shows that human capital, including education and skills, positively impacts organizational performance through training, competence, experience, and innovation initiatives.
iii. **Health Interventions:** Health investments have been shown to stimulate productivity growth in Africa, with a threshold of 45.07% human capital development.
iv. **Innovation and Entrepreneurship:** Innovations, facilitated by human capital, drive productive entrepreneurship in African countries.

Country-Specific Insights

I. **South Africa**: Human capital development is crucial for entrepreneurship and economic growth, with a focus on upskilling the labor force.
ii. **Kenya**: Education reforms prioritize STEM, digital literacy, and entrepreneurship, with a 51.81% increase in TVET enrolment.
iii. **Nigeria**: Human capital and entrepreneurial leadership style significantly predict organizational performance.
iv. **Malawi**: Limited data, but regional insights suggest investing in education and health can enhance human capital.

Policy Implications

I. Invest in education and skills training to enhance human capital.
ii. Foster entrepreneurial ecosystems that support innovation and productivity.
iii. Address infrastructure and institutional constraints to facilitate entrepreneurship.

These findings highlight the importance of human capital in driving entrepreneurship outcomes in Africa.

Nigeria's Tech Startup Incubators have been instrumental in fostering innovation and entrepreneurship in the country. Let's dive into some key players and their impact.

Background

Tech incubators like Co-Creation Hub (CcHUB), Passion Incubator, and the Tony Elumelu Foundation have become cornerstones of Nigeria's startup ecosystem. These hubs provide resources, mentorship, and funding to help startups grow.

Human Capital Components

i. **Mentorship:** Experienced professionals guide startups in areas like business strategy, marketing, and product development.
ii. **Training and Workshops:** Incubators offer training programs to equip entrepreneurs with necessary skills.
iii. **Networking Opportunities:** Startups connect with investors, partners, and peers through events and co-working spaces.

Impact

i. **Job Creation:** Incubators have supported hundreds of startups, creating thousands of jobs.
ii. **Innovation:** Startups like Paystack and Flutterwave have achieved global recognition.
iii. **Economic Growth:** Incubators contribute to Nigeria's economic diversification and growth.

Some notable incubators include:

i. **Co-Creation Hub (CcHUB):** Supports over 100 startups, creating 450+ jobs.
ii. **Start Innovation Hub:** Empowers tech talents and startups through expert guidance and resources.
iii. **Tony Elumelu Foundation:** Offers $5,000 seed capital, training, and mentorship to entrepreneurs.

These incubators have transformed Nigeria's tech landscape, driving innovation and entrepreneurship.

Ghana's Skill Bridge Apprenticeship Scheme, also known as the National Apprenticeship Program (NAP), is a government initiative aimed at bridging the skills gap and enhancing youth employability. Here's an overview:

Background
The NAP was launched to address Ghana's youth unemployment challenge, with a focus on providing practical, job-ready skills. The program is part of the government's broader education reforms, designed to bridge the gap between traditional education and the practical skills demanded by the economy.

Human Capital Components

i. **Technical and Vocational Training:** The program offers free, high-quality technical and vocational training in priority industries like agriculture, manufacturing, construction, fashion, renewable energy, ICT, and traditional crafts.
ii. **Mentorship and Practical Experience:** Apprentices receive mentorship and hands-on practical training under experienced master craftspersons and qualified instructors.
iii. **Entrepreneurial Skills:** The program emphasizes entrepreneurial mindset development, encouraging apprentices to start their own businesses.

Impact

i. **Job Creation:** The NAP aims to train 100,000 apprentices by 2026, with a focus on creating employment opportunities.
ii. **Skills Development:** The program addresses the skills gap, enhancing employability and income levels among beneficiaries.
iii. **Inclusive Approach:** The NAP prioritizes social inclusion, with at least 40% of beneficiaries being women and 5% persons with disabilities.

The NAP is a critical step towards Ghana's economic transformation, providing young people with practical skills to drive innovation and growth.

Ethiopia's Agri-Innovate Farmer Enterprise Project is part of the country's broader efforts to modernize its agricultural sector. Here's an overview:

Background
The project aims to enhance agricultural productivity, improve market access, and increase incomes for smallholder farmers in Ethiopia.

Human Capital Components

i. **Training and Capacity Building:** Farmers receive training on modern farming practices, business management, and market linkages.
ii. **Access to Finance:** The project provides financial support to farmers, enabling them to invest in improved inputs and technologies.
iii. **Market Linkages:** Farmers are connected to markets, improving their bargaining power and income.

Impact

i. **Increased Productivity:** Adoption of modern farming practices has led to increased crop yields.
ii. **Improved Income:** Farmers have seen improved incomes due to better market access and higher productivity.

iii. **Job Creation:** The project has created employment opportunities in agriculture and related sectors.

Key Initiatives

i. **Agro-Industrial Parks:** Development of parks to process raw agricultural products, create jobs, and boost exports.
ii. **Digital Tools and Smart Farming:** Adoption of satellite solutions, AI-powered advisory, and resource management technology.
iii. **Climate Resilience Strategies:** Initiatives to support adaptation to climate change through sustainable land use and resource management.

These initiatives are transforming Ethiopia's agricultural sector, improving livelihoods and contributing to economic growth.

Strategies for Integrating Entrepreneurship and Human Capital Development

Integrating entrepreneurship and human capital development is crucial for driving economic growth, innovation, and poverty reduction in Africa. Effective integration requires a multifaceted approach, focusing on education, access to resources, mentorship, policy support, and innovation.

Education and Skills Training

Education and skills training are foundational for equipping individuals with the capabilities needed for entrepreneurship.

i. **Entrepreneurship Education:** Incorporating entrepreneurship into school curricula can equip students with business skills, mindset, and confidence to start ventures. For example, universities in South Africa and Kenya have introduced entrepreneurship courses and programs.
ii. **Vocational Training:** Providing practical skills training aligned with market needs enhances employability and entrepreneurial capabilities. Countries like Ghana and Rwanda have implemented vocational training programs focusing on sectors like agriculture, manufacturing, and ICT.
iii. **Digital Literacy:** Promoting digital skills is essential for entrepreneurship in today's technology-driven economy. Initiatives like coding bootcamps and digital skills training in Nigeria and Kenya have empowered youth with digital capabilities.

Access to Finance and Resources

Access to finance and resources is critical for entrepreneurs to start and grow businesses.

i. **Funding Opportunities:** Creating access to finance through grants, low-interest loans, or equity investments can support startups. Initiatives like the African Development Bank's Africa50 fund and Nigeria's Entrepreneurship Development Fund provide financial support to entrepreneurs.
ii. **Resource Sharing:** Establishing shared resources like co-working spaces, labs, and equipment can reduce costs for entrepreneurs. Spaces like iHUB in Kenya and Co-Creation Hub in Nigeria offer resources and support to startups.
iii. **Technology Access:** Providing access to technologies like digital tools and platforms can enhance business operations and reach.

Mentorship and Networking

Mentorship and networking are vital for entrepreneurial success.

i. **Mentorship Programs:** Connecting entrepreneurs with experienced mentors can provide guidance, insights, and support. Programs like the Tony Elumelu Foundation's mentorship initiative in Nigeria pair entrepreneurs with seasoned mentors.
ii. **Networking Events:** Facilitating connections with investors, partners, and peers through events and conferences can create opportunities for collaboration and growth. Events like the Africa Tech Summit and Lagos Digital Summit bring together entrepreneurs and stakeholders.
iii. **Peer Learning:** Encouraging peer learning among entrepreneurs' fosters sharing of experiences and best practices.

Policy Support

Supportive policies are essential for fostering entrepreneurship and human capital development.

i. **Supportive Policies:** Advocating for policies supporting entrepreneurship, innovation, and skills development creates an enabling environment. Governments like Rwanda and Kenya have implemented policies to promote entrepreneurship and tech development.
ii. **Regulatory Simplification:** Simplifying business registration, compliance, and tax processes reduces barriers to entrepreneurship. Countries like South Africa and Mauritius have streamlined business processes.
iii. **Incentives:** Offering incentives like tax breaks or grants for startups and entrepreneurs can encourage venture creation and growth.

Innovation and Technology Adoption

Innovation and technology adoption drive business growth and competitiveness.

I. **Innovation Support:** Supporting innovation through incubators, accelerators, and innovation hubs fosters tech entrepreneurship. Hubs like Bongo Hive in Zambia and M-Labs in Kenya support innovation.
ii. **Tech Adoption:** Encouraging adoption of technologies enhancing productivity and competitiveness helps businesses grow. Digital tools for marketing, finance, and operations can boost entrepreneurial success.
iii. **Research and Development:** Promoting R&D in universities and industries can drive innovation and entrepreneurship.

Implementation Considerations

i. **Contextual Adaptation:** Strategies should be tailored to local contexts, challenges, and opportunities.
ii. **Stakeholder Engagement:** Engaging stakeholders like governments, private sector, and civil society ensures buy-in and effective implementation.
iii. **Monitoring and Evaluation:** Regularly assessing impact and adjusting strategies enhances effectiveness.

These strategies can enhance entrepreneurship's contribution to human capital development and poverty reduction in Africa.

Policy Recommendations

To enhance entrepreneurship's contribution to human capital development and poverty reduction in Africa, policymakers can consider the following strategies:

Enhance Entrepreneurship Education

i. Integrate entrepreneurship into school curricula at all levels, emphasizing practical skills and mindset.
ii. Promote vocational training aligned with market needs in sectors like tech, agriculture, and manufacturing.
iii. Example: Countries like South Africa and Kenya have introduced entrepreneurship courses in universities.

2. Improve Access to Finance

i. Establish funds or partnerships providing accessible finance for startups and entrepreneurs.
ii. Encourage financial inclusion, targeting women and youth entrepreneurs.
iii. Example: Initiatives like the African Development Bank's Africa50 fund support infrastructure and entrepreneurship projects.

3. Strengthen Entrepreneurial Ecosystems

i. Support development of innovation hubs, incubators, and accelerators.
ii. Foster partnerships between universities, industries, and entrepreneurs to drive innovation.
iii. Example: Hubs like iHUB (Kenya) and Co-Creation Hub (Nigeria) support tech startups.

4. Promote Digital Skills and Innovation

i. Invest in digital literacy programs targeting youth and entrepreneurs.
ii. Support tech innovation and adoption of digital tools in businesses.
iii. Example: Coding bootcamps in Nigeria and Kenya empower youth with digital skills.

5. Address Regulatory Barriers

i. Simplify business registration and compliance processes.
ii. Consider incentives like tax breaks for startups and entrepreneurs.
iii. Example: Countries like Rwanda and Mauritius have streamlined business processes.

6. Foster Mentorship and Networking

i. Support mentorship programs connecting entrepreneurs with experienced professionals.
ii. Organize networking events for entrepreneurs, investors, and partners.
iii. Example: The Tony Elumelu Foundation's mentorship initiative in Nigeria.

7. Implementation Considerations

i. Tailor policies to local contexts and challenges.
ii. Engage stakeholders like private sector, academia, and civil society.

iii. Monitor and evaluate policy impact to adjust strategies.

These policy recommendations can enhance entrepreneurship's role in human capital development and poverty reduction in Africa.

Future Research Directions

Further research can enhance understanding and strategies for leveraging entrepreneurship for human capital development and poverty reduction in Africa.

1. **Impact of Digital Technologies**
   i. Investigate how digital tools and platforms shape entrepreneurship, skills development, and job creation.
   ii. Explore barriers to digital adoption among entrepreneurs in different sectors.

2. **Entrepreneurship Education Effectiveness**
   i. Assess impacts of entrepreneurship education on entrepreneurial outcomes like venture creation and growth.
   ii. Identify best practices for integrating entrepreneurship into curricula.

3. **Access to Finance and Entrepreneurship**
   i. Study effects of different financing models (e.g., microfinance, venture capital) on entrepreneurship.
   ii. Identify strategies improving financial inclusion for entrepreneurs, especially women and youth.

4. **Human Capital and Entrepreneurial Success**
   i. Examine relationships between specific skills (e.g., digital, managerial) and entrepreneurial performance.
   ii. Explore how human capital investments influence innovation and business growth.

5. **Policy Effectiveness**
   I. Evaluate impacts of entrepreneurship support policies on outcomes like job creation and poverty reduction.
   ii. Identify policy designs most effective in different contexts.

6. **Contextual Factors**
   i. Investigate how cultural, institutional, and economic factors shape entrepreneurship.
   ii. Explore strategies for tailoring interventions to local contexts.

7. **Sustainability and Entrepreneurship**
   i. Study links between entrepreneurship, environmental sustainability, and green jobs.
   ii. Explore opportunities for sustainable entrepreneurship in African contexts.

8. **Comparative Studies**
   i. Conduct cross-country comparisons of entrepreneurship ecosystems and policies.
   ii. Identify lessons from successful interventions applicable across Africa.

These directions can enhance understanding of entrepreneurship's role in human capital development and poverty reduction.

Conclusions

Entrepreneurship plays a pivotal role in human capital development and poverty reduction in Africa. By leveraging entrepreneurship, countries can drive economic growth, innovation, and job creation.

Key conclusions include:

1. **Human Capital is Crucial for Entrepreneurship**
   i. Investments in education, skills, and health enhance entrepreneurial capabilities and outcomes.
   ii. Context-specific approaches to human capital development are necessary.

2. Entrepreneurship Drives Economic Growth
   i. Entrepreneurship contributes to economic diversification, innovation, and job creation.
   ii. Supportive ecosystems, access to finance, and policies are vital for entrepreneurial success.

3. **Context Matters**
   i. Strategies should be tailored to local contexts, challenges, and opportunities.
   ii. Understanding cultural, institutional, and economic factors is key.

4. **Policy Support is Essential**
   I. Governments play a crucial role in creating enabling environments.
   ii. Policies should address access to finance, skills development, and regulatory barriers.

5. **Digital Technologies are Transformative**
   i. Digital tools and platforms enhance entrepreneurship and access to opportunities.
   ii. Digital literacy and inclusion are critical for leveraging benefits.

Implications

   i. Prioritize investments in human capital and entrepreneurship-supportive policies.
   ii. Foster collaboration among governments, private sector, and stakeholders.
   iii. Monitor and adapt strategies based on outcomes.

By focusing on these areas, Africa can harness entrepreneurship for human capital development and poverty reduction.

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Chapter 6

LEVERAGING DATA ANALYTICS TO REDUCE VULNERABILITIES IN NIGERIA'S SMEs

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Abstract
The harsh environment under which the small and medium scale Enterprises (SMEs) operate in Nigeria today has compounded their vulnerabilities and made the role of data analytics more significant for their survival and the sustainability. This study therefore examined the efficiency, challenges, opportunities and prospects of applying big data in SMEs operations in Nigeria. Data were gathered from 81 SMEs operators via questionnaire in line with data efficiency, challenges, opportunities and prospects of applying such data in their daily operations. Data collected were analyzed using descriptive statistics generated from SPSS output. Available evidence from the descriptive statistics indicates the efficiency of data application among SMEs; it also indicates that challenges and opportunities of using big data also affect their performance. The study therefore recommends the need for SMEs operating in Nigeria to focus on the integration of big data to boost their operational sustainability while mitigating possible dangers and vulnerability; train and retrain their staff in the art of data mining and structuring to align with the firms' goals, among others.

Keywords: *Leveraging, Data-Analytics, SMEs, Sustainability, Nigeria.*

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Introduction

The application of data in today's business environment has enabled so many businesses, notably the small and vulnerable ones to maintain sustained operations and overcome vulnerability. Businesses generally and small to medium size businesses in particular depend on data for the achievement of their objectives (Abideen and Mary, 2024), which links their successes to the level of information they have acquired, analyzed, and how well they are able to use the information to deliver quality product and services to the end users. Data analytics can inform better decision making and actions across all functions, from sales and marketing, human resource management and manufacturing, to finance and executive leadership, which encourages businesses to apply big data in cutting costs, maximizing profits, improving customer and employees' experiences, responding to market changes and outsmarting their competitors (Joey, 2023). Analytics therefore not only enable businesses' access to more data, but more different types of data which offer them greater advantage and opportunities while making decisions and developing strategies. This helps them better understood what has happened, what is likely to happen, and how they might best respond to and take advantage of it; what they can do to boost revenue, increase efficiency and productivity, improve employees' experience and meet customers' needs (Pratibha, 2023). Consequently, data analytics aid businesses, particularly small businesses to overcome vulnerability situations.

The harsh environment under which the small and medium scale Enterprises (SMEs) and other businesses operate in Nigeria today has compounded their vulnerability and made the role of data analytics more significant for their survival and the sustainability. Therefore, data analytics in SMEs is an innovative approach to reduce their vulnerability that guarantees their operational sustainability and as well, contribute significantly to the fight against poverty and unemployment in the economy. As the most populous country in Africa, with a diverse SMEs base, Nigeria has a lot to gain from a well-organized and structured data system (Abu et al, 2020). Data analytics can provide information about market opportunities and trends, better risk management approaches and performance evaluation which enable SMEs to take decisions that enhance their sustainability and reduce their vulnerability. Therefore, analytics can be capitalized on by SMEs in Nigeria for inform decision making and actions across all functions, from sales and marketing, human resources and manufacturing to finance and leadership, which encourages businesses in cutting costs, maximizing profits, improving customers' and employees' experiences, responding to market changes (Joey, 2023), that will help enhance their resilience and sustainability.

Given the harsh environment and vulnerability under which SMEs have operated in Nigeria, it has become imperative that data has to be employed in their daily operations. The use of data in running a business is not devoid of set-backs, particularly in small businesses, so are there also opportunities and prospects (Seyedan and Mafakheri, 2020; Emmanuel and Odum, 2019). In addition to the challenges and opportunities that are associated to the use of data by SMEs, impacts are also generated on their operations, which in turn influence their sustainability, resilience and vulnerability. This study therefore intends to investigate not just the impact of data application on these businesses, but would also examine the challenges, opportunities and prospects of applying such data to overcome vulnerability issues around them.

In line with above the study research questions are itemized as follows:

i. Can data analytics be used to improve the efficiency of the operational process of SMEs in Nigeria to curb vulnerability issues around them?
ii. Are the challenges associated with data analytics affecting the ease of using big data among SMEs in Nigeria?
iii. Can the opportunities of using data analytics in a firm increase the possibilities of growing potential revenue for SMEs in Nigeria?
iv. What are the best possible ways to implement data analytics in a firm for the most efficient uses and integration into the business objectives of SMEs in Nigeria to improve their resilience?

Conceptual Issues

The Concept of Data Analytics

Data analytics is the process of transforming data into insights to improve business decisions (Wake Forest University, 2023). However, the popular definition from Michael and Alan (2009), refers to data analytics as the skills, technologies, and practices for continuous iterative exploration and investigation of past business performance to gain insight and drive business planning. Taking this definition into consideration and relating it to the present practices, the only things that might have been added are, one, the real-time analysis available on leading analytical technologies which of course include the application of software and secondly, the predictive analytics that is a standard feature in present-day analytics software. (UNext Team, 2020). As mentioned by Kunduru and Kandepu (2023), data analytics is stated as the practice of utilizing records analysis tools and methods to extract insights and make informed selections in commercial enterprise operations. It involves accumulating, processing, and decoding information to become aware of trends, styles, and correlations that may force strategic planning, useful resource allocation, and overall performance development. By leveraging statistical analysis, information mining, predictive modelling, and visualization, data analytics allows corporations to optimize methods, mitigate dangers, and identify possibilities for the boom. It empowers stakeholders to make statistics-driven choices, enhance operational efficiency, and advantage a competitive aspect in the market. Therefore, data analytics is applicable to enable business and public entities to make effective decisions that result in productive outcomes (Yiu, Yeung and Jong, 2020; Kumar, Krishna and Aithal, 2022). The cornerstone of data analytics is pure analytics, as analytics can be considered as any data driven process that provides insight; it may report on historical information (O'Reailly, 2023). Further, Kumar, Krishna and Aithal (2022), are of the opinion that data analytics also help organizations to create a clear picture of what's working and what is not in order to improve performance in addition to facilitating faster, more-informed decision-making and respond more quickly to events and better mitigate risks among others.

There four major types of data analytics according to Daniel et al (2018) and Pratibha (2023) are:

i. Descriptive analytics: this helps organisatons track patterns and trends in current and past data. Example are key performance indicators (KPIs) and metrics.
ii. Diagnostic analytics: this is a more advanced form of analytics which examines why things happened

iii. Predictive analytics: as the name suggests, predictive analytics focuses on predicting what is likely to happen in the future.
iv. Prescriptive analytics: this aims to answer the question of what should be done or how an organization can achieve a certain outcome. It can require very sophisticated data science techniques.

Organisations are capable of combining different types of analytics to provide a more complete view of business performance and to solve problems. For instance, an organization might use descriptive analytics to look at what customers have done, diagnostic analytics to understand why, predictive analytics to forecast what they might do or want next and prescriptive analytics to determine the best way to meet their needs (Daniel et al, 2018).

Role of Artificial Intelligence

Artificial intelligence is said to be a set of technologies that enables SMEs to better understand markets and customers, analyze and learn from digital journeys, and engage in a way that mimics human intelligence and interactions at scale (Mariya, 2023). Artificial (AI) intelligence therefore helps drive insights for data analytics, performance measurement, predictions and forecasting, real-time calculations, customer servicing, intelligent data retrieval, and more. Mao et al (2022) and Hewlett (2023), are of the view that Artificial Intelligence is a powerful tool that is already widely deployed in so many organisations had discovered its great potentials for positive impact having been deployed with sufficient diligence, prudence, and care. Li and Zhang (2021), further opined that the application of AI stands to enhance efficiency and productivity of SMEs through automation, reduce human biases and errors caused by psychological or emotional factors.

However, the university of San Diego (2022) and Jin (2019), called for caution in the application of AI as it could go a long way to revolutionized global method of business operations. Despite the challenges indicated above, AI can aid SMEs in so many ways according to the University of San Diego (2022), Mao et al (2023), Mariya (2023) and Li and Zhang (2021). Some of these areas include:

i. **Automation:** AI can help automate workflows and processes, work autonomously and responsibly, and empower decision making and service delivery.
ii. **Accuracy:** AI can help business organizations control manual errors in data processing, analytics, document processing and onboarding, customer interactions, and other tasks through automation and algorithms that follow the same processes every single time.
iii. **Availability:** With AI, you can help your customers find solutions to meet their goals, and manage and control their needs whenever and where they are.
iv. **Efficiency**: When AI is used to perform repetitive tasks, people are free to focus on more strategic activities. AI can be used to automate processes like verifying or summarizing documents, transcribing phone calls, or answering customer questions like "what time do you close?" AI bots are often used to perform routine or low-touch tasks in the place of a human.
v. **Innovation:** The ability to analyze vast amounts of data quickly can lead to unique and innovative product and service offerings that leapfrog the competition. For instance, AI has been used in predictive analytics to modernize insurance customer experiences without losing the human touch.

Small and Medium Scale Enterprises (SMEs)

SMEs had been conceptualized in many ways using different parameters. One way of defining SMEs followed the statistical route in conceptualization. However, the most common to all definition, according to Hallberg (2000) is that SMEs are identified in line with the number of employees they have. Uchikawa (2019) in his study in the area of new Small and Medium Enterprises law in Japan, refers to SMEs in line with number of employees, the industry the business belongs to as well as the capital size of the company. By capital size, and following the conceptualization of Uchikawa (2019), a firm is referred to as SME if the capital size is valued at less than one hundred million (100,000,000) yen, with employees' size of less than 100 individuals. This is peculiar to the wholesale industry. In the service and retail sector, a company is referred to as SME when the capital size is less than fifty million (50,000,000) yen, and has an employee size of less than 50 individuals. While in the manufacturing sector, the number of employees is expected to be less than 300 employees, with capital size of three hundred million (300,000,000) yen (Uchikawa, 2019). All these are peculiar to Japan. Further conceptualization of SMEs was also given by Fasua (2006) in another dimension. According to Fasua (2006), there are businesses that by nature, are classified into the small and medium enterprises, regardless of the number of employees, capital size and they are not necessarily classified into any industry. This business includes and not limited to the following; food processing and packaging in no mass amount, meat retailing, production of plantain, provision of restaurant services, farm produce in terms of live stocks, school set up for nursery purposes, event planning, production of soap, fishing, among others Fasua (2006). This classification was done following the observation of the trend in Nigeria. Therefore, the classification is peculiar to Nigeria as a country.

Small and medium-sized businesses (SMEs) are critical for building competitive marketplaces and reducing poverty, especially in developing nations (Ramukumba, 2014). They help to relieve poverty by assisting in the creation of jobs (Campbell and Park, 2017). According to the Nigerian Bureau of Statistics (2021), SMEs account for around 48 percent of the country's Gross Domestic Product (GDP), 96 percent of existing enterprises, and 84 percent of employed people. Despite backing from the government and the banking industry in Nigeria, despite SMEs being the largest sector of the economy, their growth and contribution to the economy remain disproportional (Nigerian Bureau of Statistics, 2021). The European Commission (2020) restricts its definition of SMEs to employment rather than multiplicity of criteria and restricted to enterprise, which employ less than 500 workers. This definition is considered too all-embracing for a number of countries. This paper adopts the definitions for small firms which are more appropriate to their particular target group that is, operational definition. Consequently, definitions vary across environment as a result of differences in industrial organization at different levels of economic development and differences in economic development in parts of the same country (Sule, 2016). For instance, a firm that can be categorized as small scale in an advanced economy like the United State of America, given the high level of capital intensity may be classified as medium or even large in a developing economy like Nigeria. Definitions also change over time, owing to changes in price levels, advances in. technology, etc. Even in the same country, definition may vary within institutions depending on their policy focus. For instance, prior to 1992 in Nigeria, different institutions like the Central Bank of Nigeria, Nigerian Bank of Commerce and Industry, Centre for Industrial Research and Development and the National Economic

Reconstruction Fund adopted different definitions to achieve the objectives of the programme they want to execute. The criteria that have been used in the definitions include annual turn-over, gross, output, capital investment and employment (Amuchie, Asotibe and Ikpa, 2015).

Theoretical Framework

The theoretical base of the study is anchored on the CRISP-DM model. The Cross-Industry-Standard-Process model for Data Mining (CRISP-DM) (Puffers et al, 2012). The benefits of using the CRISP- DM are reduced cost and time, and minimized knowledge requirements for data mining projects. Moreover, expediting training, knowledge transfer, documentation, and capturing best practices are also the benefits of using CRISP-DM (Chapman et al. 1999). More important, particularly for researchers and practitioners, data mining can be used in innovation endeavors, boost organizational performance and promote employees and customers' confidence (Hubber, et al, 2019). Hence, CRISP-DM is useful in reducing cost and time, facilitate knowledge transfer, reuse of best practices, and minimize knowledge requirements, and on a general note, boost organizational performance and innovative activities. However, distance-based algorithms, which is used to measure the similarity between problem query and solutions from textual datasets, are not the only available solutions to idea mining. For example, deep learning, Information Retrieval (IR), topic modeling, bibliometric, social network analysis, association rule mining, and collaborative filtering algorithms could also be used for idea mining purposes (Small et al, 2014). Therefore, social and network theory (e.g., social network analysis), bibliometric, statistical methods, and IR to generate useful and new ideas from unstructured or semi-structured textual data that match the organizational goals (Workneh, 2020).

Methodology

In this study quantitative research methods were adopted. Therefore, primary data were obtained from operators of SMEs using a structured questionnaire administered through on-line survey that gave 81 responses. The data generated for the study were analysed quantitatively by utilizing SPSS as the primary device for data analysis. This decision was grounded in the structured nature of the survey data and the research's objective to quantify relationships between variables using descriptive statistics.

Results and Discussion

Analysis of Research Questions using Descriptive Statistics

The descriptive statistics for the survey which were extracted from SPSS Output offer insight into their perceptions with regard to effectiveness, opportunities and challenges of applying data analytics among SMEs in Nigeria.

Research Question One: Can data analytics be used to improve the efficiency of SMEs operations to curb their vulnerability in Nigeria.

Table 1: SPSS Output on Data efficiency on SMEs Operations

QUESTION	MEAN	SD	COMMENT
Q5	4.259	0.972	MEAN > 3.0
Q6	4.321	0.788	MEAN > 3.0
Q7	4.333	0.806	MEAN > 3.0
Q8	4.494	0.793	MEAN > 3.0
Q9	3.617	1.056	MEAN > 3.0
Q10	4.012	0.814	MEAN > 3.0
Q11	4.358	0.899	MEAN > 3.0
TOTAL AVERAGE	**4.199**	**0.875**	**MEAN > 3.0**

Source: SPSS Output

Data from table one above shows a total average mean value of 4.199 that is greater than the overall middle mean value of 3.0. Additionally, each of the mean value of the individual questions are greater than the dichotomous value of 3.0 in the linkert scale of 1,2,3,4 and 5. This implies that data analytics can be used to improve the efficiency of SMEs operations to curb their vulnerability in Nigeria.

Research Question Two: Are the challenges associated with data analytics affecting the increasing the ease of using big data among SMEs in Nigeria?

Table 2: SPSS Output on Challenges Associated with the use of Big Data by SMEs in Nigeria.

QUESTION NUMBER	MEAN	SD	COMMENT
Q12	3.642	0.966	MEAN > 3.0
Q13	3.852	0.896	MEAN > 3.0
Q14	3.580	0.947	MEAN > 3.0
Q15	3.889	0.791	MEAN > 3.0
Q16	3.444	1.049	MEAN > 3.0
Q17	3.901	0.784	MEAN > 3.0
TOTAL AVERAGE	**3.718**	**0.905**	**MEAN > 3.0**

Source: SPSS Output

Table two shows that all the mean values are above the dichotomous value of 3.0 in the linkert scale of 1,2,3,4 and 5. Similarly, the total average value of 3.718 is greater than the middle value of 3.0. This implies that the challenges associated with the use of business analytics affect the ease of using big data among SMEs Nigeria.

Research Question Three: Can the opportunities of using data analytics in a firm increase the possibilities of growing the potential revenue for SMEs in Nigeria?

Table 3: SPSS Output on Opportunities of using Big Data and Growing Potential Revenue for SMEs in Nigeria.

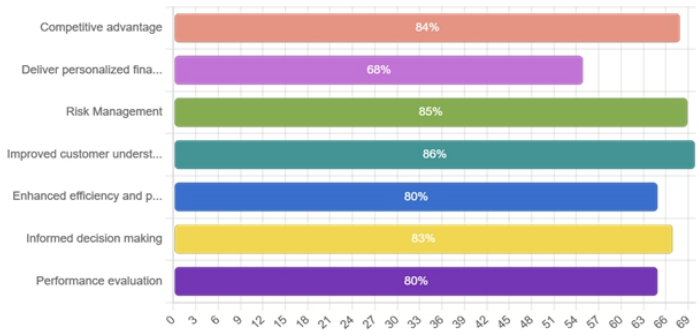
QUESTION NUMBER	MEAN	SD	COMMENT
Q18	4.222	0.725	MEAN > 3.0
Q19	4.395	0.753	MEAN > 3.0
Q20	4.333	0.725	MEAN > 3.0
Q21	4.420	0.820	MEAN > 3.0
Q22	3.914	0.778	MEAN > 3.0
Q23	4.506	0.673	MEAN > 3.0
TOTAL AVERAGE	**4.298**	**0.745**	**MEAN > 3.0**

Source: SPSS Output

Table three above shows data generated on research question three indicating that all the mean values are above the dichotomous value of 3.0 in the linkert scale of 1,2,3,4 and 5, showing a total average value of 4.298, which is also greater than the average mean value of 3.0. This shows that the opportunities of applying data analytics among SMEs in Nigeria increases the possibilities of growing the potential revenue of the businesses.

Analysis of Research Question Four using Participants Responses: What are the best possible ways to implement data analytics in a firm for the most efficient uses and integration into the business objectives of SMEs in Nigeria?

Research question 4 is aimed to propose recommendations particularly in line with the participants responses to question number 25 of the administered questionnaire as shown by the chart below which highlights the best ways to implement Business Analytics for the most efficient uses and integration into the business objectives of the financial service sector in Nigeria.



The chart above highlights or rate among the various areas data analytics can impact SMEs' operations in Nigeria. The area it makes the most impact is the improvement of SMEs' ability to understand their customers as indicated by 86% of the participants. Risk management has the second rating as indicated by 85% of the respondents indicating that risk management is the second major area data analytics can influence the performance of SMEs in Nigeria. The third area data analytics can impact on SMEs operations is competitive advantage as indicated by 84% of the respondents, while the fourth area lies on SMEs informed decision making as indicated by 83% of the respondents. Performance evaluation and performance efficiency both took the fifth position of 80% each, while the delivery of personalized services and product took the last position with 68% according to the respondents.

Discussion of Findings

This study examines the effect, challenges, opportunities and prospect of deploying data analytics to checkmate the vulnerability of SMEs in Nigeria. Data were analyzed using descriptive statistics generated through SPSS output from data obtained from primary sources. The descriptive statistics show that the use of data impact positively on SMEs operations in Nigeria. Area's impact have been felt include streamlining business processes, evaluating future business decisions using market trends, and among others in line with the views of Amit and Bala (2020) in their study on data analytics adoption among firms in India. The descriptive statistics also show that the respondents unanimously accepted that challenges affect the ease of using big data by SMEs. Such challenges identified include difficulty in aligning analytics with business goals, inexperience in data application among employees, cost of acquiring big data, among others, which is in line with the identified organizational challenges of using big data by O'Reailly (2023) and Pallavi (2021) in their study on the impact of data analytics on organizational performance.

The results of the study also indicate that the respondents understood the opportunities of applying data analytics in business operations that can lead to increased revenue generation among SMEs. Such opportunities include innovation and risk mitigation, staying competitive in the changing business environment, making informed decision, identification of spot and potential markets, opportunity for benchmarking etc, in line with the research results of Ladi and Amaya (2024) and Kumar et al (2023), who view the application of data analytics in terms of the opportunities it stands to provide to enhance organizational performance and address its challenges. In order to determine the prospect and best possible ways to apply data analytics in a firm for the most efficient uses and integrate them with the business objectives of the SMEs, the respondents pick pointed areas relevant to their business objectives in order of priority. The most important area is the improvement of the firms' ability to understand their customers which is line with the views of Rahman et al (2022) who critically examine the role of artificial intelligence on customers' satisfaction in the banking sector.

This is closely followed by risk management as the second major area data analytics can influence organizational objective. This finding agrees with the study carried out by Mao et al (2022). The next area business analytics can impact on the objectives of SMEs is competitive advantage. This is in line with the findings of Chang et al (2019) and Kumar (2023) who stressed the need for SMEs to up their stake using data to face the challenges of the competitive environment in which the firms operate. In the same vein, Huber et al (2019), agreed as various organisations including SMEs have employed the use of data to promote their market share. The fourth area where business analytics can play a significant role in reducing the vulnerability of SMEs is better informed decision making. Kumar et al (2023) and Pallavi (2021), agreed in their studies that the use of big data by SMEs has gone a long way to enable informed decision to be taken by these organizations as part of measures to realize their strategic goals thereby improving their level of resilience. Performance evaluation, as well as performance efficiency took the next stage in line with what Jayant and Rachel (2019) consider in their study as relevant in SMEs growth prospect and realization of strategic goals. Given that data analytics can be deployed to impact positively on organizational goals in the aforementioned areas, it has become imperative for SMEs to employ the use of data in their

daily operations for effective and efficient service delivery as part of their strategic ways of increasing their resilience and reducing their level of vulnerability.

Conclusion

The study which dwelled on the effect, challenges, opportunities and prospects of using data analytics to promote SMEs operations in the Nigerian embodies a far-reaching examination in line with the questions raised in the study. The findings from the inquiry conducted on SMEs operators in Nigeria give basic bits of knowledge into how data analytics has influenced their performance. Therefore, the primary exploration questions asked gave some information about the huge positive impact of data analytics on SMEs operations in Nigeria, particularly with regard to the efficiency of data usage, opportunities provided and the prospect for further improvement. However, the study also exposed some of the challenges associated with using data in the sector with some recommendations made for improvement.

Recommendations

The following recommendations are made following the results of the study.

i. SMEs in Nigeria should emphasize on the integration of data analytics to boost their operational and competitive advantages while relieving possible dangers and vulnerability. This is achievable by cashing on the opportunities of using data, which further afford the SMEs the prospects of benchmarking performance, spot and future markets identification for its old and new products, among others.

ii. **Employees' Training:** the findings that the use of big data is linked with SMEs performance, it is suggested that SMEs execute persistent training programs focusing on mode of selecting relevant data from among unstructured data. The training will further focus on ways of matching the organizational goals with data usage. Training will guarantee that staff are capable at involving big data in business operation while checkmating expected challenges

iii. **Cost Management:** It is suggested for SMEs to engage professional experts who major in mining data and sorting not only to reduce the cost of time use in business operations, but also to guarantee that only qualitative data are mined and sorted to matched the costs implication.

iv. **Policy Makers:** While taking into consideration the outcome of the research to illuminate SMEs approaches to data mining and application, policy makers ought to team up with regulatory and professional bodies to make strategies that advance data analytics execution structure. This cooperative methodology, upheld by research findings like those from Ladi and Amiya (2024), would assist with guaranteeing that big data generated are effectively utilized by SMEs to advance their resilience while curbing their level of vulnerability.

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APPENDIX
QUETIONNAIRE
USING DATA ANALYTICS TO OVERCOME THE VULNERABILITY OF SMALL AND MEDIUM SIZE BUSINESSES IN NIGERIA: CHALLENGES, OPPORTUNITIES AND PROSPECTS

1. What is your age bracket?
   Under 25
   25 – 34
   35- 44
   45 – 54
   55 and above

2. Which sub-sector does your business belong?
   Financial services
   Transportation
   Manufacturing
   Agriculture
   Mining
   Tailoring
   Education
   Mechanical/automobile works
   Trading
   Other specify

3. What role do you play in your firm?
   Directorate
   Customer service
   Operational staff
   Administrative staff
   IT staff
   Executive/management
   Other specify

4. Years of experience in the financial service industry
   Less than one year
   1-5 years
   6-10 years
   11-20 years
   Above 20 years

Data analytics and efficiency of your business

5. The use of data analytics has helped optimize and streamline business processes
   Strongly disagree
   Disagree
   Undecided
   Agree
   Strongly agree

6. Data analytics has made it easier to evaluate future business decisions and performance based on past market trends
   Strongly disagree
   Disagree
   Undecided
   Agree
   Strongly agree

7. The use of analytics has enabled easy access to customers' information/profile for prompt service delivery
   Strongly disagree
   Disagree
   Undecided
   Agree
   Strongly agree

8. Data analytics has improved ICT usage in your organization.
   Strongly disagree
   Disagree
   Undecided
   Agree
   Strongly agree

9. Risk management and product innovation are no longer problems to your organization since the adoption of business analytics your operation
   Strongly disagree
   Disagree
   Undecided
   Agree
   Strongly agree

10. You have a better logistics management approach following the adoption of data analytics
   Strongly disagree
   Disagree
   Undecided
   Agree
   Strongly agree

11. Data analytics makes it easier to monitor and evaluate employees' performance.
   Strongly disagree
   Disagree
   Undecided
   Agree
   Strongly agree

The challenges of business analytics and the ease of using big data in financial services

12. Your organization experience challenges emanating from aligning analytics with business goals.
    Strongly disagree
    Disagree
    Undecided
    Agree
    Strongly agree

13. Some of your employees find it difficult to adjust and adopt to a new method of applying data in business management.
    Strongly disagree
    Disagree
    Undecided
    Agree
    Strongly agree

14. Cost management has been an issue since the adoption of business analytics in your organization.
    Strongly disagree
    Disagree
    Undecided
    Agree
    Strongly agree

15. Clean and accurate data are difficult to come by as there is always a problem of data proliferation
    Strongly disagree
    Disagree
    Undecided
    Agree
    Strongly agree

16. Your organization does not possess advanced analytics capability and therefore finds it difficult to identify and prevent fraudulent activities
    Strongly disagree
    Disagree
    Undecided
    Agree
    Strongly agree

17. Government regulation and customers' reluctance to provide information do sometimes hinder smooth application of business analytics
    Strongly disagree
    Disagree
    Undecided
    Agree
    Strongly agree

Opportunities in using data analytics for financial services

18. By leveraging on data analytics your organization has the opportunity for innovation and risk mitigation.
    Strongly disagree
    Disagree
    Undecided
    Agree
    Strongly agree

19. Market research using data analytics gives your organization the opportunity to stay competitive in the ever-changing market environment.
    Strongly disagree
    Disagree
    Undecided
    Agree
    Strongly agree

20. There is opportunity for benchmarking and maturity assessment for more improvement.
    Strongly disagree
    Disagree
    Undecided
    Agree
    Strongly agree

21. Your firm will continue to identify ways to attract and retain talents
    Strongly disagree
    Disagree
    Undecided
    Agree
    Strongly agree

22. There is spot opportunity for new products and new market for existing products.
    Strongly disagree
    Disagree
    Undecided
    Agree
    Strongly agree

23. The application of business analytics in your organization will continue to provide opportunity for trend analysis for better performance
    Strongly disagree
    Disagree
    Undecided
    Agree
    Strongly agree

Best way to implement business analytics in financial services

24. Tick accordingly the best ways to implement business analytics in your firm for the most efficient uses and integration into the business objectives of the financial service sector in Nigeria

Competitive advantage
Deliver personalized financial services
Risk management
Improved customer understanding
Enhanced efficiency and productivity
Informed decision making
Performance evaluation
Enhanced accurate regulatory reporting
Determine customers' credit scores
Create accurate financial forecasts
Enhanced fraud detection and prevention capabilities

Chapter 7

SELECTION AND ACQUISITION PROCESSES AS PREDICTORS FOR ACCREDITATION PERFORMANCE IN ACADEMIC LIBRARIES

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Abstract
Academic libraries play a crucial role in supporting teaching, learning and research within higher education institutions and their effectiveness is often evaluated during institutional and program accreditation processes. This chapter examines the relationship between selection and acquisition processes in academic libraries and their influence on accreditation performance. Specifically, it explores how systematic collection development practices contribute to meeting accreditation standards that emphasize the adequacy, relevance, currency and accessibility of library resources. Drawing on evidence-based research and professional practices, the chapter highlights how effective policies for selecting and acquiring information resources can serve as predictors of successful accreditation outcomes. The chapter further analyzes the theoretical foundations linking collection development activities with institutional quality assurance frameworks. It discusses key practices such as needs assessment, user-centered selection, collaborative decision making with faculty and the adoption of transparent acquisition procedures. In addition, the chapter examines collection assessment methodologies including benchmarking, usage analysis and evidences-based evaluation that libraries employ to demonstrate compliance with accreditation requirements. These approaches enable libraries to provide measureable indicators of resource adequacy and support institutional accountability. Furthermore, the chapter emphasizes the importance of integrating benchmarking and data driven decision making into collection management processes. By aligning acquisition workflows with institutional strategic goals and accreditation expectations, libraries can strengthen their contribution to academic quality and institutional credibility. The chapter concludes by proposing practical strategies for library administrators and technical services staff to enhance

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selection and acquisition practices in ways that directly support accreditation preparedness and performance. Overall, the chapter provides a conceptual and practical framework for understanding how well-structured collection development processes can function as reliable predictors of accreditation success in academic libraries.

Introduction

Academic libraries constitute one of the most critical academic support systems within higher education institutions. They provide the intellectual resources required for teaching, learning, research, innovation and professional training. The strength of any academic programme is closely linked to the quality, relevance, accessibility and currency of the information resources available in the institutional library. Consequently, academic libraries are subjected to rigorous evaluation during programme accreditation exercises, where their collection, services and operational systems are examined whether they adequately support institutional academic goals. In Nigeria, agencies such as the National Universities Commission emphasis library adequacy as a fundamental requirement for programme approval and institutional credibility (Ilorah 2016). Within this context, the process through which library resources are selected and acquired have emerged as foundational determinants of accreditation performance. Selection and acquisition are not merely routine technical functions; rather they present strategies professional activities that directly influence the academic strength, credibility and sustainability of library collection. Selection determines the intellectual direction of the library by identifying which materials are appropriate for inclusion based on curriculum requirements, research priorities, user needs and institutional objectives. Acquisition, on the other hand, ensure that these selected materials are actually procured, processes, documented and made available for use in a timely and efficient manner. Together, these processes from the operational backbone of collection development and ultimately shape the library's readiness for accreditation assessment (Brown and Forsyth, 1999).

The growing complexity of higher education systems has intensified the importance of systematic selection and acquisition processes. Universities are continuously expanding their academic programmes, introducing new disciplines, increasing postgraduate research activities and adopting interdisciplinary teaching approaches. Such expansion generates increasing demand for specialized textbooks, scholarly journals, reference materials and electronic databases. Without structured and well-coordinated selection procedures, libraries risk acquiring materials that are outdate, irrelevant, duplicated or insufficient to support academic programmes, similarly, ineffective acquisition systems may result in procurement delays, incomplete subscriptions, missing essential course texts or lack of documentation all of which can negatively influence accreditation outcomes (Lasig et al., 2024). Accreditation bodies typically evaluate academic libraries based on several measurable indicators, including adequacy of core textbooks, availability of recommended readings, currency of scholarly publications, accessibility of electronic resources and evidence of systematic collection management. These indicators are directly shaped by how effectively the library performs its selection and acquisition responsibilities. For instance, when librarians collaborate with academic departments to analyze course outlines and reading lists before selecting materials, the resulting collection is more likely to align with

curriculum needs. When acquisition units maintain efficient procurement workflows and vendor relationships, essential materials arrive on time and remain continuously available.

Conversely, where selection decision is made without systematic consultation or acquisition procedures are slowed by administrative inefficiencies, the library may present visible resources gaps during accreditation inspections (Clayton State University, 2025). The predictive role of selection and acquisition processes becomes even more pronounced in developing countries, where academic libraries often operate under financial constraints, fluctuating exchange rate, bureaucratic procurement regulations and shortages of professional staff. Under such circumstances, the mere allocation of funds does not automatically translate into effective collection development. Rather, the presence of structured policies, transparent decision-making procedures, prioritization frameworks and strategically to maximize accreditation readiness. Libraries that institutionalize these professional processes are better positioned to maintain balanced collections, sustain journal subscription and respond promptly to emerging academic needs, thereby strengthening their accreditation performance (Ilorah, 2016). Furthermore, the transition from traditional print dominated collections to hybrid and digital information environments has introduced new dimensions into selection and acquisition management. Modern academic libraries must now evaluate electronic licensing agreements, subscription packages, database usability, remote access systems and long-term digital preservation strategies. Selection decisions therefore extend beyond choosing individual books to include assessing digital platforms, negotiating access rights and analyzing usage statistics. Acquisition functions similarly require technical coordination involving payment systems, authentication technologies, metadata integration and continuous subscription monitoring.

Accreditation panels increasingly recognize these digital resources management capabilities as indicators of institutional academic competiveness and global research connectivity (Evidence based Library and Information Practices, 2024). Another important aspect linking selection and acquisition to accreditation performance is documentation and accountability. Accreditation inspectors frequently request evidence such as collection development policies, departmental recommendation records, purchase orders, subscription invoices, vendor contracts, accession registers and database access logs. These documents demonstrate that the library's collection growth is guided by systematic professional procedures rather than arbitrary or reactive purchasing. Thus, beyond the physical presence of materials, accreditation success depends heavily on the library's ability to demonstrate procedural consistency, financial transparency and professional compliance in its selection and acquisition operations (Clayton State University, 2025). From a managerial perspective, selection and acquisition processes also function as instruments of institutional strategic planning. Through careful analysis of academic programme expansion, student enrolment trends, research output patterns and emerging disciplinary priorities, libraries can forecast future resource needs and adjust procurement strategies accordingly. This proactive planning capacity reduces the likelihood of emergency acquisition shortly before accreditation visits a practice that often leads to incomplete documentation, rushed procurement and unsustainable subscription commitments. Instead, libraries operating with long term, policy driven selection and acquisition

frameworks maintain continuous accreditation readiness as an embedded institutional culture (Yoakum, 2025). The interdependence between selection and acquisition further reinforces their predictive significance. Selection without acquisition produces theoretical resources plans that never materialize into accessible collections.

Acquisition without proper selection risk purchasing irrelevant or low priority materials that fail to support academic programme, effective accreditation performance therefore depends on the integration of both processes into a coordinated system of professional collection management. When this integration is achieved, the library demonstrates organizational efficiency, academic responsiveness and institutional accountability qualities highly valued by accreditation authorities (Lasig et al., 2024). Scholarly literature in library and information science consistently highlights that institutions with clearly documented collection development policies, active faculty participation in selection decision, stable procurement funding and automated acquisition tracking system tent to achieve stronger accreditation outcomes than those relying on informal or fragmented procedures. Such findings underscore the need to conceptualize selection and acquisition not simply as technical library routines but as measureable predictors of institutional academic quality (Brown and Forsyth, 1999; Ilorah, 2016). In light of these considerations, this book chapter examines the theoretical foundations, operational structures and institutional implications of selection and acquisition processes in academic libraries, with particular emphasis on their role as predictors of accreditation performance. The chapter analyzes how systematic resources identification, professional evaluation, efficient procurement and continuous monitoring contribute to the adequacy, relevance and accessibility of library collections. Its further explores the administrative, financial, technological and collaborative factors that influence these processes and discusses strategic approaches for strengthening them in order to enhance institutional accreditation success. By situating selection and acquisition within the broader framework of academic quality assurance, this chapter argues that accreditation performance in academic libraries is not merely determined by the number of books or databases available, but fundamentally by the effectiveness, coordination and sustainability of the professional processes through which those resources are chosen, obtained and maintained. Understanding this relationship is essential for librarians, university administrators, policymakers and scholars seeking to strengthen higher education systems and ensure that academic libraries continue to function as reliable foundations of institutional excellence.

Conceptual clarification

This section provides an in-depth conceptual explanation of the three core constructs of the chapter selection, acquisition and accreditation performance as they relate to academic libraries. each concept is discussed broadly from theoretical, operational, professional and accreditation assessment perspectives to establish a strong foundation for understanding how selection and acquisition processes predict accreditation outcomes.

Concept of selection in academic libraries

Selection in academic libraries refers to the systematic decision-making process through which librarians determine which information resources should be added to the library collection in order to support teaching, learning, research and community service functions

of the parent institution. According to professional standards developed by the American Library Association, selection involves evaluating materials based on relevance, authority, accuracy, cost, format suitability and user needs. Selection is therefore not merely choosing books; it is a structured intellectual, professional and policy guided process. It answers the fundamental question: what materials should the academic library own to effectively support its academic programme? (Clayton State University, 2025).

Nature of selection as a strategic Academic Function

Selection is a forward-looking academic planning activity. It ensures curriculum relevance, research support adequacy, knowledge currency and accreditation readiness. For examples, if a university introduces a new programme in Urban and Regional Planning, the library must select core textbooks on planning theory, GIS manual, environmental impact assessment guides transportation planning resources and planning law documents. Failure in this selection process means students and lectures lack essential learning materials, which accreditation panels will detect immediately (Lasig et al., 2024).

Selection as a Needs Driven Process

Selection must reflect user information needs. Academic libraries serve undergraduate students, postgraduate students, lecturers, researchers and external scholars. Each group has different materials needs. Undergraduate students need introductory textbooks, study guides and simplified reference works. Researchers need peer reviewed journals, advanced monographs and research datasets. If the library selects only basic textbooks but lacks rearch journals, accreditation teams may judge the collection as inadequate (Ilorah, 2016).

Principles Guiding Selection

Several principles guide effective selection in academic libraries. relevance to curriculum requires that materials directly support academic programmes, for example, a medical faculty requires anatomy textbooks, clinical manual and pharmacology references. Selecting unrelated materials wastes funds and weakens accreditation preparedness. Authority and scholarly quality demand that libraries select works written by recognized scholars, published by accredited publishers and sourced from peer reviewed outlets. When students rely on unofficial online materials instead of scholarly publications, this may indicate poor selection quality in the library. Currency of information is particularly critical in fields like medicine, engineering and computer science, which require up to date materials. If most library materials are twenty years old, accreditation bodies may rate the collection as obsolete. Balance in subject coverage requires libraries to maintain subject proportionality. If seventy percent of the budget goes to business books while science programmes expand, accreditation panel will observe imbalance and may question the library's support for those growing programmes (Clayton State University, 2025).

Selection Policy as Institutional Evidence

A written collection development policy is a critical accreditation document. This policy defines selection criteria, responsibility structure, faculty involvement, format priorities and replacement rules. Accreditation agencies such as the National Universities Commission require libraries to demonstrate systematic selection procedures. Without a documented

policy, the selection process appears arbitrary and may undermine accreditation confidence (Ilorah, 2016).

Role of faculty participation in selection

Academic libraries do not operate in isolation. Faculty members recommend core textbooks, suggest journals and identify emerging research areas. For example, engineering lecturers recommending new AI design manuals ensures the library stays aligned with curriculum changes. Where faculty are excluded, libraries risk acquiring irrelevant materials that fail to support actual teaching and research needs (Clayton State University, 2025).

Selection in the Digital Era

Modern selection includes e-books, online databases, institutional repositories and open access resources. Organizations such as the international federation of Library Associations and Institutions emphasize hybrid collection development combining print and digital resources. Failure to select digital resources today may severely harm accreditation scores, as students and researchers increasingly expect remote access to scholarly content (Evidence Based Library and Information Practice, 2024).

Concept of Acquisition in Academic Libraries

Acquisition refers to the process through which selected library materials are actually obtained and added to the collection. While selection answers the question "what should be bought?" acquisition answers "How will the library obtained it?" this distinction is fundamental: excellent selection decisions have no practical value if acquisition processes fail to bring materials into the library's accessible collections (Brown and Forsyth, 1999).

Acquisition as an Operational Implementation Process

Acquisition transforms selection decisions into physical or digital ownership. It includes ordering materials, processing payments, receiving items, verifying accuracy and recording inventory. If selection is excellent but acquisition fail through delayed orders, lost shipments, payment problems or poor vendor management accreditation performance still suffers because materials are not available when needed (Lasig et al., 2024)

Major Acquisition Methods

Purchase represents the primary acquisition method. For example, a library buys two hundred new planning textbooks to support a newly approved programme. The efficiency and timeliness of purchase transactions directly affect whether materials arrive before students begin their courses. Subscription is used for academic journals, databases and online platforms. Annual subscriptions to research databases require careful financial planning and timely renewal. If subscriptions lapse due to delayed payment or budget shortfalls, accreditation teams will note missing access to essential scholarly content. Gifts and donations provide another source of materials. Libraries often receive donated books, but these must still meet selection standard. Old donated textbooks from 1985, for instance, may be rejected because they are outdated and would harm collection currency ratings during accrediting reviews. Exchange programmes enable libraries to exchange publications with other institutions. Two universities might exchange faculty research journals, expanding available resources at minimal cost. Such arrangements demonstrate

collaborative collection development, which accreditation panel may view favorably (Brown and Forsyth, 1999).

Importance of Timeliness in Acquisition

Accreditation teams assess whether students have current access to required materials. Delayed acquisition creates academic gaps. If textbooks arrive two years after programme approval, students in those first cohorts lack essential resources. This timing dimension makes acquisition speed a direct factor in accreditation readiness (Lasig et al., 2024).

Acquisition Budget as a Quality Indicator

Acquisition funding signals institutional commitment to library quality. Accreditation panels often ask what percentage of institutional budget goes to the library and how much is spent per student. Low funding leads to weak acquisition, which in turn produces poor accreditation outcomes. The relationship between budgetary investment and accreditation performance is well documented in the literature (Ilorah, 2016).

Acquisition Documentation

Libraries must maintain comprehensive records including purchase invoices, vendor records, subscription lists and accession register. These documents serve as audit evidence during accreditation visits. When reviewers can trace the path from selection decision to acquired item through clear documentation, they gain confidence in the library's operational integrity (Clayton State University, 2025).

Digital Acquisition Systems

Modern academic libraries use automated acquisition modules within integrate library systems. These systems track order, manage vendors and monitor delivery timelines. Automation increases accountability, reduces processing errors and improves accreditation readiness by ensuring that acquisition workflows are transparent and verifiable (Evidence Based Library and Information Practices, 2024).

Concept of Accreditation Performance in Academic Libraries

Accreditation performance refers to the extent to which an academic library satisfies the standards set by educational regulatory bodies during institutional or programme evaluation exercises. It measures adequacy of frequency of resources, currency of materials, accessibility of collections, professional staffing and service effectiveness. Libraries are evaluating not merely on what they hold but on how well those holdings support institutional academic objectives (Lasig et al., 2024).

Library as a Core Accreditation Component

Libraries are central to academic programme approval. Accreditation teams inspect book to student's ratios, journal availability, electronic database access, reading space adequacy and staff qualifications. A programme may fail accreditation solely due to poor library support, making library quality a potential bottleneck in institutional academic development (Ilorah, 2016).

Dimensions of Accreditation Performance

Resources adequacy examines whether the library holds sufficient materials to support its programmes. A law programme, for example, require thousands of legal texts. If only fifty exist, accreditation rating will decline regardless of other library strengths. Resource currency assesses whether materials are recent. Outdated books signal weak academic support and suggest that the library is not keeping pace with knowledge development in the disciplines it serves. Accessibility considers whether students can use materials easily. Open shelving, online catalogues and remote database login all contribute to accessibility ratings. Even excellent collections have limited value if users cannot access them efficiently. Service efficiency includes lending services, reference assistance, ICT support and user education. These service dimension complement collection in determining overall accreditation performance (Clayton State University, 2025).

Accreditation Scoring Outcomes

Libraries may receive rating such as full accreditation support, interim support or denied support. These outcomes strongly depend on selection and acquisition effectiveness. Libraries that score poorly on collection metrics often find that selection and acquisition process deficiencies are identified as root causes (Lasig et al., 2024).

Accreditation as Continuous Quality Assurance

Accreditation is not a one-time event. Libraries must continuously update collection, renew subscriptions and replace obsolete materials. This ongoing requirement makes sustainable selection and acquisition processes essential. Libraries that lack systematic procedures may achieve accreditation once through exceptional effort but cannot maintain compliance over time (Yoakum, 2025).

Conceptual Link Between Selection, Acquisition and Accreditation performance

The conceptual relationship linking these three constructs can be summarized as follows: Selection ensure that relevant materials are identified based on curriculum needs, research priorities and user requirements. Acquisition ensures that selected materials actually become available through timely procurement, efficient workflows and sustainable finding. Accreditation performance reflects whether these processes worked successfully to produce collections that meet regulatory standards.

Thus, strong selection combined with efficient acquisition produces strong accreditation outcomes. Weakness in either process creates vulnerabilities that accreditation reviewers will detect. This predictive relationship makes selection and acquisition processes legimate subjects of study for those seeking to understand and improve library accreditation performance (Brown and Forsyth, 1999; Lasig et al., 2024; Clayton State University, 2025).

Theoretical framework: process Quality and Outcome Achievement

The Logic Model Approach

understanding how selection and acquisition processes predict accreditation outcomes begins with a logic model framework. In this conceptualization, inputs budget allocations, staff expertise, collection policies flow through processes selection decision, acquisition workflows, vendor management to produce outputs acquired material that ultimately generate outcome accreditation compliance, user satisfaction (Brown and Forsyth, 1999).

The predictive power of processes lies in their reproducibility and documentation. Accreditation reviewers examine not merely what libraries hold, but how they determine what to acquire and whether those decisions align with institutional needs. A library that can demonstrate systematic processes for identifying curricular requirements, evaluating available resources and acquiring appropriate materials provides evidence of institutional capacity for ongoing quality maintenance.

The Compliance Continuum

Research by Lasig and Colleagues (2024) at central Luzon State University revealed that more than half of major subject courses across various curricular programs were non complaint with regulatory standards, including a significant percentage of courses with zero title copyrighted within the preceding five years. This finding illustrates the compliance continuum: libraries range from highly complaint meeting or exceeding standards across all programs to significantly deficient, with most occupying intermediate positions where some programs meet standards while others fall short. These study's methodology using regulatory standards to analyze collection compliance demonstrates how libraries can position themselves on this continuum through systematic assessment. Notably, the researchers identified numerous curricular programs with title gaps of fifty percent or higher that required prioritization in acquisition planning (Lasig et al.; 2024). This gap analysis represents a critical link between assessment processes and target acquisition.

Selection Processes and Accreditation Alignment

Policy Foundations for Complaint Selection

Selection processes begin with policy frameworks that establish decision making criteria. The Clayton State University Library collection development policy (2025) exemplifies how institutional guidelines can explicitly connect selection to accreditation requirements. The policy states that since accrediting agencies generally use these standards to evaluate library collections, it is important that the library maintain these standards (Clayton State University, 2025). This explicit acknowledgement of accreditation within collection policy creates what might be termed “accreditation conscious selection” a decision-making approach that considers compliance implications alongside traditional selection criteria. The policy operationalizes this through specific guidelines including appropriateness for graduate and undergraduate curricula, identified strengths and weaknesses of subject areas, currency and timeliness and expected usage (Clayton State University, 2025). Each of these criteria connects to accreditation review dimensions. Curricular appropriateness addresses whether collections support program objectives. Identified strengths and weaknesses demonstrate institutional self-awareness. Currency and timeliness respond to accreditation expectations for current materials. Expected usage reflects attention to return on investment.

Participatory Selection Structures

Selection processes that distribute responsibility across stakeholders create multiple benefits for accreditation preparation. The Clayton State Policy (2025) establishes distinct roles for library administration, liaison librarians, faculty and students. This distributed model ensures that selection decisions incorporate diverse perspectives on institutional needs. Library administration bears responsibility for fund allocation based on the needs of

academic departments, with the Library Budget Committee monitoring to ensure that funds are assigned to areas with the most pressing needs (Clayton State University, 2025). This administrative oversight creates accountability for resource distribution aligned with institutional priorities. Liaison librarians, assigned to academic departments, are responsible for selecting materials in their assigned subject areas and should build relationship with faculty to assist them in identifying resources for their subject areas (Clayton State University, 2025). This liaison model creates direct communication channels between library selectors and academic programs the very programs whose needs accreditation reviewers will assess. Faculty participation, channeled through a library committee consisting of faculty representing all colleges, ensures faculty involvement in collection development and library policy (Clayton State University, 2025). This governance structure provides documentation of faculty engagement with library collections, which accreditation reviewers may interpret as evidence of collection relevance.

Selection Criteria with Accreditation Implications

Specific selection criteria carry particular weight for accreditation preparation. Currency requirements appear prominently in both library policies and accreditation standards. The central Luzon state University study (Lasig et al., 2024) employed copyright within the last five years as a key compliance indicator, finding that a substantial portion of major subject courses had zero recent titles. These findings suggest that selection processes failing to prioritize currency create predictable accreditation vulnerabilities. The Clayton State policy (2025) includes currency and timeliness among its general selection guidelines. However, without specific operational definitions of acceptable currency levels, selectors may lack clear guidance for prioritizing recent materials. Libraries seeking to strengthen accreditation performance should consider establishing explicit currency targets aligned with disciplinary expectations and accreditation requirements. Expected usage, another selection criterion, connects to accreditation through efficiency considerations. Accreditation reviewers examine whether institutions allocate resources efficiently to achieve educational objectives. Selection processes that consider usage expectations drawing on circulation data, interlibrary loan patterns and faculty input demonstrate attention to efficient resource allocation.

Acquisition Processes and Accreditation Readiness

Vendor Selection and performance

The acquisition process extent beyond title selection to encompass how libraries procure materials. Research by Brown and Forsyth (1999) examined how academic librarians evaluate and select approval plan vendors, identifying factors that influence acquisition effectiveness. Their survey of academic librarian found that traditional services, including expertise in managing approval plans profiling and acquisition services customer service, discount rate, along with corporate reputation and business practices retained their core status (Brown and Forsyth, 1999). For libraries pursuing accreditation, vendor relationships affect collection quality through multiple mechanisms. Profiling expertise determines how effectively approval plans match acquisition to institutional needs. Customer services influence how quickly gaps can be addressed when accreditation preparation reveals deficiencies. Discount rate affects how many materials can be acquired within constrained budgets. The researchers also found that outsourcing services such as cataloging or physical

processing with approval plan vendors, although never, appeared established and of considerable interest to some segments (Brown and Forsyth, 1999). This finding anticipated current practice, where many libraries integrate cataloging and processing services with acquisition workflows. Such integration affects accreditation preparation by determining how quickly acquired materials become accessible to user a consideration for reviewers examining collection availability.

Budget Allocation and Expenditure processes

Acquisition processes include how libraries allocate and expend funds across disciplinary areas. The Clayton State policy (2025). Describe a structured approach: estimated subscription and standing order cost are calculated first, followed by reserves for reference materials and replacements, with remaining funds allocated for one-time monographic purchases. Allocation decision considers enrollment figure, changes to the university curriculum, the average cost of materials in a particular field of study, or any other criteria which the Dean of libraries deems equitable to apply (Clayton State University, 2025). This structure approach to allocation creates predictability in acquisition patterns. For accreditation preparation, predictability enable libraries to project when specific subject areas will receive investment and to identify gaps requiring targeted attention. Libraries lacking systematic allocation processes may discover accreditation vulnerabilities only when formal review approaches. The policy also addresses end of year expenditures, noting that frequently the library receives allocations at the end of the fiscal year and these funds may be used to pay for large one-time purchases or may be put on deposit with a vendor to be expended (Clayton State University, 2025). This flexibility allows libraries to address collection gaps identified through assessment, potentially improving accreditation readiness.

Evidence Based Acquisition Decision Making

Recent research has examined evidence-based approaches to acquisition decision, with implications for accreditation performance. A study on instrument development for evidence-based librarianship in the acquisition decision of electronic resources (Evidence Based Library and Information Practice, 2024). The instrument, developed based on well-established theories and models including Technology Organization and Environment, Innovation Diffusion theory and a Concern based adoption model with newly added construct addressing user needs and preferences, demonstrated acceptable validity and reliability. The internal consistency reported strong values across multiple reliability measures (Evidence Based Library and Information Practice, 2024). For accreditation purposes, evidence-based acquisition processes provide documentation that acquisition decision rest on systematic analysis rather than intuition or tradition or tradition. When reviewers inquire about how resources were selected, libraries can reference usage data, needs assessments, and comparative analysis all evidence of thoughtful stewardship.

Collection Assessment as The Mediating Variable

Assessment Methodologies for Accreditations

Collection assessment serves as the mediating variable linking selection and acquisition processes to accreditation outcomes. Without assessment, libraries cannot know whether their processes produce complaint collections. With systematic assessment, libraries can

identify gap, adjust processes and demonstrate improvement to reviewers. The central Luzon state university study (Lasig et al., 2024) employed an action research model of interactive reflection and improvement, follow the four steps for carrying out the research plan act, observe and reflect. This methodology allowed researcher to asses' collection compliance against regulatory standards and identify programs requiring prioritization. The researchers concluded that the library collection assessment technique is crucial for identifying gaps in the collection and determining areas where additional resources may be required (Laig et al., 2024). This finding position assessment as the diagnostic tool that reveals whether selection and acquisition processes have achieved their intended outcomes.

Quantitative Standard and Compliance Measurement

Accreditation standards often include quantitative expectations for library collection. The central Luzon State University study (Lasig et al., 2024) employed a specific Commission on Higher Education Memorandum order to analyze the collection adequacy could be measured. The findings revealed that only a small percentage of total programs were able to reach above seventy percent compliance with CHED standards (Lasig et al., 2024). This quantitative gap analysis enable prioritization, identifying curricular programs with title gaps of fifty percent or higher that needed to be prioritized in the acquisition of book titles (Lasig et al., 2024). For libraries preparing for accreditation, such quantitative assessment provides actionable intelligence. Rather than guessing which areas require attention, librarians can target acquisitions precisely where gaps exist. This targeting represents the practical application of assessment findings to acquisition decision making.

Benchmarking Against Peer Institutions

Beyond quantitative standards, benchmarking against peer institutions offers another assessment approach with accreditation implications. Yoakum (2025) introduced one strategic, low-cost benchmarking approach: using your business schools Competitive and Aspirant Institutions lies they create as part of the accreditation process for the Association to Advance Collegiate Schools of Business. This approach enables librarians to examine what resources peer and aspirant institutions subscribe to, thereby identifying collection gaps, strengthening resources proposals and aligning acquisitions with institutional ambitions (Yoakum, 2025). The method yields practical methods for identifying and using AACSB peer data or alternative approaches if not accredited tips for integrating findings into budget justifications and a renewed perspective on how to navigate collection development challenges strategically beyond the input of faculty (Yoakum, 2025). Benchmarking against aspirant institutions connects collection development to institutional strategic goals. When libraries can demonstrate that their collections align with those of peer and aspirant institutions, they provide evidence that the institution competes effectively in its academic marketplace a consideration in many accreditation frameworks.

Case Studies in Selection, Acquisition and Accreditation

Case study1: University of Rizal System in the Philippines provide a compelling case study of how strategic acquisition decisions can directly influence accreditation outcomes. The university beefed up its library, which helped earn the approval of independent accreditating institution for the state universities and colleges through is partnership with the department of science and Technology's STARBOOKS program (Department of science and Technology,

Philippines, 2026). The improvement was particularly significant give resources constraints. According to the URS head librarian, the university budget for new book title acquisition was quite limited relative to enrollment. The main campus had more than two thousand students, which meant that URS allocated less than five hundred pesos per student per semester for book acquisition (Department of science and technology, Philippines, 2026). Through its linkage with DOST-STII, URS was able to raise the number of book collections and secure accreditation.

STARBOOKS added tens of thousands more library contents on science and technology various formats without requiring internet connection (Department of Science and Technology, Philippines, 2026). This acquisition dramatically increased available resources despite budget limitations. The accreditation outcome reflected multiple dimensions. The accreditation was granted to URS for passing the AACCUP evaluation based on parameters such as administration, personnel, book collections, library services, physical set up and facilities, financial support and linkages to other institutions (Department of Science and Technology, Philippines, 2026). The library's strategic acquisition decision contributed to success across multiple evaluation criteria. This case illustrates how creative acquisition strategies can address resources constraints while advancing accreditation readiness. By leveraging partnerships and alternative resource models, libraries can expand collections beyond what traditional acquisition budgets would permit.

Case Study2: FAN Nnamdi Azikiwe University and Benchmark Implementation

Research at FAN Nnadi Azikiwe University, Awka, Nigeria, examined the blueprint or benchmark in the selection and acquisition of library materials in the twenty first century (Ilorah, 2016). The study highlighted the minimum standards and Guidelines for Academic Libraries in Nigeria, selection and acquisition practices in the library and challenges encountered. The research recommended, among other things, the establishment of a collection development committee, review of the collection development policy on ground and immediate adoption of information and communication technologies in the selection and acquisition processes of the library (Ilorah, 2016). These recommendations reflect the importance of governance structures, policy frameworks and technological integration in creating selection and acquisition processes capable of meeting standards. The study's focus on blueprint and benchmark suggests that benefit from explicit models against which to compare their practices. When selection and acquisition processes align with professional benchmark, they are more likely to produce collections that meet accreditation standards.

Case Study 3: Universitas Gadjah Mada and International Accreditation

The visitation of ACQUIN, an international accreditation body, to the Library and Archives of Universitas Gadjah Mada illustrates how libraries feature in comprehensive institutional accreditation (Universitas Gadjah Mada Library, 2025). The visit was part of the accreditation assessment for numerous study programs from the faculty of cultural Science, the Faculty of social and Political Science and the graduate School, positioning the library as one of the key facilities the academic quality of the university (Universitas Gadjah Mada Library, 2025). The assessment team toured library facilities including popular study spaces among students, followed by a visit to the archival diorama, discussion rooms and the podcast studio, which serves as a creative space supporting academic expression and collaboration (Universitas

Gadjah Mada Library, 2025). Through this review, ACQUIN obtained a comprehensive picture of how a modern library functions not merely as a collection space, but as an integrated learning ecosystem that fosters collaboration, creativity and knowledge exchange (Universitas Gadjah Mada Library, 2025). This expanded conception of library value beyond collections to encompass space, services and creative support reflects evolving accreditation expectations. While this case emphasizes facilities and services rather than selection and acquisition processes, it reinforces the library's strategic role in accreditation. The library's ability to demonstrate alignment with institutional mission and responsiveness to user needs attributes shaped by selection and acquisition decision contributes to positive accreditation outcomes.

Challenges in Linking Selection and Acquisition to Accreditation

Documentation Burden

One significant challenge in demonstrating the connection between selection and acquisition processes and accreditation outcomes is documentation burden. Libraries must not only conduct appropriate selection and acquisition activities but also maintain records that enable reviewers to understand and evaluate those activities (Clayton State University, 2025). Accreditation self-studies typically require descriptions of collection development policies, selection criteria, allocation methodologies and assessment practices. Libraries lacking comprehensive documentation may struggle to demonstrate processes quality even when their collections are adequate. Conversely, libraries with well documented processes can more effectively communicate their approach to reviewers.

Currency Maintenance Across Disciplines

The currency challenge identified in the central Luzon State University study (Lasig et al., 2024) where a substantial portion of major subject course had zero recent titles illustrates a persistent difficulty. Selection and acquisition processes must continuously refresh collections to maintain compliance, yet budget constraints, publishing delays and competing priorities create obstacles. Different disciplines have varying currency expectations. Sciences typically require very very recent materials, while humanities may value older works alongside new publications. Selection and acquisition processes must accommodate these disciplinary variations while ensuring that no program falls below acceptable currency thresholds.

Balancing Breadth and Depth

Selection and acquisition processes must balance collection breadth across all programs against depth within individual disciplines. The Central Luzon State University finding (Lasig et al., 2024) that only a small percentage of programs reached above seventy percent compliance suggests that breadth challenges may be widespread. Libraries with limited resources must make difficult decisions about resource distribution. Processes that systematically identify priority areas whether through gap analysis, faculty input, or usage data enable more strategic allocation. However, even strategic allocation may leave some programs below desired compliance levels.

Vendor Management Complexities

Acquisition processes involving multiple vendors create coordination challenges. The approval plan research by Brown and Forsyth (1999) identified various factors libraries consider in vendor selection, including expertise, customer service discount rate and corporate reputation. However, managing relationships with multiple vendors while maintaining consistent collection quality requires significant staff attention. Libraries must also navigate the transition from print to electronic resources, which involves different acquisition models, licensing considerations and access mechanisms. The evidence-based acquisition research addresses these complexities, offering validated instruments for evaluating e-resource decisions (Evidence Based Library and Information Practice, 2024).

Best Practice for Accreditation Oriented Selection and Acquisition

Establish Explicit Connections to Standards

Libraries seeking to strengthen accreditation performance should explicitly connect selection and acquisition processes to relevant standards. This connection can be embedded in collection development policies, as demonstrated by the Clayton State policy (2025) referencing accrediting agency standards. When selectors understand how their decisions relate to accreditation requirements, they can prioritize materials with compliance implications.

Implement Systematic Gap Analysis

Regular gap analysis against accreditation standards enables libraries to identify deficiencies before formal review. The Central Luzon State University Methodology (Lasig et al., 2024) comparing holdings against regulatory requirements by program and course provides a model for systematic assessment. Libraries should conduct such analyses on a regular cycle, while results informing acquisition priorities.

Develop Targeted Acquisition Strategies

When gap analysis reveals deficiencies, libraries need target acquisition strategies to address them. The university of Rizal System's partnership with STARBOOKS (Department of Science and Technology, Philippines, 2026) illustrates creative targeting: identifying a specific need science and technology resources and pursuing an innovative solution. Libraries should develop contingency plans for addressing gaps, including strategies for rapid acquisition when needed.

Integrate Benchmarking into Decision Making

Benchmarking against peer and aspirant institutions, as described by Yoakum (2025), provides external validation for collection decisions. Libraries should regularly review peer institution collections, particularly in areas where accreditation standards reference comparative performance. Benchmarking data can strengthen budget justifications and resource proposals.

Document Processes and Decisions

Comprehensive documentation enables libraries to demonstrate process quality to accreditation reviewers. Documentation should include collection development policies, selection criteria, allocation methodologies, assessment findings and acquisition strategies

(Clayton State University, 2025). When reviewers can trace the logical connection between library processes and collection outcomes, they gain confidence in institutional capacity for ongoing quality maintenance.

Engage Stakeholders in Selection and Assessment

Distributed selection responsibility, as modeled in the Clayton State policy (2025), ensures that selection decisions incorporate diverse perspectives. Faculty engagement in selection and assessment provides evidence that collections support curricular needs a key accreditation consideration. Libraries should maintain active liaison relationships and faculty library committee structures.

Future Directions

Predictive Analysis for Collection Development

Emerging analytical capabilities may enable libraries to predict accreditation performance based on selection and acquisition patterns. By modeling relationships between acquisition investments and compliance outcomes, libraries could optimize resources allocation to maximize accreditation readiness. The evidence-based acquisition research (Evidence Based Library and Information practice, 2024) represents an early step toward such predictive capacity.

Integration with Institutional Data Systems

As libraries develop more sophisticated assessment capabilities, integration with institutional data systems become increasingly valuable. Linking library collection data with curriculum mapping, enrollment patterns and program review cycles would enable more strategic alignment of selection and acquisition with institutional needs. Accreditation self-studies could draw on integrated data to demonstrate library engagement with institutional planning.

Evolving Standards and Emerging Formats

Accreditation standards continue to evolve in response to changes in higher education and scholarly communication. Libraries must adapt selection and acquisition processes to address emerging formats, open access models and changing user expectations. The ACQUN visitation at UGM (Universitas Gadjah Mada Library, 2025), which highlighted creative spaces and collaborative facilities alongside traditional collections, suggests expanding conceptions of library value that selection and acquisition processes must support.

Conclusion

This chapter set out to examine how selection and acquisition processes in academic libraries function as predictors of accreditation performance. The discussion demonstrated that the effectiveness of library collections used in accreditation evaluation is not determined solely by the number of resources available, but by the quality, structure and consistency of the professional processes through which those resources are identified, procured and maintained. By exploring theoretical perspectives, operational practices and empirical examples, the chapter highlighted how systematic collection development procedures influence institutional readiness for accreditation review. The analysis revealed that well-structured selection practices aligned with curriculum requirements and research priorities

are essential for building relevant and balanced collections, while efficient acquisition mechanisms ensure that these materials are obtained in a timely and sustainable manner. When both processes operate in an integrated and policy guided manner, libraries are better able to provide adequate, current and accessible resources that meet regulatory expectations. The chapter also emphasized the importance of collection assessment benchmarking and evidence-based decision making as mechanisms that enable libraries to identify resources gaps, prioritize acquisitions and demonstrate compliance with accreditation standards.

The chapter contribute to knowledge in library and information science and higher education quality assurance by conceptualizing selection and acquisition not merely as technical operations but as strategic predictors of institutional academic quality. By linking collection development processes directly to accreditation outcomes, the chapter provides a framework that helps librarians, university administrators and policymakers understand how technical services functions support broader institutional goals such as programme approval, academic credibility and research development. From a practical and policy perspective, the findings suggest that academic libraries should institutionalize comprehensive collection development policies, adopt evidence-based acquisition strategies, strengthen faculty participation in selection decisions and maintain systematic documentation of procurement processes. Regular collection assessment and benchmarking against accreditation standards and peer institutions should also be embedded into routine library management practices to ensure continuous accreditation readiness rather than last minute preparation. Despite these contributions, the chapter is primarily conceptual and analytical, drawing on existing literature and documented case examples rather than primary empirical data from a single institutional context. Future research could therefore expand this work by conducting quantitative or mixed methods studies that empirically measure the relationship between selection and acquisition practices and accreditation outcomes across different universities or national contexts.

Comparative studies across developing and developed higher education systems would also deepen understanding of how financial, technological and organizational factors influence these processes. Based on the insights presented, it is recommended that academic institutions prioritize investment in professional collection development structures, strengthen collaboration between libraries and academic departments and integrate digital resource acquisition strategies into long term institutional planning. Libraries should also leverage automated systems and data analytics to enhance transparency, accountability and strategic decision-making acquisition management. In conclusion, the sustainability and credibility of academic programmes depend significantly on the strength of the library collections that support them and these collections are shaped fundamentally by the effectiveness of selection and acquisition processes. When these processes are systematic, transparent and strategically aligned with institutional goals academic libraries become powerful instruments for achieving and sustaining accreditation success.

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Chapter 8

ISLAMIC PATHWAYS OF GIVING AS TOOLS FOR SUSTAINABLE POVERTY ERADICATION IN AFRICA

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Abstract
This chapter explores the multifaceted Islamic framework of giving as a sustainable mechanism for poverty alleviation in Africa. Drawing from Qur'anic injunctions, Prophetic traditions, and classical juristic interpretations, the discussion identifies and analyzes thirteen major channels of giving in Islam, such as Zakah, Sadaqah, Waqf, Hadyyah, and Kaffarah, each designed to promote social balance, compassion, and economic justice. The chapter argues that the Islamic model transcends the temporary relief approach of modern welfare systems by fostering both moral accountability and long-term community empowerment. It further examines how these spiritual and economic instruments, when applied systematically, can help reduce inequality, enhance productivity, and encourage social solidarity in African societies plagued by chronic poverty. The paper concludes that revitalizing traditional Islamic giving institutions through effective management, policy support, and awareness can serve as a viable path toward achieving the Sustainable Development Goals (SDGs) and ensuring lasting socio-economic stability across the continent.

Keywords: *Zakah, Sadaqah, Waqf, Poverty alleviation, Sustainable Development, Islamic Giving, Africa.*

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Introduction

Poverty remains one of the most persistent challenges confronting African societies in the twenty-first century. Despite decades of foreign aid, economic reforms, and development programs, a large percentage of the population in Sub-Saharan Africa still lives below the poverty line. The World Bank reports that millions of Africans continue to struggle with food insecurity, poor healthcare, and unemployment, which together create cycles of deprivation that are difficult to break. These realities raise a crucial question about sustainability: why have most modern poverty alleviation strategies failed to achieve lasting impact? One major reason is that such approaches are often material and policy-driven, overlooking the moral, spiritual, and communal foundations that sustain human wellbeing. Islam, as a comprehensive way of life, presents an alternative model rooted in faith, ethics, and social solidarity. The Qur'an and the Sunnah of the Prophet Muhammad (peace be upon him) emphasize the centrality of giving, sharing, and caring for others as expressions of faith and as means of maintaining social balance. The Prophet said, "The believer does not eat his fill while his neighbour goes hungry." This moral call goes beyond individual charity; it establishes a divine economic order based on compassion, responsibility, and justice. The Islamic philosophy of giving is not merely an act of generosity; it is a systematic approach to redistributing wealth, empowering the needy, and maintaining social cohesion. It operates at both obligatory and voluntary levels, from *Zakkah* (obligatory alms) to *Sadaqah Jariyah* (continuous charity) and *Waqf* (endowment). These mechanisms are designed not only to meet immediate needs but also to create enduring welfare systems that ensure sustainability. In essence, Islam combines spiritual motivation with practical economic solutions, a balance that modern systems often lack.

Furthermore, the concept of giving in Islam is directly linked to the principle of *Tazkiyah* (purification). By giving, a Muslim purifies both his wealth and his soul, while contributing to the purification of society from envy, greed, and inequality. The Qur'an states, "Take alms from their wealth in order to purify them and sanctify them with it" (Qur'an 9:103). Thus, the spiritual purpose of giving reinforces its socio-economic impact, making the act of charity a means of both personal growth and collective progress. In African societies, where communal values and kinship are already deeply rooted, the Islamic system of giving finds a natural ground for implementation. The culture of mutual assistance, neighbourliness, and collective responsibility aligns with Islamic teachings on social solidarity (ta'*awun*). However, in many African Muslim communities, these values are being eroded by modern materialism, weak institutional structures, and a lack of organized Islamic social finance mechanisms such as *Zakkah* and *Waqf* management boards. Consequently, while Muslims continue to give individually, the collective impact remains limited and unsystematic. This chapter seeks to explore how the Islamic pathways of giving, both obligatory and voluntary, can serve as effective and sustainable instruments for poverty eradication in Africa. It argues that Islam offers not only spiritual motivation for generosity but also a comprehensive economic framework that ensures social justice and long-term prosperity. By revisiting the rich heritage of *Zakkah*, *Sadaqah*, *Waqf*, and other forms of giving, the chapter aims to show that Islamic giving, when institutionalized and properly managed, can significantly contribute to sustainable development in African societies.

Definition of Terms

i. **Zakah:** A compulsory form of almsgiving in Islam, paid annually from specific categories of wealth once they reach the *nisab* threshold. It is intended to purify wealth and redistribute resources to eligible beneficiaries among the poor and needy (Qur'an 9:60).
ii. **Sadaqah:** A voluntary charity that may be given at any time and in any amount, to support individuals or public welfare. It goes beyond financial donations to include acts of kindness, compassion, and moral support (Kahf 2017).
iii. **Waqf (Endowment):** A permanent charitable endowment where property or wealth is dedicated for public benefits such as education, healthcare, and infrastructure. Its capital remains intact while the generated benefits serve society continuously (Cizakça 1998).
iv. **Infaq:** General spending in the way of Allah, whether obligatory or voluntary, is intended to sustain community welfare, social justice, and economic balance.
v. **Poverty Alleviation:** The process of reducing and eventually eliminating deprivation by empowering individuals and communities with access to resources, opportunities, education, and basic needs.
vi. **Sustainability:** Developing systems and policies that ensure the long-term welfare of present and future generations, balancing economic, social, and spiritual dimensions of life. In the Islamic context, sustainability is tied to justice ('*adl*) and trust (amanah) over earth's resources.
vii. **Islamic Social Finance:** A faith-based economic system that channels financial resources through Islamic instruments such as *Zakah*, *Sadaqah*, *Waqf*, and *Infaq* to achieve shared prosperity and social welfare while observing Shari'ah principles.

The Concept of Giving in Islam

Giving in Islam occupies a central place in the faith and moral consciousness of every Muslim. It is not viewed merely as a voluntary social act, but as a sacred duty and a reflection of one's faith in God. The concept of giving ('*ata'* or *infaq*) in Islam derives from the belief that all wealth ultimately belongs to Allah, and humans are only trustees of what they possess. The Qur'an reminds believers, "And spend [in charity] out of that in which He has made you successors" (Qur'an 57:7). This verse underscores the idea of stewardship, indicating that giving is part of fulfilling the trust between humans and their Creator.

The Spiritual Foundation of Giving

At its core, giving in Islam is an act of worship. It connects the giver to Allah through gratitude and selflessness. The Prophet Muhammad (peace be upon him) taught that charity does not reduce wealth; rather, it brings increase and blessing. This principle highlights the spiritual economics of Islam, where generosity leads to divine reward and worldly abundance. Islam thus transforms giving from a mere economic transaction into a form of spiritual investment. The Qur'an uses various terms to describe giving, such as *zakkah* (purification), *sadaqah* (truthful giving), *infaq* (spending), and *ihsan* (excellence). Each term carries a unique nuance that contributes to a broader understanding of giving as a multidimensional moral and social act. The term *zakkah* itself implies purification and growth, purification of wealth and soul, and growth in blessing and spiritual rank. The act of giving, therefore, is not only a social obligation but also a means of self-purification and personal development.

Ethical and Social Dimensions

Giving in Islam is guided by the ethical principles of sincerity (*ikhlas*), justice (*adl*), and compassion (*rahmah*). A Muslim gives not out of pride or to gain social recognition, but purely for the sake of Allah. The Qur'an warns, "O you who believe! Do not render in vain your charities by reminders of your generosity or by injury, like the one who spends his wealth to be seen by people" (Qur'an 2:264). This instruction emphasizes that charity loses its moral value if it is done for show or accompanied by arrogance. Socially, the system of giving promotes balance and mutual care among members of the community. Islam discourages the accumulation of wealth in the hands of a few and calls for its redistribution to maintain justice and stability. The Qur'an states that wealth "should not merely circulate among the rich from among you" (Qur'an 59:7). This principle lays the foundation for an equitable economic system where the needs of the poor are met through the social responsibility of the wealthy.

The Economic Function of Giving

Beyond the moral and spiritual benefits, Islamic giving serves an essential economic function. It reduces inequality, prevents social unrest, and stimulates economic circulation. When the wealthy give a portion of their wealth, it enables the poor to participate in the economy, thereby reducing dependency and fostering productivity. *Zakkah* and *Waqf* institutions in classical Islamic societies played vital roles in financing education, healthcare, and welfare programs long before the emergence of modern social security systems. Moreover, Islam links economic giving with sustainability. It encourages spending on projects that produce continuous benefits for society. The Prophet Muhammad (peace be upon him) said, "When a person dies, all his deeds come to an end except three: continuous charity, beneficial knowledge, or a righteous child who prays for him." This hadith defines *sadaqah jariyah,* continuous charity, as one of the most sustainable forms of giving, ensuring that goodness endures beyond a person's lifetime.

Giving as a Path to Social Harmony

The culture of giving also strengthens human relationships. Through charity, the rich and the poor become partners in building a just and compassionate society. The giver feels empathy, while the receiver gains dignity and hope. The Prophet said, "The upper hand is better than the lower hand," meaning that those who give are in a more virtuous position, yet this does not diminish the dignity of those who receive. By linking both sides through faith and shared humanity, Islam transforms charity into a bridge that unites different social classes and reduces resentment. The Islamic concept of giving, therefore, is comprehensive. It encompasses faith, ethics, economics, and social welfare. It encourages Muslims to see wealth as a trust, giving as a duty, and generosity as a path to both personal salvation and communal wellbeing. In the African context, where communal life and mutual support are culturally valued, this concept offers a framework for sustainable poverty eradication that harmonizes moral and material dimensions of development.

The Islamic Philosophy of Wealth and Social Responsibility

Islamic thought presents a distinctive worldview of wealth that transcends material accumulation and individual possession. Wealth, from an Islamic perspective, is not an end in itself but a means to attain moral excellence, social balance, and the pleasure of Allah

(SWT). It is viewed as a trust (*amānah*) rather than an absolute ownership. The Qur'an consistently reminds believers that everything they possess is ultimately owned by Allah: "And give them from the wealth of Allah which He has bestowed upon you" (Qur'an 24:33). This divine ownership defines the moral foundation of economic relations in Islam. Individuals are merely trustees who must use resources responsibly for both personal welfare and societal benefit. Wealth in Islam, therefore, carries a dual function: private enjoyment and public responsibility. The Prophet Muhammad (peace be upon him) emphasized that the most beloved wealth to Allah is that which benefits others. Hence, the accumulation of wealth without corresponding social obligation is strongly discouraged. Islam establishes a dynamic balance between earning and giving, ownership and accountability, thereby promoting sustainable economic ethics. The concept of "sharing in blessings" (*barakah*) reinforces the idea that prosperity expands when distributed rather than hoarded.

Wealth as a Trust (*Amānah*)

In Islam, the idea of *amānah* reflects both divine trust and human responsibility. Every individual is entrusted with resources, be they material, intellectual, or spiritual, and will be held accountable for their use. The Qur'an states, "Then you will surely be asked that Day about pleasure" (Qur'an 102:8). This verse captures the moral dimension of wealth management: even lawful possessions demand ethical utilization. The Prophet (SAW) also said, "The son of Adam will not move from before his Lord on the Day of Judgment until he is asked about his wealth how he earned it and how he spent it" (al-Tirmidhi, 2417). This understanding of wealth as a trust shapes Muslim attitudes toward poverty alleviation. A Muslim who recognizes that wealth belongs to Allah is naturally inclined to share it. In this sense, Islamic charity is not a favour done to the poor; it is a duty that restores balance and justice. Thus, acts of giving in Islam are both moral and spiritual imperatives that ensure the circulation of wealth and prevent societal inequality.

The Purpose of Wealth in Human Life

Islam links wealth with purpose. It is a means of fulfilling human needs, supporting family and dependents, and contributing to communal welfare. The Qur'an declares: "Seek, with what Allah has given you, the home of the Hereafter, but do not forget your share of the world" (Qur'an 28:77). This verse captures Islam's balanced view that wealth should serve both worldly needs and eternal goals. Hence, Islam rejects both ascetic poverty that neglects worldly duties and reckless extravagance that disregards moral responsibility. Wealth should circulate within society to maintain economic vitality. The Qur'an commands that wealth should not "circulate only among the rich" (Qur'an 59:7). Through mechanisms such as *Zakah*, *Sadaqah*, *Waqf*, and *Qard al-Hasan*, Islam ensures that wealth moves across social strata, stimulating growth while eradicating poverty. This approach, when applied to Africa's economic context, provides a sustainable model of wealth redistribution grounded in moral values rather than political expediency.

Balancing Ownership and Obligation

Islamic philosophy does not negate personal ownership; it regulates it. Ownership is a divine concession, conditional upon fulfilling social obligations. The Prophet (SAW) was both a trader and a giver, embodying the ethical harmony between earning and spending. Islamic jurisprudence (*fiqh*) promotes the principle of "*lā ḍarar wa lā ḍirār*" (no harm, no

harassment), guiding economic transactions to prevent exploitation and ensure fairness. The balance between ownership and obligation creates a system where economic justice is built into spiritual consciousness. When Muslims pay *Zakah*, give *Sadaqah*, establish *Waqf*, or feed others, they do more than perform rituals; they reinforce a culture of compassion and collective responsibility. This ethical vision offers a powerful framework for addressing Africa's persistent poverty: rather than relying solely on external aid, Muslim societies can mobilize internal moral and financial resources for self-sustaining development.

The Islamic Framework of Giving: Pathways to Poverty Alleviation

Islam provides an extensive framework for giving that is both spiritually rewarding and socially transformative. Unlike many economic systems that view charity as optional or sentimental, Islam institutionalizes giving as a moral and communal obligation. Through a variety of mechanisms, Muslims are encouraged to share their wealth, time, and resources for the welfare of others. This system of giving not only alleviates poverty but also sustains economic balance, nurtures empathy, and strengthens social cohesion. In the African context, where poverty and inequality remain pressing challenges, the Islamic philosophy of giving provides a viable, faith-based approach to sustainable development. The following subsections outline the key forms of giving in Islam and their potential contributions to poverty reduction and social welfare.

Zakah (Obligatory Charity)

Zakah is the cornerstone of Islamic social finance. Derived from the root *zakā,* meaning "purity" and "growth," it purifies both wealth and the heart of the giver. The Qur'an commands, "And establish prayer and give *Zakah*" (Qur'an 2:43). It is a fixed obligation on Muslims who possess the minimum threshold (*nisāb*). *Zakah* redistributes wealth systematically from the rich to the poor, addressing structural poverty. Funds are channeled to eight categories mentioned in Qur'an 9:60, including the poor, the needy, and those in debt. In Africa, institutionalizing *Zakah* through national and community-based agencies can create sustainable social safety nets. For instance, organized *Zakah* collection can fund education, health, microfinance, and agricultural projects, empowering beneficiaries to become self-reliant rather than dependent.

Sadaqah (Voluntary Charity)

Sadaqah goes beyond obligation; it reflects sincerity and compassion. The term originates from *sidq*, meaning truthfulness, signifying that charity is an expression of genuine faith. The Prophet Muhammad (peace be upon him) said, "Charity extinguishes sins as water extinguishes fire" (al-Tirmidhi, 2616). Sadaqah can take many forms: monetary help, kind words, a smile, or even removing harm from the road. It strengthens community ties and uplifts the less privileged. In addressing poverty, *Sadaqah* encourages continuous mutual aid and complements *Zakah* by reaching those not covered under obligatory giving. Community-based *Sadaqah* initiatives such as food drives, clothing banks, and local support networks can be pivotal in addressing urban and rural poverty in African societies.

Waqf (Endowment)

Waqf is one of Islam's most sustainable institutions of giving. It refers to dedicating an asset for perpetual charitable use. The Prophet (SAW) said, "When a person dies, his deeds come

to an end except for three: continuous charity (*Sadaqah Jariyah*), beneficial knowledge, or a righteous child who prays for him" (Muslim, 1631). Historically, *Waqf* institutions funded education, health, housing, and social welfare in Muslim civilizations. In modern Africa, reviving and managing Waqf properties transparently can address the chronic underfunding of essential services. A *Waqf*-based approach ensures sustainability, as the principal asset remains intact while its benefits continuously support society.

Hadiyyah (Gift Giving)
Hadiyyah, or gift giving, fosters love and social unity. The Prophet (SAW) encouraged Muslims to exchange gifts, saying, "Give gifts to one another, and you will love one another" (al-Bukhari, *Adab al-Mufrad*, 594). Although not obligatory, *Hadiyyah* softens hearts and reduces social distance between economic classes. In African contexts where community ties are essential, gift-giving reinforces mutual care and social trust. When practiced with sincerity and moderation, it builds networks of solidarity that are vital for collective poverty alleviation.

Ithaam al-Ta'am (Feeding the Hungry)
Feeding others is among the most emphasized charitable acts in Islam. The Qur'an praises those who "give food, despite love for it, to the needy, the orphan, and the captive" (Qur'an 76:8). The Prophet (SAW) said, "Feed the hungry, visit the sick, and free the captive" (al-Bukhari, 5373). Feeding the hungry addresses immediate poverty and symbolizes compassion. In many African cities, hunger remains a pressing issue despite food abundance in some regions. Establishing community kitchens, Ramadan feeding programs, and school meals through Islamic organizations embodies this prophetic practice and ensures social inclusion.

Qard al-Hasan (Benevolent Lending)
Qard al-Hasan is a distinctive Islamic economic instrument. It involves giving a loan without expecting profit or interest, purely for the sake of Allah. The Qur'an refers to it as a "loan to Allah": "Who is it that would loan Allah a goodly loan so He may multiply it for him many times over?" (Qur'an 2:245). In addressing African poverty, *Qard al-Hasan* can serve as an ethical alternative to exploitative microfinance systems. It empowers small traders, farmers, and artisans to grow economically without falling into debt traps. Islamic banks and community cooperatives can institutionalize this form of assistance to promote financial inclusion.

Kaffarah (Expiation Offering)
Kaffarah refers to compensatory charity given to atone for specific sins or broken oaths. For instance, one who breaks a fast or an oath must feed the poor as a form of expiation (Qur'an 5:89). Beyond personal atonement, *Kaffarah* promotes a culture of responsibility and social care. It transforms individual repentance into communal benefit, directing resources toward the needy and maintaining moral accountability in society.

Fidyah and Fidya (Ransom or Substitutional Charity)
Fidya is similar to *Kaffarah* but applies when one is unable to perform certain religious obligations, such as fasting, due to illness or old age. The Qur'an allows substitution through

feeding the poor (Qur'an 2:184). In practice, *Fidya* ensures that even those unable to perform acts of worship can contribute socially. Organized collection and distribution of *Fidya* during Ramadan can fund community feeding programs and medical care, particularly for vulnerable populations in Africa.

Nadhar (Vows)
Nadhar, or vows, involve dedicating something to Allah contingent upon a fulfilled condition. When a Muslim makes a vow to give charity upon achieving a goal, it transforms gratitude into a tangible social benefit. Though voluntary, fulfilling vows demonstrates integrity and reinforces faith-based generosity.

Tawzi' *al-Mirath* (Fair Distribution of Inheritance)
Islamic inheritance (mirāth) ensures equitable distribution of wealth after death. The Qur'an's detailed inheritance laws (Qur'an 4:11–12) prevent the concentration of wealth in a few hands. Properly applied, these laws sustain intergenerational equity and social balance. In African societies where informal inheritance practices sometimes marginalize women and orphans, applying Islamic inheritance laws can protect vulnerable groups and promote economic justice.

It'am al-Jār (Feeding the Neighbour)
Feeding the neighbour is a noble prophetic practice. The Prophet (SAW) said, "He is not a believer whose stomach is filled while his neighbour goes hungry" (*al-Tabarani*). Neighbourly care builds local solidarity, the foundation of sustainable communities. In African cities where poverty often hides behind walls, reviving the ethics of neighbourly feeding can rebuild social trust and communal responsibility.

Sadaqah Jariyah (Continuous Charity)
Sadaqah Jariyah refers to an ongoing charity whose rewards and benefits continue even after death. Building a school, digging a well, or publishing beneficial knowledge are examples. It is the most sustainable form of giving, merging spiritual continuity with social development. In Africa, *Sadaqah Jariyah* projects—such as boreholes, scholarship schemes, and educational foundations are vital for long-term poverty reduction.

Attakrim (Honourable Generosity)
Attakrim emphasizes dignified generosity. It is not just giving, but giving with honour and respect. The Qur'an instructs, "Do not nullify your charities with reminders or injury" (Qur'an 2:264). True generosity preserves the recipient's dignity and avoids creating dependency. This value is essential for sustainable poverty alleviation in Africa, where charitable acts must empower rather than humiliate. *Attakrim* turns charity into partnership and compassion into social transformation.

Sustainability Lessons from Islamic Giving
The Islamic philosophy of giving goes beyond immediate relief. It is designed to build enduring social structures that preserve dignity, promote justice, and sustain prosperity. Each form of giving discussed above, *Zakkah, Sadaqah, Waqf, Qard al-Hasan*, and others, offers lessons that are profoundly relevant to contemporary African development

challenges. In essence, Islam's concept of generosity aligns closely with the modern idea of sustainability, which emphasizes empowerment, balance, and long-term social welfare.

Empowerment over Dependency

One of the most distinctive features of Islamic giving is its focus on empowerment rather than dependency. Islam encourages the able-bodied poor to become self-reliant. The Prophet Muhammad (peace be upon him) once helped a man sell his belongings to buy an axe, telling him to collect firewood instead of begging (Abu Dawud, 1641). This story captures the spirit of empowerment that lies at the heart of Islamic charity. *Zakah, Sadaqah*, and *Qard al-Hasan* all encourage productive use of wealth. When these funds are invested in vocational training, small businesses, or agricultural projects, they move beyond charity to create economic resilience. In many African nations, such empowerment-based charity can transform local economies, reduce unemployment, and prevent the social stigma associated with perpetual aid dependence. Furthermore, Islamic charity recognizes the psychological dignity of the recipient. Acts of giving should uplift rather than humiliate. By prioritizing empowerment through education, entrepreneurship, and microfinance, Muslim communities can make charity a catalyst for sustainable growth.

Institutionalizing *Waqf* and *Zakah*

Sustainability in Islamic social finance depends on institutionalization. Historically, Muslim societies thrived when Waqf and *Zakah* were organized under transparent systems. Waqf institutions built universities, hospitals, and public utilities that lasted for centuries without government funding. Similarly, structured *Zakah* collection ensured that wealth circulated fairly within society. In Africa, where informal giving is common but often uncoordinated, institutionalizing these practices is vital. Creating Zakah and Waqf boards at national or regional levels can ensure accountability, equitable distribution, and measurable impact. Modern technologies such as digital payment systems and data mapping can also make *Zakah* and *Sadaqah* more efficient and inclusive. Nigeria, for example, has seen growing interest in *Zakah* and *Waqf* management through state and private initiatives. If well-coordinated, such institutions could supplement government efforts in education, health care, housing, and employment creation. Institutionalized giving transforms spontaneous generosity into structured development, ensuring continuity and measurable outcomes.

Modern Applications and Policy Recommendations

The modern African state, facing poverty, inequality, and youth unemployment, can draw inspiration from Islamic giving models to promote ethical and inclusive development. Several policy directions can be derived from the principles of Islamic giving:

i. Integrating Faith-Based Social Finance: Governments and NGOs can partner with religious institutions to mobilize *Zakah*, *Waqf*, and *Sadaqah* funds for social development projects. This strengthens community participation and builds trust.
ii. Promoting Ethical Microfinance: *Qard al-Hasan* (interest-free loans) should be incorporated into national poverty alleviation programs. These interest-free financial services align with Islamic ethics and protect the poor from exploitation by high-interest lenders.
iii. Establishing Sustainable Waqf Projects: Modern Waqf assets can fund schools, hospitals, renewable energy projects, and agricultural cooperatives. The profits

generated can continuously support welfare programs without depleting the original capital.

iv. Encouraging Corporate *Zakah* and Social Responsibility: Muslim-owned businesses can be motivated to institutionalize *Zakah* and *Sadaqah* contributions as part of their corporate social responsibility (CSR). This bridges the gap between profit and social good.

v. Education and Awareness: Educating Muslims about the transformative potential of their giving obligations can enhance compliance and transparency. Islamic Studies and Economics departments in African universities can integrate *Zakah* and *Waqf* studies into their curricula.

vi. Data and Impact Measurement: Establishing data-driven systems for tracking *Zakah* distribution and social impact can ensure that giving leads to measurable poverty reduction and community development.

When these principles are applied holistically, Islamic giving evolves from a mere act of worship into a framework for sustainable economic transformation. It empowers individuals, strengthens families, and revitalizes communities.

Faith, Sustainability, and the African Future

Faith and sustainability are not opposing forces; they are complementary. Islam's approach to giving integrates spirituality with social action, faith with responsibility, and worship with development. By embracing these values, Africa can cultivate a model of growth rooted in ethics, solidarity, and balance. Islamic giving promotes circulation of wealth, social inclusion, and economic justice—all of which are prerequisites for sustainable development. If systematically applied, these principles can help Africa move from a culture of dependency to one of dignity, from sporadic charity to structured empowerment.

Conclusion

The Islamic philosophy of giving provides a timeless and comprehensive model for addressing poverty through ethical redistribution, empowerment, and sustainability. Unlike conventional approaches that often treat poverty as a purely economic issue, Islam recognizes it as a moral, spiritual, and social challenge that requires both structural and individual responses. Every act of giving, whether through *Zakah*, *Sadaqah*, *Waqf*, *Qard al-Hasan,* or other charitable pathways serves not only to relieve hardship but to preserve human dignity and social balance. At the heart of this philosophy lies a profound truth: wealth belongs to Allah, and human beings are merely its trustees. This awareness transforms economic activity into an act of worship and stewardship. When Muslims give, they affirm their faith and sustain their community. The Qur'an's call to charity is therefore not a call to loss, but to renewal of faith, justice, and human solidarity. In the African context, where poverty persists despite abundant natural and human resources, Islamic giving offers both ethical and practical solutions. Institutionalized *Zakah* can serve as a reliable mechanism for redistributive justice; Waqf can ensure continuity of social services; *Sadaqah* can build compassion and social trust; and *Qard al-Hasan* can promote inclusive economic growth. Together, these pathways form a multidimensional framework capable of complementing government and international development efforts.

Furthermore, the Islamic model aligns with the United Nations' Sustainable Development Goals (SDGs), especially those focused on eradicating poverty (Goal 1), promoting decent work (Goal 8), and reducing inequalities (Goal 10). Yet, unlike secular models, Islam grounds these goals in spirituality, ensuring that development remains human-centered and morally guided. The essence of sustainability in Islam is not merely environmental or economic; it is spiritual sustainability, ensuring that wealth circulates in ways that please Allah and uplift humanity. Therefore, to "think sustainability" from an Islamic perspective is to think holistically: to view every act of giving as part of a divine system of balance (*mīzān*), where justice, compassion, and accountability converge. Africa's poverty challenge cannot be solved by external aid alone; it requires a revival of internal moral economies rooted in faith and mutual care. As the Prophet Muhammad (peace be upon him) taught, "The upper hand is better than the lower hand" (al-Bukhari, 1429), a statement that perfectly captures Islam's vision of empowerment through giving. In conclusion, the Islamic framework of giving rich with moral depth and economic wisdom invites Muslims in Africa to reimagine generosity not as a seasonal act, but as a sustainable social system. By reviving and institutionalizing these prophetic models of sharing, African societies can move closer to achieving both material prosperity and spiritual fulfillment. It is in this synthesis of faith and action, of worship and work, that the enduring solution to poverty lies.

Recommendations

Based on the analysis presented in this chapter, the following recommendations are proposed to enhance the role of Islamic charitable instruments in addressing poverty sustainably in Africa:

i. **Strengthen *Zakah* Administration:** African nations with Muslim-majority populations should adopt structured *Zakah* management systems through recognized institutions to ensure transparency, accountability, and equitable distribution to the deserving categories.
ii. **Revitalize Waqf Institutions:** Governments, Islamic organizations, and wealthy individuals should invest in modern *waqf* projects such as hospitals, schools, microfinance funds, agriculture, and renewable energy initiatives that generate continuous benefits.
iii. **Promote Awareness and Literacy on Islamic Social Finance:** Religious leaders, educators, and media platforms must intensify campaigns to educate Muslims about the economic and spiritual benefits of *Zakah*, *Sadaqah*, and *Infaq*.
iv. **Encourage Community-Based Development Projects:** Local mosques and Islamic centers should mobilize community giving to fund cooperative ventures that create employment, skill development, and long-term livelihoods rather than temporary relief.
v. **Enhance Digital Philanthropy Systems:** Governments and Islamic NGOs should embrace digital technology for collecting, tracking, and reporting charity funds to increase trust, efficiency, and accessibility, especially in rural communities.
vi. **Policy Collaboration between Scholars and Government:** Islamic scholars should partner with policymakers to design pro-poor economic frameworks grounded in maqasid al-Shari'ah (objectives of Islamic law), emphasizing justice, dignity, and social security.

vii. **Support Entrepreneurship and Productive Giving:** Charity funds should shift from one-time handouts to empowerment: microloans, vocational training, and financial inclusion programs that help beneficiaries become self-reliant contributors to society.

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Chapter 9

SCIENCE AND TECHNOLOGY FOR AFRICA'S DEVELOPMENT

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Abstract
Africa's development is dependent upon a number of factors for its actualization. These factors range from human and natural resources to scientific and technological innovations. However, as important as nature's gifts land and minerals are, science and technology are central to meaningful economic transformations, social progress and sustainable development. Unfortunately, despite the recognized importance of scientific and technological growth, many African countries remain positioned at the periphery of global innovations systems compared to other regions, progress in research intensity, technological production and innovation diffusion has been relatively slow and uneven. A lack of investment in science and technology has been the bane of Africa and this has hampered its development. It's a sad commentary that the continent of Africa is faced with structural and institutional constraints that have hindered them from embracing digital innovations through science and technology. This chapter examines the role of science and technology in Africa's depth by exploring the interconnections among certain variables including technological advancements, human capital, governance, infrastructure and innovation architecture. It also employs a qualitative, synthesis of existing scholarship, drawing on peer-reviewed literature studies, policy reports and international datasets to construct a consolidated analytical perspective. Thematic analysis was used in identification of key innovation trends, challenges and opportunities in Africa's development landscape. It highlights that despite the benefits of digital transformation-particularly in mobile technologies, financial services and emerging innovations such as artificial intelligence- has brought about improvement to access of services and enhanced productivity, its broader developmental impact remains constrained by limited local innovation capacity, weak institutional coordination and inadequate

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investment in research and development. To address these challenges, the chapter proposes an integrated conceptual framework that positions science and technology as a core driver of development, supported by four interdependent pillars: human capital development, innovation systems, governance and policy environment and infrastructure capacity. The analysis demonstrates that the effectiveness of S&T depends on the strength of interactions among these components rather than on technological availability alone. The study concludes by presenting some approaches to be taken to bring Africa out of this quad mine to include increased R&D investment, educational reform, good governance policy, infrastructure expansion and the promotion of context-specific innovation. It argues that a coordinated and systems-based approach is essential for enabling Africa to transition from technology consumption to endogenous innovation, thereby achieving inclusive and sustainable development.

Keywords: *Science and Technology, Innovation systems, Sustainable development, Africa, Digital transformation, Human capital, Governance and Policy.*

Introduction

Today's digital innovations can be seen in every aspect of human activity as a product of science and technology. Any scientific and technological transformations in Africa would translate to improved standard of living, economic growth, social progress and global competitiveness. Countries that have made huge investments in research, innovation and digital infrastructure have experienced accelerated industrialization and improved societal well-being in that these advancements foster production efficiencies necessary for robust economic expansion (Mugwagwa et al., 2021). It is only the countries in Europe and America that have embraced the science and technology. Many Asian countries are also in the fold. The dividends are clear. These countries now dictate the pace in production, innovation, digital infrastructure etc. Africa has not fully keyed in. This explains why Africa's GDP is only 3% yet, this is a continent rich in natural resources and large human population. Africa is backward as investments in technological innovations and scientific research is slow and uneven leading to persistent development gaps relative to other continents. However, there are some flashes of hope. For some time now, Africa has relatively witnessed some digital and technological advances, mobile technologies, digital financial services, e-learning platforms and innovation hubs have increasing transforming sectors such as agriculture, education, and healthcare delivery, thus enhancing productivity (Gebreslassie et al., 2022).

This impact has y not pulled Africa out of poverty. This is owing to the fact that these initiatives often remain fragmented, underfunded and limited in scale. There are underlying challenges including insufficient research funding, infrastructure deficit, shortage of requisite skills and weak coordination – all these hinders Africa's science and technology progress. In the light of this, the African Union came up with STISA-2024 framework to address these challenges with emphasis on the urgent need for harmonized policies that supports research infrastructure and technical competence (Sobseh, 2023). Other development frameworks including the United Nations Sustainable Development Goals

(SDGs) and Africa's Agenda 2063, point to the importance of integrating science and technology into national and regional strategies (Kahn, 2022). These initiatives underscore the positive impacts of technology on productivity, economy, society and sustainable growth. Sadly, translating these global objectives into result-oriented actions remains a critical challenge to researchers and policy makers in Africa. The actualization of these laudable objectives has often been hampered by policy voids in Africa. These policy voids should be bridged through the systematic input of human capital, expansion of national resemble architecture and development spending which remains grossly low relative to the growing body of scientific expertise (Dobrzański et al., 2021; Najib et al., 2024).

Statement of Problem

Africa, endowed with both human and abundant natural resources is far behind other continents in the world of scientific and technological innovations. The countries of Africa are more of consumers than producers. This has retarded the growth and development from every front. There are myriads of challenges they contend with including low investment in research and development, insufficient skilled human capital and weak institutional structures (Odei et al., 2022; Pedersen, 2024) This has adverse consequences- there is over reliance on imported technologies thereby limiting local innovation and adaptation capacity. No Africa country can manufacture button mobile phone let alone android phone, television set, transistor radio, motorcycles and millions of other technological inventions. Everything is imported. It is laughable that Nigeria imports toothpicks. These leads to limitation of indigenous technological creation. Moreover, lack of synergy, cooperation and coordination among institutions contribute worsening state of scientific and technological landscape in Africa.

Research Gap

Many researches often focus on isolated aspects of technology such as ICT adoption in agriculture or financial inclusion through mobile money -without examining the broader interplay between innovation, governance, human capital and economic growth. Africa accounts for less than one percent (1%) of global research output, there are telling structural gaps in Africa's research. It has become increasingly difficult to address challenges in the science, technology, engineering and mathematics (STEM). The few available literature (research works) relies heavily on experiences developed countries, which may not reflect Africa's institutional, cultural and economic realities (Rakotondrazaka & Xu, 2024). These gaps, however, are driven by lack of funding, shortage of trained personnel, government empathy and limited infrastructure. This chapter addresses these gaps by adopting an integrated framework that highlights both challenges and opportunities of well-articulated research works.

Methodological Approach

A simple and concise approach is adopted in this study. This includes a qualitative, narrative review design aimed at synthesizing existing knowledge on the role of science and technology in Africa's development. The study relies exclusively on secondary data sources, including peer-reviewed journal articles, scholarly books, policy documents, and reports from international organizations such as the African Union and the United Nations. A systematic but flexible literature search strategy was employed to identify relevant studies

published in reputable academic databases and institutional repositories. Priority was given to recent publications to ensure the inclusion of contemporary perspectives on digital transformation, innovation systems and sustainable development in Africa. The analytical approach is based on thematic synthesis, through which key themes such as innovation systems, human capital development, governance structures and technological adoption were identified, compared and critically evaluated. This approach enables the integration of diverse strands of literature into coherent framework that reflects the complex and interconnected nature of technological development on the continent. By adopting this method, this study provides a comprehensive and context-sensitive understanding of both the opportunities and structural challenges shaping Africa's science and technology landscape, while avoiding the limitations associated with single-sector or purely descriptive analyses.

Review of Existing Literature

There have been extensive examinations of the role of science and technology (S&T) in Africa's development. The emphasis has been on innovation systems, digital transformation and sustainable development outcomes. Researches and Scholars are of the opinion that technological driven innovations are integral to economic growth and structural transformation. They agree that the whole landscape is marked by a "silent" yet sluggish technological revolution where the potential for local innovation remains tied or tethered to the complexities of scaling existing solutions (Kaydor, 2025). Technological advancement in the continent is uneven as recent studies show. It is more pronounced in sub-Sahara Africa. The argument of Atiase, Kolade, & Liedong, (2020) makes waves. They argued that, although innovation research in Africa developing in Africa, much of it is influence by external local ownership of knowledge production. In the same vein, Amankwah-Amoah, & Medase, (2023) option that African universities in African countries don't have the institutional capacity and funding strength needed to drive research and innovation, forcing a reliance on external models that fail to address the peculiar nature of their institutional and economic constraints. The positive relationship between innovation and economic performance is alarming. The contribution of technological innovation to economic growth is significant in Sub-Saharan Africa, but has not reached great heights due to non –harmonized innovation systems that lack well-articulated linkages between universities, government, and the private sector (Kahn, 2022). Digital technologies, as demonstrated by Hailu, (2024) have enhanced financial inclusion and expanded access to essential services, particularly with the use of mobile platforms. Yet these tools often function outside the framework of formal industrial policy, limiting their capacity to drive deeper structural transformation.

Certain sector-specific studies further illustrate the transformative potential of science and technology. For example, Abbasov, (2025) shows that the use of mobile phone has improved market efficiency and access to information for African agriculture. On the other hand, Manu, (2025) highlights the role of mobile money in expanding financial frontier, noting that these gains must be integrated with regulatory quality and infrastructure improvement to deliver a strong and viable economy in these prevailing technologies, the impact of artificial intelligence (AI) has been positive. It has everything to drive scientific and technological innovation. According to Byaro, & Rwezaula, (2024), AI has the potential to improve productivity in developing regions, including Africa, but its adoption is constrained

by data scarcity, inadequate technical expertise and limited infrastructure to support large-scale deployment. More recent studies Kruger, S., & Steyn, R. (2023) emphasis that although AI applications are growing gradually in the healthcare and education sectors, their scalability is limited in scope. However, education remains central to meaningful technological development. Akon-Yamga et al (2024) argues that higher education systems in Africa must be restructured to align with innovation and labor market demands. This is supported by Nwokolo et al (2023) who notes that there is a clear disconnect between academic training and industry needs, and this hinder technological advancement.

Theoretical Framework

This chapter draws on an integrated theoretical foundation with National Innovation Systems (NIS) and Systems Thinking. The innovation is the interplay and interaction among key institutional actors as conceptualized by the NIS framework (which was articulated by Christopher Freeman and Bengt-Åke Lundvall. while this framework has been widely applied in developed economics, its relevance in African requires contextual reinterpretation. In many African Countries, the expected Synergies between universities, industries and government are weak or fragmented, limiting the effectiveness of innovation systems. To address this limitation, the Systems Thinking approach is incorporated to provide a holistic perspective. Doe et al (2022) describes systems thinking as an analytical lens that captures the dynamic relationships between interconnected components. Within the African context, this approach is particularly useful for understanding how deficiencies in one domain such as infrastructure can constrain progress in others, including education and innovation. The concept of technological leapfrogging further complements this framework. Wang'ang'a, (2024) argue that late-developing economics can accelerate development by adopting advanced technologies without passing through intermediate stages. Africa's rapid uptake of mobile technologies provides empirical support for this argument (Folorunso et al., 2024) However, leapfrogging alone does not guarantee sustainable development, especially in the absence of local innovation.

Critical Analysis of Existing Literature

Although the literature provides valuable insights, it exhibits several critical shortcomings that limit its explanatory and practical relevance A major limitation is lack of systemic integration. Many studies examine technological development within isolated sectors, thereby overlooking the interdependencies that shape broader development outcomes. For example, while research on mobile technology adoption. Andersen et al (2021) demonstrates clear benefits, it rarely considers how such innovations interact with education systems, industrial policies, or governance structures (Andersen et al., 2021). Another concern is the overemphasis on technology consumption rather than production. A significant portion of the literature focuses on how new African societies adopt existing technologies, with limited attention to how new technologies are created within the continent. This narrow focus reinforces a passive model of development and underestimates the importance of endogenous innovation. The issue of contextual misalignment is also evident. Many theoretical frameworks applied in African studies originate from developed economics and are often transferred without sufficient adaptation.

As a result, they fail to account for structural realities such as institutional fragility, informal economies and infrastructural deficits. The critique aligns with the arguments Jacks et al (2024), which stress the importance of context-specific instructional arrangements. Furthermore, the literature reveals a methodological imbalance, with a predominance of descriptive and cross-sectional studies. While such approaches are useful for identifying trends. They are less effective in explaining causal relationships or long-term dynamics. Hakimi et al (2022) highlight the need for more rigorous empirical methodologies including longitudinal and mixed-method designs, to better capture the complexities of technological diffusion and its subsequent impact on economic growth. Finally, the external dominance in knowledge production raises importance epistemological questions. The limited participation of African scholars in global research outputs may result in narratives that do not fully reflect the nuance of local grounded research frameworks. (Osabutey & Jackson, 2024)

Conceptual Framework

This study proposes an integrated conceptual framework that explains how science and technology (S&T) can drive sustainable development in Africa through the interaction of key structural and institutional components. The framework builds on insights from the National Innovation Systems (NIS) perspective and systems thinking, while incorporating Africa-specific realities and challenges (Kadakure & Twum-Darko, 2024; Mienye et al., 2024). As its core, the framework conceptualizes science and technology as an enabling driver, whose impact on development is mediated by four interrelated pillars: human capital development, innovation systems, governance and policy environment and infrastructure capacity. These elements operate within a dynamic ecosystem in which feedback loops and interdependencies determine the overall effectiveness of sustainable development initiatives (Dodoo et al., 2025). This holistic perspective acknowledges that deficiencies in one area, such as digital infrastructure, can significantly impede progress in others, thereby necessitating integrated policy approaches rather than isolated interventions (Tamasiga et al., 2022).

Core Components of the Framework

I. **Science And Technology (S&T) Inputs:** Science and technology constitute the foundational inputs of the framework. these include: a) research and development investments, encompassing both public and private sector expenditure on scientific inquiry and technological innovation; b) the adoption and adaptation of frontier technologies, including but not limited to artificial intelligence, biotechnology, and advanced materials, which demonstrates heterogeneous effects on economic growth, particularly a modest growth-enhancing effect that reduces at higher quantiles but is augmented by egalitarianism (Ofori et al., 2025); and c) the overall scientific and technological knowledge base, as reflected in publications, patents, and technical expertise, acknowledging the imperative for contextually grounded research to ensure relevance and impact within diverse African settings (Forscher & Schmidt, 2024). These inputs serve as catalysts for innovation, productivity enhancement and sectoral transformation. However, their effectiveness is critically moderated by the institutional and structural capacities within which they are applied (Oghuvbu et al., 2022).

ii. **Human Capital Development:** Human capital represents a critical enabler of technological advancement, encompassing the skills, knowledge, and creative capacities of a population (Adenle et al., 2023). it encompasses: a) robust educational systems that prioritize STEM disciplines and interdisciplinary approaches (Luo et al., 2024); b) vocational and technical training initiatives aligned with industrial demands; and c) continuous professional development and research opportunities that foster a culture of innovation and scientific inquiry (Dirir, 2023). A skilled workforce enhances the ability to adapt, adopt and create technologies locally. In the African context, gaps in STEM education and misalignment between academic training and industry needs continue to limit innovation capacity and technological absorption (Tyxhari et al., 2023).

iii. **Innovation Systems:** Innovation systems refer to the network of institutions involved in knowledge creation and diffusion, including universities, research centers, private firms, and governmental bodies (Omonijo & Zhang, 2025). Effective innovation systems require strong collaboration and knowledge exchange among these entities, thereby facilitating the translation of scientific discoveries into marketable products and services (Ofori et al., 2024). In many African countries, weak linkages and limited funding reduce the capacity of these systems to generate impactful innovation.

iv. **Governance and Policy Environment:** The policy and institutional context play a central role in shaping technological development. This includes: a) regulatory frameworks that promote investment in R&D and intellectual property protection; b) policies that incentivize entrepreneurship and technology transfer; and c) stable political environments that foster long-term planning and commitment to science and technology initiatives (Chibebe et al., 2024). Supportive governance structures facilitate investment in innovation, protect intellectual property and promote collaboration. Conversely, policy inconsistency and weak institutions hinder technological progress (Qamruzzaman & Kor, 2023; Udo et al., 2024). Infrastructure, helps with the deployment and total diffusion of technological solutions especially in energy and digital connectivity state. The framework also emphasizes that these components use a dynamic interaction among them.

v. **Development Outcomes:** The combined effect of these components leads to key development outcomes, including economic growth and industrialization, job creation and entrepreneurship, improved service delivery in healthcare and education and enhanced social inclusion and reduced inequalities (Ketchoua et al., 2025). However, the realization of these outcomes depends on the degree of alignment and coordination among the framework components.

vi. **Contextual Considerations for Africa:** The framework recognizes several contextual factors that shape its application in Africa: high dependence on imported technologies, limited R&D investment, informal economic structures and rapid population growth and urbanization, all of which necessitate tailored policy interventions to foster indigenous innovation and technology adaptation (Asongu et al., 2025). These factors necessitate context-sensitive approach that prioritizes local innovation, capacity building and institutional strengthening (Afolabi & Adeyinka, 2024).

Framework Proposition

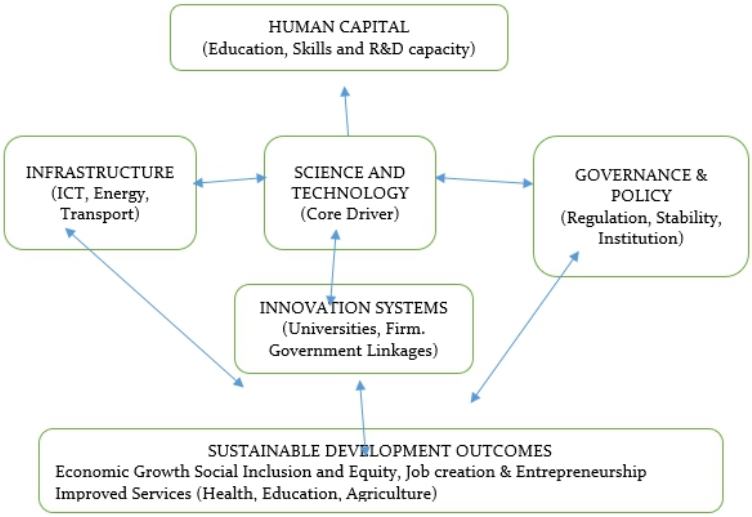

Figure 1: Integrated science and technology development framework for Africa, illustrating the dynamic interactions between science and technology, human capital, governance, infrastructure and innovation systems in driving sustainable development outcomes.

Discussion and Thematic Analysis

In this section, the role of science and technology in African's development is examined thoroughly with the use of the proposed conceptual framework. This uses ideas gotten from existing literature thereby providing an adequate analytical perspective on how structural, institutional and technological factors relate to improve the innovative outcomes over the continent.

i. **Science and Technology Which Acts as a Tool to the Economic Transformation:** In Africa, the idea of innovations has rapidly become the source of economic diversification. Kuti et al. (2023) proposed that the integration of digital tools and technical knowledge has improved productivity in some areas like agriculture and healthcare. Sobseh (2023) gave an instance that mobile technologies which have enhanced market access for farmers, reduced the high price of transactions and also initiated access costs to financial services. Hence, the S&T transformative potential however remains constrained by the continent's limited capacity for internal innovation (Nwokolo et al., 2023). Many of the technological improvements seen in Africa were as a result of exogenous developed solutions instead of locally generated scientific breakthroughs (Pedersen, 2024). As a result, the long-term impact on industrialization and structural transformation is often limited. Sustainable economic development needs to move away from technology production, supported by strong research and innovation ecosystems ("Global Sustainable Development Report 2023," 2023).
ii. **Digital Transformation and Socio-Economic Involvement:** Digital transformation have appeared to be one of the most significant developments in Africa's technological landscape. Innovations like online banking, online learning

platforms and digital health systems have increased the access to essential services, especially for underserved populations in developing and remote areas (Kaydor, 2025). These modern tools have led to financial inclusion, improved educational access and health care delivery (Asongu et al., 2025) for example, online banking platforms have helped so many individuals to take part in formal financial systems, whereas online learning tools have reduced the educational system in remote areas (BOIKANYO, 2025). Not minding the importance, digital inequality still remains a major concern. Little access to the network, high cost of data and disparities in digital literacy continue to remove vital portions of the population. There will be risks of digital transformation causing existing socio-economic inequalities instead of reducing them if there are no deliberate policy interventions (Ogundipe et al., 2023).

iii. **Structural Hindrances in Innovation and Technological Improvement:** The effectiveness of S&T in driving development is significantly obstructed by continuous structural bottlenecks. Lack of infrastructure especially in energy and digital connectivity is one of the most notable hindrances (Status of Digital Agriculture in 47 Sub-Saharan African Countries," 2022). Unsteady electricity supply and low bandwidth access prevent the scalability of technological solutions, thereby preventing their importance for widespread socio-economic impact (Arsène, 2024). In addition, fostering indigenous innovation and technological advancement across the region is as a result of low investment in research and development (Ofori et al., 2025). Some African countries apportion a minimal percentage of their GDP to R&D, thereby reducing the capacity of universities and research institutions to create new knowledge and then change it into practical applications (Gumbo & Moos, 2025). The institutional vulnerabilities further worsen these problems. The reduction of the effectiveness of S&T initiative is due to Fragmented policy frameworks, bureaucratic inefficiencies and lack of coordination among stakeholders. These systematic issues emphasize the importance for a more integrated and coordinated method to innovation policy and implementation over the continent. (Kala, 2023; Udo et al., 2024).

iv. **Human Capital and Skills Development:** Human capital plays an important role in knowing the success of technological improvement. An experienced and skilled workforce is move for the adoption, adaption and creation of new technologies. In Africa, however, notable gaps exist in education and skill development. A lot of educational sectors are not well arranged enough with the demands of new technological economies, leading to skill mismatches and lack of technical expertise (Garcia, 2025). This notably deficit is compounded by lack of digital literacy programs, that are important for making sure that marginalized areas can take part effectively in the digital economy and overcome the pervasive digital divide (Okonkwo, 2025). Moreover, little investment in science, technology, engineering and mathematics (STEM) education restricts the improvement of technical knowledge individuals needed to control the industrial growth and competitiveness (Awode & Oduola, 2024; Selemela et al., 2023) solving these problems needs complete educational changes that prioritize practical skills, innovation and entrepreneurship (Hapompwe et al., 2024)

v. **Governance, Policy and Industrial Changes:** The act of governance and policy environment is a core source of technological progress. Policies that are effective can lead to innovation, attract investment, and fast–track collaboration between academia, industry, and government (Gebreslassie et al., 2022). In many African countries, however, policy implementation remains unstable. While several nations have mapped out national strategies for science, technology and innovation, but the way it is carried out is often delayed by weak institutional frameworks, little funding, and a lack of coordination among key stakeholders (Villalba et al., 2025). Issues such as constant corruption, political instability and doubt sabotage the effectiveness of governance structures by preventing the stability of the predictable environment needed to keep technological development and investment moving (Khene et al., 2026). In order to develop an enabling environment for technological improvement, there must be policy coherence and institutional capacity must be strengthened as well. These ideas enable the governments, academia and the private sector to establish partnerships among themselves thereby building a robust national development system (Mantey, 2024)

vi. **Emerging Opportunities: Artificial Intelligence and Frontier Technologies:** Upcoming technologies, especially artificial intelligence (AI), represent significant opportunities for accelerating development in Africa. AI applications have the power to change some sectors such as healthcare, agriculture, education, and public administration that have great impact in solving the complex developmental challenges (Matthee & Scheepers, 2023). For example, AI-driven diagnostics tools can improve healthcare delivery in under-privileged areas while predictive agriculture can enhance agricultural yields and resilience to climate change through efficient resource management (Tregenna, 2023). Similarly, digital platforms powered by advanced technologies in the same way, can support entrepreneurial growth and development (Ajayi-Nifise et al., 2024). However, the involvement of these technologies is limited by problems like restricted data infrastructure, lack of technical expertise and ethical concerns attributed to data governance and algorithmic unstableness. To completely use these opportunities, African countries must make an effort to invest in digital infrastructure, develop local expertise and establish good regulatory frameworks that solve these problems while encouraging responsible innovation (Diallo et al., 2024)

vii. **Policy Implications and Recommendations:** When analyzing African's science and technology landscape, it pinpointed some strategic policy implications in order to sustain development and strive innovation growth. These laid down recommendations will help to strengthen the continent's technological capacity, push institutional resilience and engage inclusion of socio-economic transformation.

viii. **Strengthening Research and Development(R&T) Investment:** To sustain investment in research and development should be paramount for fronting indigenous technological advancement thereby reducing much dependence on imported innovations. The African government in power should of necessity increase R&D budgets to at least 1% of GDP, in line with international benchmarks (Nwokolo et al., 2023). In addition, there should be dedicated funds solely for innovation to support indigenous technological developers and starts ups

(Carpenter et al., 2026). Strengthening partnership of public-private is also a move to mobilize financial resources, share risks, and hastened innovation within high-impact research frame such as healthcare, agriculture and so on (Kasongo & Makamu, 2024). By promoting investment in R&D will go a long way in moving adoption of technology from passive to active (Gong et al., 2025).

ix. **Enhancing Human Capital and Technical Skills:** There is no advancement in African's technology without human capital development in the center. It is necessary to rephrase educational system to be atone with industry demands, particularly in STEM disciplines, data science, artificial intelligence and biotechnology (Egbeleo & Sodokin, 2025). Expansion of vocational and technical training programs should be look into by the government with its target on emerging technology areas while promoting digital literacy in all levels. (Dirir, 2023). Polices mainly on limiting brain drain and retaining skilled actors in this region renews local innovation ecosystems (Omonijo & Zhang, 2025). In an atmosphere where competent workforce is developed, benefits such adoption, adaption and creation of indigenous technologies, will be of Africa's gain.

x. **Building Strong Innovation Ecosystems:** Effective towards innovation needs strong cooperation's among universities, research institutions, industries and government (Udo et al., 2024). The countries under this region urgently needs to create innovation clusters, hubs or research network for both national or regional to boost collaborative innovation and knowledge exchange (Byaro & Rwezaula, 2024). Incentives initiatives such as grants, tax relief and co-financing scheme should be made available to private sector, to encourage them to fully invest in research and innovation activities (Byaro & Rezaul, 2024; Dirir, 2023). Furthermore, to establish intellectual property protection scheme will improve commercialization processes, safeguard innovators and encourage entrepreneurship (Ofori et al., 2024). This coordination in the innovation ecosystem will positively impact technological initiatives and then ensure that the fruits of innovations is showcased economically and socially.

xi. **Strengthening Governance and Policy Coordination:** Governmental effectiveness and policy coherence points towards the maximization of benefits of science and technology. Development of integrated national innovation strategies that align with continental frameworks such as STISA-2024 and Agenda 2063 is one of the tasks of the government (Chibebe et al., 2024). Coordination among ministries that works for the technology, education, industry and infrastructure development must be improved to prevent fragmentation or duplication of the policy (Adenle et al., 2023). Then, when there are transparency, accountability and institutional efficiency, tendency of stable regulatory environments is assured leading to long-term technological development (Afolabi, 2023). Remember, structure build on strong governance are proves of sustainable and inclusive technological development.

xii. **Expanding Infrastructure and Digital Connectivity:** Infrastructure is central for both technological diffusion and economic inclusion. This region should prioritize investment in areas like digital infrastructure, broadband connectivity, data centers, and internet exchange system in-order to hasten the growth of digital trade and innovation (Africa, 2025). Renewable energy such as reliable and steady electricity

supply is a gateway for renewing technology driven industries and digital economies (Abbas, 2025). Moreover, upgrading the transportation and logistics systems reduced the problem of limited access and non-distribution of technological products and services across urban and rural areas (Buru et al., 2025). Enhanced infrastructure will allow technological access for more communities and strengthen socio-economic inclusion across the continent (Sobseh, 2023)

xiii. **Promoting the Adoption of Emerging Technologies:** Emerging technologies such as artificial intelligence, block chain and big data analytics present real ways to move Africa's potentials. Policymakers should enforce regulatory frameworks whose work towards improving the ethical, secure and responsible use of these technologies (Lay & Tafese, 2025). Support mainly for pilot programs and big-scaling initiatives for implementation in sectors A sectors such as healthcare, governance and education should be in place (Begazo et al., 2023). Further requirements to reduce technological dependence and better local expertise is solely on capacity-building programs and knowledge sharing. (Pedersen, 2024).

Summary of Policy Implications

In a nutshell, for Africa to grow through S&T, there is need for a key which is wholly integrated and coordinated as remarked by this chapter. Enlisting the branches of this key is of importance such as investing R&T, developing human capital, strengthening innovation systems, improving governance, expanding infrastructure, embracing emerging technologies, Fostering Regional and South-South Cooperation and promoting context-sensitive innovation. it is worth noting that it is not about having this key, but putting it in use will bring about a gigantic wave in Africa's science and technology landscape for rapid growth.

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