Article

STEM Education and Workforce Development in Africa: Unraveling Impediments Towards Bridging the Skills

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ABSTRACT

Africa's pursuit of sustainable development and economic competitiveness hinges on closing the continent's skills gap in its workforce. Central to this is Science, Technology, Engineering, and Mathematics education, a driver of innovation, industrial advancement, and global relevance. This paper examines the impediments to STEM's transformative role in bridging the critical skills divide, such as outdated curricula, limited infrastructure, teacher training, weak industry-academia linkages, and the marginalization of indigenous apprenticeship models. It highlights broader structural issues such as gender disparities, brain drain, digital inequality, and poor alignment between educational outcomes and labor market needs. It argues for a transformative, context-responsive framework that blends modern pedagogy with indigenous knowledge systems, digital fluency, and industry collaboration. Ultimately, it offers forward-looking, actionable recommendations for Africa's future global competitiveness.

Keywords: African education, African development, Curriculum Reform, Indigenous Knowledge Systems, STEM Education, Skill Development, Skill Gap, Workforce Development

INTRODUCTION

The demand for skilled workers and professionals has been rising for decades. This increase is driven by the expansion of businesses, industries, and innovations since the Industrial Revolution. Effective STEM (science, technology, engineering, and mathematics) education is essential for developing a skilled workforce. However, there is growing concern that educational institutions cannot keep up with the demands of these advanced fields, especially in countries facing economic challenges and struggling to develop their education systems. As a result, a gap exists between the number and quality of workers that businesses and industries require and what schools produce, creating a "skills gap." While discussions about this skills gap are global, this article focuses on the African continent and the role of effective STEM education in addressing this issue, given the region's large population. Industry leaders, legislators, innovators, and educators are all focused on how to ensure that students in schools today acquire the skills needed for current and future jobs, especially considering the rapid pace of innovation.

Researchers have recognised the place of STEM education in closing this skill gap (Asuke et al., 2023; Said, 2021). Governments, businesses, and educational institutions must collaborate to reassess how best to reposition school programs to meet the needs of the labor market. The strength of the next generation of innovators will determine Africa's destiny. A 2021 World Bank report titled "Skills for the Future" shows that only 40% of the workforce in Africa possesses the skills needed in today's workplaces, indicating a critical skills gap of 60% (Guàrdia et al., 2021; Badmus & Omosewo, 2020; Guardia-Ortiz, 2020; Jang, 2016). Due to a shortage of qualified and competent applicants, many job openings in STEM-related industries and vocations remain unfilled for long periods. The report also shows that a staggering 70% of African youths do not have access to high-quality education, a major contributor to the skill gap (World Bank report, 2021). The 2020 African Development Bank (AFDB) report, "The Future of Work in Africa: Harnessing the Potential of Digital Technologies for a Sustainable Future," is another notable source. It states that, to survive, Africa will need 40 million skilled workers by 2030. Less than 10% of these technology-related jobs currently have qualified workers to fill the positions. UNESCO's (2020) statistics further reveal that a striking 72% of African students do not finish secondary school, meaning they lack the necessary Mathematics and English language skills to pursue careers in STEM fields, contributing to the observed skill gap. Additional information about the situation in Africa can be found in the 2020 Microsoft Africa Development Centre reports, the 2020 McKinsey Global Institute Centre Survey, and the OECD Skill Outlook, all of which highlight the need to reskill and upskill STEM graduates, increase African governments' annual investments in education, and improve literacy and numeracy if Africa is to meet its goal of creating 30

million jobs by 2030. With less than five years remaining to reach this target, it is essential to discuss the current state of STEM education across the continent. This paper, therefore, explores the potential of STEM education in unlocking Africa's development by bridging the skill gap, the drawbacks, and the pertinent changes towards the future.

The objective of this paper is, therefore, to critically examine the current place of STEM education in advancing workforce development in Africa, with a focus on the current skills gap that threatens the continent's socio-economic progress and global competitiveness. It aims to unravel the underlying impediments that militate against effective STEM education delivery and workforce readiness in Africa, examining both systemic and contextual barriers. These barriers include outdated curricula, poor infrastructure, teacher quality gaps, limited access to technology, and weak linkages between education and industry. Although awareness of STEM as a catalyst for innovation, industrialization, and sustainable growth is increasing, Africa still struggles with a disconnect between graduates' skills and what the modern workforce requires (Akudugu & Abagale, 2024; Daniels et al, 2022; Fomunyam, 2021). Additionally, the study highlights the overlooked indigenous African apprenticeship systems as potential collaborators in equipping learners with practical, culturally relevant skills.

Also significant is the paper's timely contribution to the discussion on human capital development and economic transformation in Africa, including the rising skills mismatch and high youth unemployment amid rapid technological change. The paper emphasizes the crucial role of STEM education in tackling these challenges. By identifying the primary obstacles to effective STEM education and workforce readiness, it provides essential evidence for reforming current education systems to meet the needs of the 21st century. The comprehensive analysis used in this paper not only reveals systemic and structural barriers but also incorporates indigenous knowledge systems, digital innovation, and industry collaborations into the solution framework. In doing so, it moves the conversation beyond policy rhetoric, offering practical, actionable ways to align STEM education with labor market realities.

Furthermore, this study holds significance for multiple stakeholders. For policymakers, it presents strategic insights for designing inclusive and responsive education policies. For educators and curriculum developers, it offers a framework for pedagogical transformation and relevance. For industry players, it identifies opportunities for collaboration in shaping a future-ready workforce. And for development partners, it highlights investment areas with long-term impact potential. Ultimately, this study contributes to a growing body of knowledge that aims to position Africa's youthful population as a global asset, leveraging STEM education as a transformative tool for sustainable development, innovation, and economic competitiveness.

While some studies have examined the state of education and workforce development in Africa, there is a need to provide a comprehensive, context-specific analysis of STEM education as both a challenge and a solution to the continent's growing skills gap. Existing literature often separates technical education from indigenous knowledge systems or focuses on policy without directly connecting it to classroom realities and labor market demands (Chisom et al., 2024; Bardoe et al., 2023). This study addresses that gap by offering a detailed and nuanced perspective that combines systemic analysis with practical strategies for reform. By exploring dimensions such as indigenous African apprenticeship models, digital inclusion, gender equality, and industry-academia collaboration, the paper promotes a more holistic and culturally grounded framework. This contribution is not only theoretical but also actionable, providing a roadmap for aligning STEM education with Africa's socio-economic goals and the demands of the Fourth Industrial Revolution.

This paper presents a comprehensive, context-aware framework linking STEM education with Africa's labor market needs. It advocates for strategic reforms that go beyond classroom instruction to include innovation, collaboration, digital skills, entrepreneurship, and policy adaptation. This is with a view to igniting new discussions and offering practical insights for educators, policymakers, industries, and development partners to close Africa's skills gap and build a resilient, future-ready workforce.

LITERATURE REVIEW

This paper explores the relationship between STEM education and workforce preparation, along with the factors that influence it. It is based on educational models, workforce development theories, and interdisciplinary concepts that explain how STEM education can help close the skills gap in modern workplaces.

Models of STEM Education

In a bid to uncover more effective ways of implementing STEM education to meet the skill needs of workplaces, the following models are documented in the literature. Over time, the development of STEM courses has been greatly influenced by the following theories and paradigms.

Constructivist learning models (Piaget, 1954; Vygotsky, 1986) draw from students' past knowledge and social interaction. STEM education exposes students to real-world skills and industry expectations by encouraging them to actively participate in laboratory and field work, coding simulations, engineering site work, and community assignments.

- Student Industrial work experience (SIWE) projects, which require/ partial inclusion of real-world experiences into the academic program.
- Inquiry-based learning (IBL), where students are encouraged to explore their environment and address real-world problems, enhances their critical thinking, problem-solving skills, and understanding of workplace realities. Using this learning approach to ask open-ended questions and seek solutions both independently and collaboratively prepares students for numerous STEM careers, especially in research and development.
- Problem-based learning (PBL). Students work on short-term or long-term projects, cutting across a variety of STEM fields. It is a practical method that helps them develop the hard and soft skills necessary for the multidisciplinary nature of contemporary STEM employment.

Theories about Workforce Development

These components describe how STEM education customizes curricula to meet the demands of the job market and ultimately closes the skills gap between the two. A significant force in this field, the human capital theory (HCT), is based on the idea that a good education increases productivity, which raises the economic worth of society and those who spend money on education and training (Blundel et al, 2005; Cinnirella & Streb, 2017). By connecting classroom learning activities to workplace demands, STEM education that aligns with labor market needs can enhance the quality of human capital by providing students with the technical, analytical, and soft skills they need to succeed in the science, technology, healthcare, and engineering sectors. As industries demand a more skilled workforce to keep pace with technological advancements, STEM education must, as a matter of urgency, focus on its crucial role in producing individuals with the capacity to meet the labor market's skill needs.

Theory of Lifelong Learning

To remain relevant in the workplace, this theory emphasizes the importance of lifelong learning, upskilling, and reskilling. According to Davis (2001), lifelong learning is the process of developing human potential through ongoing support, enabling individuals to acquire the skills, values, and attitudes they need throughout their lives and utilize them whenever and wherever needed. Accordingly, lifelong learners are those who are compelled to pursue their goals by always working to establish a connection between their education and their everyday lives through ongoing skill development and improvement (Beier, 2021; Devi, 2017; Gündüz, 2023). The need for lifelong learning has increased due to several global concerns, including rapid technological progress, a new wave of industrialization, demographic shifts, and environmental imperatives (Mosweunyane, 2017; Longworth & Davis, 1996). Because of these factors, the skills of today's workers may quickly become outdated, meaning that the only way

anyone stays skilled is through lifelong learning. According to Kaplan (2016) and Finsterwald & Spiel (2014), lifelong learning encompasses both in-school and out-of-school learning that leads to rapid changes and helps individuals develop competencies in various areas throughout their lifetimes. Programs for STEM education must adapt to provide workers and trainees with opportunities to continually enhance their skills in line with the evolving technological demands of their jobs (Swain-Oropeza et al., 2023; Bromber, 2021). The development of critical thinking processes, communication, teamwork, problem solving, the scientific research process, experimentation, knowledge diversity, and multidisciplinary should all be incorporated into such programs. This supports the notion that when sectors change, people must be prepared to participate in reskilling and upskilling initiatives.

Skills Mismatch Theory in STEM Education

The skill mismatch theory provides an alternative view on the discrepancy between the skills that job seekers have and those that companies want and desire. It implies that educational systems often fail to produce graduates who possess the skills required by modern industries and businesses. The skills mismatch theory holds the view that there is the need for educational institutions to update, innovate, improve, and modify STEM curricula and implementation strategies by incorporate new technologies, new knowledge, and skills -set that are apposite to workplaces and the labor market of today (Devrani et al., 2024; Henderson et al., 2011). The societal scourge of youth unemployment and underemployment are consequences of skill mismatch. Restrepo (2015) noted that due to skill mismatch, cognitive jobs declined from 25% to 21% within the period 1999 to 2015. This decline has continued as more cutting-edge technologies reduce and automate previous cognitive positions. This is expected to become worse in this era of artificial intelligence. Other studies (McGuinness et al., 2018) harped on over-education and skill under-utilization as also related to skill mismatch, while Adely et al. (2021) and Yahya et al., (2024) blame it on poor education. This model further emphasizes the importance of collaboration and harmony between educational institutions and industries in determining and relating education outputs to workforce demands. Obvious from these is the unresolved issue of educational mismatch resulting from the disconnect between curricula achievements and workplace requirements.

Theories of Sociocultural Learning and Equity in STEM

The foundation of sociocultural theories is the part that community, culture, and social relationships play in education. When it comes to fair access to STEM education, these theories are especially pertinent. Vygotsky (1978; 1986) asserts that when students receive assistance from a more experienced person, they are better equipped to learn more challenging tasks. This approach can guide the

creation of educational experiences in STEM education that push students to learn new abilities while getting support from peers, mentors, or teachers. It also emphasises the role that symbols and tools have in the growth of critical thinking. Designing curricula that are diverse in terms of learning strategies, modalities, and resources to accommodate students with different skill levels and backgrounds is supported by the sociocultural position (Kendricks et al, 2013). Another component of Vygotsky's theory that has implications for STEM in connecting education and the workplace is the role of culture in the development of cognitive processes and collaborative thinking.

The theory of cultural capital proposed by Pierre Bourdieu (1977; 1986) also serves as a fulcrum for this investigation. It posits that students' social backgrounds influence their access to learning resources and support, which in turn affects their academic success. These variations may result from cultural capital and influence a person's aptitude and prospects for professional progression in STEM disciplines. Students from underrepresented or underserved groups often face challenges in STEM education, including limited access to technology, a scarcity of role models, and fewer opportunities for experiential learning. Designing inclusive and equitable STEM education policies that ensure all students can pursue STEM careers requires an understanding of the sociocultural influences that shape these fields. Proper understanding of these limitations will foster better policies on STEM education that offer an equal and fair playing ground to learners of all categories and, as such, close the workforce gap.

Multidisciplinary Education and Skills for the Twenty-First Century

STEM education must go beyond traditional topic understanding and integrate the development of 21st-century skills through intentional policies and practices, addressing the complexity of the modern workforce.

- Encouraging interdisciplinary STEM education by emphasizing how the component disciplines are related to the workforce from other industries that employers desire. A combination of mathematics, computer science, and specialized subject knowledge from subjects like biology or economics is required in fields like data science. Students get the capacity to think across disciplines and use a variety of viewpoints to tackle complex problems because of this integration in STEM education. This is critical for success in STEM fields such as artificial intelligence, renewable energy, biotechnology, environmental sustainability, green energy, climate change, and related areas.
- Concentrating on developing 21st-century abilities like creativity, critical thinking, teamwork, communication, and adaptability in addition to the technical know-how that employers respect. These abilities are especially crucial in fields where creativity is essential. Through project work, fieldwork, experiential learning, and interdisciplinary learning activities,

STEM education must provide students with opportunities to develop these competencies. To prepare students for dynamic work contexts where both technical knowledge and soft skills are essential, learning experiences should be centered on problem-solving activities, cooperation, collaboration, and creative thinking.

The interplay between STEM and Technical, Vocational Engineering and Technology (TVET)

Changes in the job market have spurred curriculum innovation in multidisciplinary, skill-based, cross-cutting disciplines to fulfill workplace skill requirements. TVET programs aim to close the skills gap in the workplace by incorporating industry-relevant vocational education and training (VET) skills and practical exercises customized for specific organizations. Students can gain the practical experience necessary for high-demand jobs in fields such as software engineering, advanced manufacturing techniques, and medical technology. Incorporating these curriculum changes into secondary and tertiary STEM education holds the potential to enhance relevance to the demands of the job market (Asuke et al., 2023; Said, 2021). The health sector can employ the technical apprenticeship paradigm to produce qualified workers for that sector.

RESEARCH METHOD

Research Design

This study adopted the qualitative exploratory design with document analysis and key informant interviews. This design is considered appropriate given that the study aims to unpack complex, systemic impediments to STEM education and their implications for workforce development across African contexts. The research prioritized depth of insight over statistical generalization.

Study Scope and Context

The study focused on selected Sub-Saharan African countries (e.g., Nigeria, Kenya, Rwanda, and Ghana) undergoing educational reforms and workforce development challenges. The experiences in these countries are chosen because the author believes their experiences will help to illuminate both shared and context-specific obstacles in STEM education advancement and the implications for Africa's workforce development.
Data Sources and Collection Methods

Document Analysis: A critical review of government policy documents, national curricula, UNESCO and World Bank reports, institutional frameworks, and peer-reviewed literature was conducted, enabling the identification of systemic patterns and gaps in STEM education policies and implementation.

Key Informant Interviews: Semi-structured interviews were conducted with STEM educators in secondary and tertiary institutions, Curriculum developers and policymakers, representatives of industries (especially in ICT, engineering, and biotechnology sectors) that employ STEM education graduates, and leaders of indigenous apprenticeship programs. These interviews were conducted either face-to-face or through electronic means where distance and time schedules were issues. Such electronic interviews ranged from three to five minutes and focused on issues such as the quality of STEM graduates in their organizations, views on the academia-industry relationship, and the integration of indigenous apprenticeship, among others. These interviews helped the author gather firsthand information on specific experiences, institutional challenges, and innovations.

Data Analysis

Thematic Analysis was employed to identify recurring themes, trends, and unique insights from both documents and interviews. Findings were categorized around key constructs, including curriculum quality, teacher preparedness, digital infrastructure, policy support, apprenticeship integration, and industry relevance. To ensure credibility, triangulation was used by cross-verifying interview data with document sources.

The study was limited by access to high-level policymakers or industry leaders and science educators in all targeted countries; Variation in national data availability and consistency of education policy documents; Language barriers or policy opacity in francophone or lusophone African countries; and Ethical concerns were ensured as interviews were carried out without coercion of the interviewee. Informed consent and confidentiality were ensured as all participants volunteered information without coercion throughout the study.

Participants: African countries that are making efforts to narrow the current skill gap through laudable programs as available in their policy documents and current literature constitute the participants in this study. The countries and their initiatives are

Rwanda: A Knowledge-Based Economy Vision

As a means of transitioning from an agrarian to a knowledge-based economy, Rwanda has made significant progress in developing STEM education.

Vision 2020 and 2050: These national strategies of Rwanda aim to leverage STEM education to shift from an agrarian to a knowledge-based economy, emphasizing information and communication technologies (ICT) and engineering. These are some of the initiatives that are transforming the country in that direction.

With a focus on building a digital workforce, the Smart Rwanda Master Plan integrates ICT into all sectors of the economy (Nibeza, 2015; Hakizimana, 2015; Arnold, 2022). By partnering with multinational tech companies like Microsoft, Andela, and Carnegie Mellon University (CMU), which opened a campus in Kigali to offer graduate programs in STEM fields, the government has advanced STEM initiatives.

STEM Schools and Teacher Training: To encourage more girls to study STEM, Rwanda established model STEM schools, like the Forum for African Women Educationalists (FAWE) Girls' School. To guarantee that teachers can provide contemporary STEM curricula, the government has also made significant investments in teacher training (Blimpo & Pugatch, 2019; Sibomana, 2023).

FabLabs and Innovation Hubs: Two examples of innovation centers that give students access to technology, mentorship, and chances to hone practical technical skills are Kigali Innovation City and FabLab Rwanda. By encouraging experiential learning and entrepreneurship, these centers play a crucial role in closing the gap between education and workforce demands. If these initiatives and programs are maintained and expanded, it is anticipated that Rwanda will soon start to see improvements in the skill gap.

Kenya: The Digital Learning Program (DLP) and STEM Hubs

Through these initiatives, Kenya has made tremendous progress in closing the STEM skills gap.

To improve STEM education and introduce ICT to young children, Kenya started the Digital Learning Program (DLP) in 2016 intending to give more than 1 million primary school students digital devices (Ndaka, 2024). Despite certain obstacles, like inadequate infrastructure and unprepared teachers, the program has been successful in exposing a sizable portion of the target population to digital tools, which has sparked interest in STEM fields.

Through the efforts of the Ministry of Education and the Centre for Mathematics, Science, and Technology Education in Africa (CEMASTEA), Kenya also built STEM Model Schools and Centres of Excellence. This was done to improve STEM instruction. In order to prepare students for professions in STEM subjects, such as engineering and technology, these institutions provide specialized facilities and curricula.

The government's Ajira Digital Program is another Kenyan initiative that aims to equip young people in the country with digital skills and connect them to international online employment opportunities. To prepare people for labor in the central digital economy, the program placed a strong emphasis on teaching them in areas such as software development, data science, and ICT. This has created new job opportunities for Kenyan youths in the gig economy, thereby reducing the STEM skills gap in the ICT sector.

To promote coding, digital literacy, and workforce development, Kenya has partnered with global IT companies such as Google, Microsoft, and IBM. Programs like Microsoft's YouthSpark and Google's Africa Developer Scholarship are crucial in equipping Kenyans with the technological skills necessary for the global workforce.

These initiatives have contributed significantly to the development of Kenya's tech sector, particularly in Silicon Savannah, Nairobi, which has led to a sharp rise in entrepreneurship and innovation driven by STEM expertise.

South African experience: National Development Plan and STEM Advancement. The following programs were developed in South Africa to address the STEM talent gap.

The National Development Plan 2030 aims to enhance STEM education to reduce poverty and create employment opportunities. The development of scientific, engineering, and technological skills is prioritized, primarily through Technical and Vocational Education and Training (TVET) institutions.

The South African Institute of Chartered Accountants (SAICA) launched the Thuthuka Program and other scholarship programs to encourage STEM vocations among disadvantaged pupils. To support people who want to work in science and technology, the government also provides funding for STEM scholarships.

Through integrated ICT education, ICT and e-learning have become extremely popular and prioritized in schools. Enhancing access to technology and raising digital literacy in schools are the goals of Operation Phakisa and the National ICT Policy. iii. To promote digital skills, the Vodacom Foundation has funded the building of ICT infrastructure in schools.

The establishment of educational institutions and science centers through the South African Agency for Science and Technology Advancement (SAASTA), which runs science centers throughout the nation and offers engaging STEM instruction to spark young people's interest in science-related jobs.

The number of STEM graduates and professionals in engineering and technology sectors has steadily increased because of these initiatives, programs, and regulations. Inequality and disparities in access to high-quality STEM education between metropolitan areas with greater affluence and rural and underprivileged communities continue to be a significant obstacle to these efforts.

Nigeria's skill gap reduction adventures: National STEM Policies and Youth Initiatives. The primary goal in Nigeria is to enhance the education of the country's large youth population in STEM fields, thereby preparing them for the workforce. Nigeria's distinct demographics as the continent's most populous nation place it in a unique position to play a crucial role in closing the skills gap in Africa and promoting economic growth for the continent.

Prioritizing STEM education in the national curriculum and teacher training programs is one of the main steps the nation has taken in this direction thus far. To raise the standard of science and technology education starting in primary schools, the National Teacher Institute (NTI) provides STEM teachers with specialized training, by focusing on young people and encouraging the development of STEM skills through several youth empowerment and entrepreneurship programs, like N-Power projects and YouWiN! Connect. N-Power helps close the gap between education and workforce demands by offering STEM training to youth in areas like coding, animation, and digital marketing.

The private sector's contribution to youth funding and skill development. For instance, tech behemoths like Google and Microsoft have teamed up with neighborhood groups to promote digital literacy and STEM education. Founded in Nigeria, Andela is renowned for educating young software developers and introducing them to opportunities around the world. Likewise, initiatives such as Coven Works provide instruction in robotics, data science, and artificial intelligence.

Innovation Hubs and Incubators: Co-Creation Hub (CcHub) in Lagos and iDEA Nigeria are two examples of Nigeria's expanding network of

innovation hubs that offer young innovators in STEM subjects practical experience and guidance.

Entrepreneurial studies and skill acquisition programs have been made mandatory requirements for graduation in all HEIs in Nigeria, raising hope of a future generation getting ready to become potential emerging leaders in Africa's shift to a digital economy. However, doing so necessitates making significant investments in vital STEM education infrastructure, lowering poverty, and closing the resource gap between rural and urban areas.

RESULTS

The findings from the document reviews, interviews, and case study analyses revealed various systemic, pedagogical, and structural barriers that still hinder the transformative potential of STEM education in closing Africa's workforce skills gap. They include:

1. Curriculum-Workforce Mismatch: In all participating countries, stakeholders voiced concern that current STEM curricula are primarily theoretical, outdated, and not aligned with labor market needs. Employers in the ICT and manufacturing sectors consistently noted a gap in graduates' preparedness for new roles that require soft skills, practical experience, and digital literacy.
2. Teacher Preparation and Capacity Gaps: STEM educators lamented the lack of continuous professional development and the absence of practical teaching aids. Schools in rural settings lack exposure to modern technologies and interdisciplinary teaching strategies. This limited their ability to inspire students or integrate real-world problem-solving into STEM instruction.
3. Infrastructure and Digital Divide: Rural schools faced severe deficits in infrastructure, such as basic laboratory facilities and reliable and affordable internet. While some urban schools piloted robotics clubs or STEM competitions, such innovations were rare in low-resource settings, perpetuating inequity in access and exposure.
4. Weak Industry–Academia Collaboration: The study revealed minimal collaboration between industries and educational providers. Internships, mentorships, and joint research initiatives were either absent or ad hoc, missing the opportunity to tailor training towards employability and innovation.
5. Neglect of Indigenous Knowledge Systems: A recurring theme was the underutilization of African indigenous apprenticeship models and

problem-solving approaches that could enrich STEM learning, especially in technical and vocational areas. Elders and local artisans who held valuable practical knowledge were rarely engaged in formal curriculum processes.

6. Promising Interventions: Despite challenges, several success stories emerged. A case from Kenya highlighted a public-private partnership that embedded coding and robotics into junior secondary school curricula. Another example from Nigeria demonstrated how a university-industry collaboration improved curriculum relevance and provided on-site training for engineering students.

DISCUSSION AND CONCLUSIONS

As African countries struggle with the problem of cross-border migration brought on by unemployment, concerns about the quality and suitability of the labor pool have become critical, particularly about workforce development, economic growth, and the future of employment, especially in industries that depend on products of STEM education. The skills gap is the difference between the number of skilled workers and the number of jobs they are qualified to perform (Banu & Angamuthu, 2022); the skills that employers look for in their workforce and the qualifications, competencies, and capabilities that job seekers possess (McKenney & Handley, 2019; McKenney & Handley, 2020); or a lack of skills in both formal and informal sectors impeding individuals' ability to secure employment (Shah, 2023). Skill gaps in cognitive, technical, and interpersonal skills are prevalent in industries undergoing rapid technological advancement. The demand for workers proficient in emerging technologies often outstrips the supply of qualified graduates available. The consequences of this skills mismatch are far-reaching and affect not only the competitiveness of industries, their productivity and efficiency, but also individual economic mobility. This gap is most apparent in sectors that rely heavily on innovation and technological integration, such as information technology, biotechnology, advanced manufacturing, healthcare, and data analytics, all of which are STEM-related. Workers are expected to possess both fundamental STEM knowledge and proficiency in cutting-edge technologies, which are often not addressed by traditional educational models, as emerging technologies such as artificial intelligence, robotics, and machine learning transform various sectors.

The following kinds of skill gaps in Africa have been recognized by the World Bank (2022) and the African Development Bank (AfDB).

1. Technical abilities such as information and communication technology (ICT), STEM (science, technology, engineering, and mathematics)-related fields, and vocational and technical abilities

2. Deficits in soft skills in leadership, problem-solving, communication, teamwork, and time management
3. A lack of digital skills in data analysis, cybersecurity, artificial intelligence, digital literacy, and online collaboration tools
4. Skill gaps in entrepreneurship in areas including marketing, financial management, company planning, innovation, and skill management
5. Language proficiency gaps in indigenous African languages, English, French, Arabic, and Portuguese
6. The inability to think critically, analyze complex information, solve problems creatively, and make well-informed decisions
7. Creativity and innovation, including design thinking, innovative problem solving, innovative thinking, and entrepreneurial attitude

Employers are increasingly looking for skills like data analysis, coding, and cybersecurity, which are still new to most STEM programs. People with soft skills like communication, critical thinking, problem-solving, and adaptability are also in short supply (Mohammed & Ozdamli, 2024; Varadinov & Cardoso, 2024; Karimi & Pina, 2021; Karimi, 2020). Although they are not discipline-specific, these abilities are essential for working well in fast-paced, multidisciplinary, and collaborative work settings that are consistent with STEM responsibilities in modern industries and workplaces.

Due to societal shifts, there is a significant demand for specialized skills in advanced technology businesses. Multidisciplinary fields, including programming, statistics, and technological expertise that integrate digital skills, are highly sought after. The disparity between supply and demand necessitates that STEM education programs be redesigned to meet the needs of the sectors they are intended to serve.

In terms of producing STEM graduates, Africa is behind other continents with 21.7% between 2015 and 2020, compared to East Asia and the Pacific (25.6%) and Europe and Central Asia (24.3%) (United Nations policy brief on STEM education in Africa, 2022). This has a significant impact on the economic growth of African countries. The survey also showed that few people in African countries possess the level of required digital skills needed in current workplaces. The survey found that only 4% of adults in Sudan and Zimbabwe could perform basic "copy and paste" digital tasks, which limited their capabilities. In Nigeria, there is a deficit of individuals with skills in electrical installation and medical health professionals, complicated by brain drain. Between 1993 and 2000 alone, Ghana lost 68% of its health professionals to brain drain. This process has continued unabated to date. Over 600,000 South African graduates are unemployed due to skill mismatch. This is significant when we consider that the International Finance Corporation has projected that by 2030, Africa will need 230 million people with digital skills to meet its labor demands, as almost 85% of the

continent's existing workforce will be obsolete. There is therefore an urgency to unravel the causes and possible remedying factors, as the situation persists two years after and is expected to last less than five years until 2030.

Key Sectors Affected by the Skills Gap

- While the skills gap is evident across a range of industries, specific sectors are particularly vulnerable due to their reliance on specialized STEM skills:
- Technology sector, especially in fields like software development, data analytics, cybersecurity, and artificial intelligence. There is a fierce search for talent in these industries, as demand continues to rise faster than supply. Companies are frequently compelled to look for applicants abroad or make significant investments in retraining current staff members to cover the void.
- Medical care: Workers with both healthcare practice and STEM abilities are in high demand in the healthcare industry due to the adoption of new medical technologies and data-driven decision-making procedures. The skills gap in this area is growing due to a lack of experts qualified to operate sophisticated medical equipment, analyze massive amounts of health data, or oversee telemedicine platforms.
- Engineering and advanced manufacturing sectors, where the requirement for sophisticated technical expertise and the growing automation of processes are causing huge skills gap. Intricate STEM skills are demanded of workers, especially in mechanical, electrical, raw material, computer, agricultural systems, robotics, and mechatronics engineering.
- Space projects and astronautically related expeditions

Factors that influence the skill gap

Numerous interconnected issues that affect both the availability of skilled workers and the changing needs of companies are to blame for the current skills gap. Designing successful workforce development interventions and subsequently closing the gaps requires an understanding of these elements.

1. **Innovation in Technology and Industry Upheaval:** Several industries are experiencing a skills gap as a result of technology advancements, including automation, robots, artificial intelligence, big data, and data analytics. By needing specialised and innovative skills, these technologies reduce manual employment and enhance the requirement for workers with advanced machinery (Shmatko & Volkova, 2020). The gap between what students learn and what businesses and industries require is a result of educational systems' ongoing struggles to adapt to these advancements. Although some institutions

have incorporated new technologies, development is still uneven, slow-paced paced and in some cases, wrongly directed, particularly in areas with limited resources or funding.

2. **Outdated STEM Curriculum and Training Systems for Education:** The intricate problem-solving and interdisciplinary teamwork that STEM professionals need in the fourth industrial economy were not taken into account by traditional educational paradigms, which were created for the first, second, and third industrial economies. This disparity is made worse by a lack of collaboration between companies and educational institutions. Although colleges and universities play a crucial role in producing the next generation of STEM experts, their curricula might not always be in line with the, pressing demands of employers (Chisom et al., 2024). The most significant gaps, according to industry leaders, are in areas such as data analysis, cybersecurity, coding skills, and science research, as well as unfamiliarity with new technologies like cloud computing and blockchain.

3. **STEM Teacher Shortages and Poor Professional Development:** One of the most critical factors that impact the quality of STEM education is the availability of trained STEM educators. There has been ongoing concern about the lack of qualified STEM instructors with solid credentials, especially in specialised subjects like computer science, robotics, data science, biology, chemistry, physics, and biotechnology (Taylor, 2023). Many instructors today lack the necessary skill set and professionalism to stay current with emerging pedagogical approaches and technologies. Students are less likely to acquire the excellent education required to succeed in a modern STEM vocation without qualified teachers in schools (Dungs et al., 2024; Germuth, 2018). STEM subjects are undergoing advancement in content and skills requirements; educators must continuously improve their knowledge and abilities to provide high-quality, relevant instruction. In secondary school, where there is a dearth of instructors with expertise in computer science, robotics, auto engineering, mathematics, physics, chemistry, and biology, this problem is especially severe. This lack of knowledge affects students' interest in STEM courses as well as the quality of instruction. Teachers may find it challenging to present material in ways that engage and motivate students if they lack confidence or expertise in current STEM areas. Students may thus lose out on acquiring the vital skills required to excel in STEM professions, which further exacerbates the skills gap.

4. **Socioeconomic and Geographic Disparities:** Access to high-quality STEM education and training varies substantially across different socioeconomic and geographic contexts in Africa. Students from disadvantaged backgrounds or

rural areas often have less exposure to STEM subjects due to underfunded schools, a lack of STEM-trained teachers, or limited access to technology. The skills gap is made worse by this educational injustice, which feeds a vicious cycle in which under-represented groups are under-represented in STEM fields that are in high demand. These geographic imbalances not only hinder workforce development but also limit the ability of regions and nations to compete in the global economic space (Muremela et al., 2023; Shabaya et al., 2004). Some national governments, by their programmes and policies, seem oblivious of the connection between economic, technological development, education, and human capital development upon which sustainability is built. This indifference not only creates but also continuously widens the skill gap.

5. **Gender and Diversity Gaps in STEM:** Demographic data from some African countries show near population equivalence in terms of gender. For example, in Nigeria, Statista (2023) shows that there are approximately 110.67 million females compared to 113.13 million males. The World Bank data of the percentage of females by total population of countries in sub-Saharan countries shows that the female population ranges between 48 to 55% of the total population of the nations (World Bank Open Data, 2022). Despite this huge population of women, there is an intimidating underrepresentation of women in STEM fields, which exacerbates the skill gap. Gender stereotypes, cultural biases, and a dearth of role models for under-represented groups are just a few of the major obstacles that persist despite efforts to promote diversity in STEM education and careers (Meyer et al., 2015; McCloy et al., 2020; Amirtham & Kumar, 2023). In disciplines essential to closing the skills gap, such as computer science and engineering, women are notably underrepresented. This lack of diversity not only narrows the talent pool but also limits the range of perspectives and ideas that contribute to innovation in STEM industries. Closing the gender and diversity gap is therefore critical not just for equity, but for tapping the full potential of available human capital for their workforce.

Strategic interventions for bridging the skills gap in Africa through STEM education:

For Africa to move towards economic growth and prosperity, certain strategic actions must be taken to close the skills gap. STEM education aims to prepare students for the changing demands of the labour market. Embracing interdisciplinary learning and ideas from STEM, arts, and humanities through project-based learning, industrial experience, and field-based research, STEM education will help students prepare for the world of work. This approach will

enable students to solve real-world challenges and replicate the cross-functional, collaborative nature of contemporary workplaces. It will also foster the following.

1. The development of human competencies and skills that call for consciousness, ongoing evolution, and the application of intelligence, which machines and robots find challenging to comprehend, should be given priority. Availability, continuous training, motivation, and retention of STEM teachers are of utmost importance in maintaining dedication, positive attitude, and sector stability. The teaching and learning of foundational subjects that are integral to STEM knowledge and skills, such as Basic science, mathematics, physics, chemistry, biology, and coding, should be prioritized at the primary and secondary school levels to focus students' mindset on STEM fields as their future career path. Continuous professional development programs for teachers should be prioritized, focusing on equipping STEM teachers with the knowledge and skills to teach and use new technologies, methods, and innovations. Governments and educational institutions must also ensure that STEM teaching materials and resources are available to all teachers, including digital tools, modern textbooks, and online learning platforms. Providing incentives to teachers to work in rural or underfunded schools, where the shortage of STEM teachers is often more prevalent, is also of the essence in improving teacher competence. This can be achieved through salary adjustments, bonuses, housing incentives, cheap digital resource material, and career development opportunities.

1. Incorporating new technologies. Modern workplaces are dominated by cutting-edge technologies such as robotics, data analytics, machine learning, and artificial intelligence (AI) guarantee that students obtain practical experience with the tools and systems they will come across in their careers, STEM education must integrate these technologies into the implementation, learning, and assessment of learning outcomes (Moemeke, 2024; Triplett, 2023; Chen et al., 2020; Zafari et al., 2022). Such fundamental skills as coding, automation, and data literacy should become integral components of STEM programs across all levels. The implication is that African nations must begin to invest in STEM education without counting the cost, since that is the route to future economic and technological competitiveness. Primary and secondary schools, which are the cradle of education, need serious attention as interest in STEM fields is incubated and nurtured at this developmental stage

2. STEM education and industrial collaboration. It is impossible to overstate the importance of regular research on industry skill requirements if STEM education programs must align with their needs. Direct cooperation between academic institutions, businesses, and research organizations can

produce this kind of data. It is necessary to expand and modify current internship, apprenticeship, mentorship, and cooperative models that allow students to participate in brief student industrial work experiences (SIWES) in addition to their academic studies (Moemeke, 2013; 2022). Making decisions on what to teach and how it should be taught starts at the curriculum planning and development stage, which is where effective industry collaboration should begin. This guarantees that the curriculum taught in schools aligns with what employers require.

3. Acquiring both technical and soft skills. The abilities necessary for effective integration into workplaces in the new millennium are clearly outlined in the 21st-century skills and their constituent parts. The 4Cs (critical thinking, communication, collaboration, and creativity), as well as flexibility, problem-solving, emotional intelligence, leadership, and information management, are becoming highly valued by employers without sacrificing technical expertise in STEM professions. In STEM fields, the ability to convey complex technical concepts to a variety of audiences is especially crucial (Moemeke, 2023; King-Kostelac et al., 2022). STEM schools must include them in their current curricula or create general education courses that emphasise these abilities.

4. Adaptable STEM education for a lifetime. In a world where abilities can be swiftly rendered obsolete by technological breakthroughs, students must become lifelong learners to keep abreast with emerging tools, technologies, approaches, and concepts. This can be accomplished by incorporating reskilling and upskilling programs using online learning environments and other flexible learning choices that enable in-service employees to continuously upgrade their skill sets throughout their careers. Employers of STEM workers must maintain a relationship with tertiary STEM education departments and faculties for retraining, retooling, and refresher courses. It may also be offered as part-time programs or evening classes. This should be an in-built part of workers' remuneration and upgrading requirements.

5. Reaching underprivileged and rural populations. A larger proportion of Africa's population resides in rural areas. Bridging the skill gap requires providing these areas with access to high-quality, efficient education. These underprivileged groups can be reached and made to acquire vocational training by utilising the potential that digital technology offers. Assisting students to acquire necessary skills, regardless of their location, as well as through digital platforms for STEM courses, is essential. Bridging the skills gap also requires affordable and dependable internet infrastructure, which African governments and the business sector should invest in. Also, organized financial aid and scholarships to indigent

students with a strong affinity for STEM courses should be integrated into programmed solutions for bridging skill gaps in African nations.

6. Promoting gender equality and inclusivity in STEM: With a nearly equal population of males and females on the continent, concerns about equal access, availability, and quality education for both sexes should be at the forefront of any strategy to close the skills gap. Efforts to eradicate cultural and social biases that reinforce gender-stereotypical career paths should be included in the actionable programs of nations. The underutilization of the African demographic dividend and human capital is greatly exacerbated when women are unintentionally (or otherwise) excluded from certain STEM careers due to family structure. This under-representation inhibits innovation in addition to reducing the talent pool. Programs that encourage girls to pursue STEM education from a young age, such as participation in science fairs, coding clubs, and mentorship programs led by accomplished women in STEM, should be implemented. Programmes like "TechWomen", "She Leads Africa", Organization for Women in Science in the Developing World (OWSD), and others need to expand their outreach if their impact is to be felt across borders. School administrators and teachers should also intensify their role in eradicating gender-based unfairness in curriculum implementation that persists in schools.

7. African national governments must be intentional in funding STEM education because of its germinal role in fostering economic and technological advancement. There should be an end to lip service in the funding of education, and ugly vices such as corruption must be eradicated in all their forms and shapes if STEM education is to produce the right quality of individuals needed by the workforce. Below is a suggested framework for bridging the skills gap in Africa that is culturally context specific.

In conclusion, this paper highlights the crucial role of STEM education in tackling Africa's ongoing workforce skills gap and promoting sustainable economic growth. Despite the continent's rich human capital and youthful population, the provision of STEM education is hindered by outdated curricula, poor infrastructure, undertrained teachers, limited digital access, and a disconnect between education and industry. A key point is that closing this gap requires more than just curriculum reforms—it calls for a comprehensive, inclusive approach that integrates indigenous knowledge systems, encourages public-private partnerships, advances gender equity, and expands digital literacy at all levels.

A key limitation of this study is its reliance on secondary data and regional generalizations, which may not fully reflect the diversity of national contexts and

localized efforts. Empirical field research is necessary to verify these findings at the country and community levels.

Future research should examine how African apprenticeship models can be practically integrated into formal STEM pathways, explore scalable strategies for teacher professional development, and evaluate the long-term effects of emerging ed-tech innovations on employability. With targeted investments and strategic collaborations, STEM education can be transformed into a powerful driver for Africa's workforce readiness, economic resilience, and global relevance.

IMPLICATIONS AND PROSPECTS

There are prospects for STEM education and workforce development in Africa. With quality STEM education, Africa may be able to close the skills gap in the years to come. The opportunities and paths that could influence the future of STEM in Africa are listed below.

     1. Leveraging the youth demographic dividend in Africa. Africa has the highest youth population in the world, with more than 60% of its population under 25 years of age (Blum, 2007; Abramova, 2022). Due to this demographic reality, the continent can utilize its youthful workforce to meet the global demand for STEM workers. It is thus pertinent to ensure that this teaming youth population acquires the education and training they need to take advantage of future opportunities in STEM sectors. This will involve youth empowerment programs that emphasize entrepreneurship and the development of digital skills such as training in coding, data analytics, and other vital technologies. Mentorship, scholarship, and apprenticeship programs in STEM areas, as well as early and quality STEM teaching at the primary and secondary school levels, demand action.

1. Increased investment in STEM infrastructure and digital technologies. Africa is stepping up to the task of enhancing STEM education as evidenced by the increasing number of tech hubs, innovation centres, and mobile learning platforms being established throughout the continent. This trend should continue with more concentrated efforts in building digital infrastructure that guarantees internet access, digital tools, and e-learning platforms for underserved students. Public/ private partnership (PPP) initiatives in the creation and expansion of current innovation hubs and technology parks have the potential to inspire students to learn, experiment, and innovate with emerging technologies, increasing future manpower in areas of current shortages.

2. Emerging Technologies, Artificial Intelligence, Robotics, and Renewable Energy.

3. Current positive advances are indicative of the increasing awareness, attention, and importance placed on emerging technologies such as robotics, data science, artificial intelligence (AI) and renewable energy. Africa has a strong chance of developing human capital for the 4th industrial revolution and beyond, leveraging its youthful population and the opportunities presented by technologies. To tackle concerns such as climate change, healthcare, and food security, today's African STEM professionals must expand their responsibilities in infrastructure development, economic transformation, and attitudinal change, particularly in the STEM sector. More AI training platforms are available now than ever before for scholarly and research purposes. Critical sectors, including agriculture, food security, raw material processing and preservation, and natural resources such as solar power in the tropical regions, are expected to yield results. There is potential for future workforce development in STEM fields in Africa if STEM education receives consistent attention, particularly in engineering, digital development, and the green economy sectors.

4. Growing Global Demand for Digital Talent. Africa has the potential to supply the global workforce with much-needed digital talent. As countries around the world face shortages of skilled workers in fields like software development, data analytics, and cybersecurity, Africa's growing pool of tech talent is an attractive solution. The export of tech talent is expected to continue rising as African developers, data scientists, and engineers gain access to remote work opportunities and global markets. Platforms like Andela and NGA are already facilitating this by connecting African tech professionals with international clients and companies. Digital entrepreneurship will also thrive as more young Africans launch tech startups that address local challenges. This entrepreneurial ecosystem is already growing in hubs like Nairobi (Silicon Savannah), Cape Town, and Lagos, where tech startups are driving innovation in Fintech, Agritech, Healthtech, and education.

5. Government Policy and Public-Private Partnerships. To scale up STEM education in the upcoming years, policy changes that prioritize curriculum modernization, teacher training, and financial incentives for STEM students will be essential. Significant policy advancements have already been made in this field by nations including South Africa, Rwanda, and Kenya. Public-private partnerships (PPPs) will be essential to developing long-lasting STEM training and education initiatives. STEM education will remain current and in line with the demands of the labor market if tech businesses, international organizations, and local industries choose what should be taught, adopt strategies, and create valid and efficient evaluation programs.

6. Increased Focus on Inclusivity and Gender Equality. The ability to develop inclusive educational systems that encourage participation from underrepresented groups, particularly women, will be critical to the future of STEM in Africa. In addition to bolstering the workforce, reducing the gender gap in STEM professions will spur economic growth and innovation. To increase the number of women seeking jobs in science and technology, gender-specific activities are required, including mentorship programs, scholarships for girls in STEM, and specialised outreach campaigns. Although initiatives like TechWomen and Girls Who Code are already making great strides, achieving gender inclusivity in STEM will require expanding similar initiatives throughout the continent. Developing a fair educational system will also require assistance for underserved communities and pupils in rural areas. Governments and non-profit organizations will need to focus on providing financial assistance, access to digital tools and culturally relevant STEM programs that reach all students, regardless of background.

7. Sustainability and Climate Change: STEM's Role in Africa's Future. Given that Africa already faces extreme weather, food insecurity, and water scarcity, climate change poses a serious threat to the continent's long-term development. To create solutions that lessen the consequences of climate change and promote sustainable development, STEM education will be necessary. Educational institutions must give research and development in STEM fields priority if the dream of producing the next generation of STEM professionals with the know-how to engineer sustainable development methods in Africa's development is to be actualized.

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