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Research Article

Integrating Emerging Technologies into Science, Technology, Engineering, and Mathematics (STEM) Curriculum for Enhanced Skills Acquisition in Kano State Science and Technical Schools

Hamzah Sanusi Nassarawa*, Iliyasu Bashir, Enefola Haruna Aminu, Aminu Muhammad, Bello Ibrahim Kangiwa

Department of Computer Science Education, Federal College of Education (Technical), Bichi, Nigeria

Abstract

STEM education is pivotal for fostering innovation, economic growth, and workforce readiness in the 21st century, particularly in developing contexts where technological skills are becoming indispensable. In Kano State, Nigeria, STEM education is confronted with challenges such as outdated curricula, inadequate infrastructure, and limited exposure to emerging technologies including Artificial Intelligence (AI), Internet of Things (IoT), Robotics, and Virtual Reality/Augmented Reality (VR/AR). These challenges have hindered the ability of science and technical schools to equip learners with the practical skills and digital literacy required for the Fourth Industrial Revolution. This study investigates the current state of STEM education in Kano, highlighting systemic barriers such as insufficient teacher training, poor access to electricity and internet facilities, and fragmented policy implementation. It further reviews international and African best practices, drawing lessons from case studies in Rwanda, Kenya, and Ghana, where the integration of digital tools into STEM learning has significantly improved student engagement, creativity, and employability. The paper proposes a contextualized framework for Kano State that emphasizes policy alignment, curriculum modernization, infrastructure development, teacher capacity building, and public–private partnerships. The study underscores the transformative potential of emerging technologies to foster experiential learning, bridge educational gaps, and promote sustainable innovation. Recommendations include targeted investments, localized content development, and continuous professional training to ensure effective adoption and long-term impact.

Keywords

STEM Curriculum, Emerging Technologies, Skills Acquisition, Kano State Education, AI in Education, Educational Innovation

1. Introduction

Science, Technology, Engineering, and Mathematics (STEM) education serves as a cornerstone for national development, technological advancement, and economic competitiveness. In Nigeria, and particularly in Kano State, STEM education is

*Corresponding author: hsnassarawa.se@fcetbichi.edu.ng (Hamzah Sanusi Nassarawa)

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increasingly recognized as essential for empowering the youth with relevant 21st-century skills such as problem-solving, innovation, critical thinking, and digital literacy [4]. However, the delivery of STEM education in Kano's science and technical schools is often limited by outdated curricula, inadequate teacher capacity, poor infrastructure, and minimal exposure to emerging technologies such as Artificial Intelligence (AI), Internet of Things (IoT), Robotics, Virtual and Augmented Reality (VR/AR), and 3D Printing [7, 12].

The integration of these emerging technologies into the STEM curriculum can transform learning environments by enabling hands-on, experiential, and project-based learning. For instance, robotics can cultivate skills in mechanical design and programming, while VR simulations allow learners to explore scientific concepts in immersive settings, reducing the limitations imposed by scarce laboratory resources [15]. Globally, such integrations have improved student engagement, increased knowledge retention, and enhanced skills acquisition, especially in resource-constrained settings [2]. In Africa, initiatives like LabHackathons have demonstrated how low-cost, locally developed technology can address educational equipment shortages while fostering innovation and entrepreneurship [15].

Despite the global momentum, Kano State's science and technical schools have yet to fully embrace these advancements. Previous studies suggest that while the state government has made efforts to promote STEM education—through policy reforms and investments in ICT centers—the practical integration of emerging technologies into classroom instruction remains limited [1, 3]. Moreover, challenges such as insufficient teacher training, unreliable electricity, and limited internet access continue to impede the adoption of such innovations. Therefore, it is imperative to propose a contextualized framework that aligns emerging technologies with the existing STEM curriculum, taking into account the socio-economic realities and infrastructural limitations of Kano State. This paper explores the current state of STEM education in Kano, reviews relevant emerging technologies, and proposes a strategic framework for their integration into the curriculum. By doing so, it aims to contribute to the ongoing discourse on educational innovation and provide actionable pathways for skills enhancement and workforce development in Northern Nigeria.

2. Emerging Technologies for STEM Education

The integration of emerging technologies into STEM education has become a global imperative for equipping learners with the skills needed to thrive in a rapidly changing digital economy. Technologies such as Artificial Intelligence (AI), the Internet of Things (IoT), Robotics, 3D Printing, Virtual Reality (VR), and Augmented Reality (AR) are transforming how students engage with complex STEM concepts by promoting experiential, hands-on, and inquiry-based learning [10, 15].

AI and Machine Learning, for instance, can be used to personalize learning experiences, provide intelligent tutoring, and analyze student performance data for targeted intervention. In Rwanda, initiatives like the Africa Digital Academy and Coding in Schools Program have introduced AI and programming from the primary level, empowering students with future-ready competencies [11]. Similarly, *IoT* enables students to build and monitor real-world systems such as smart agriculture or energy management projects, thus enhancing their problem-solving and design thinking abilities [2].

Robotics plays a critical role in building students' interest in engineering and computer science. Through competitions and practical challenges, learners develop algorithmic thinking and teamwork skills. Kenya's national and international robotics contests and Ghana's STEMbees initiative, which targets girls' participation in robotics and AI, highlight how such programs can inspire innovation and bridge gender gaps [13, 6].

3D Printing allows students to prototype ideas and understand engineering design cycles, fostering creativity and tangible learning outcomes. Meanwhile, *VR and AR* are revolutionizing science education by offering immersive experiences—for example, simulating chemical reactions or exploring anatomy in virtual environments. Universities in South Africa have adopted VR for engineering and medical training, showing the potential for higher education institutions to lead in tech adoption [16].

In Africa, these technologies are not only enhancing STEM learning but also addressing systemic challenges such as limited laboratory resources and teacher shortages [14]. Programs like Ghana Code Club and Nigeria's RoboRAVE demonstrate that with the right infrastructure and training, even resource-constrained schools can integrate cutting-edge tools to boost student outcomes [8, 5]. Thus, emerging technologies offer an opportunity to democratize access to quality STEM education and prepare students for the Fourth Industrial Revolution.

3. Current State of STEM Education in Kano State

Kano State, located in Northwestern Nigeria, is home to a wide network of science and technical schools established to promote vocational and STEM education. These schools aim to equip students with practical skills and scientific knowledge necessary for national development. However, despite the government's commitment to education, the current state of STEM education in Kano reveals significant challenges in infrastructure, curriculum modernization, teacher readiness, and technological integration [1, 3].

Most science and technical schools in the state still rely heavily on traditional teaching methods that emphasize rote

memorization rather than hands-on, problem-solving learning approaches. Laboratories are either outdated or under-equipped, limiting students' ability to engage in meaningful scientific experimentation [3]. Additionally, although digital literacy is gaining traction, the integration of emerging technologies such as artificial intelligence (AI), robotics, and Internet of Things (IoT) into the STEM curriculum is virtually nonexistent. This digital gap hinders Kano students from competing on equal footing with their peers globally who are already exposed to such innovations from an early age [2].

Teacher capacity remains another critical issue. Many science and technical teachers in Kano State lack the necessary training and exposure to effectively integrate digital tools into their instruction. While some professional development efforts have been initiated, they are often fragmented and insufficient in both reach and depth [4]. *Moreover, the absence of structured frameworks for continuous teacher training in STEM pedagogy and emerging technology use continues to impede progress.*

Despite these challenges, the Kano State government has made recent policy efforts aimed at revitalizing science and technology education. For example, it has advocated strategic investment in ICT infrastructure and technical education through public-private partnerships [1]. However, the success of these initiatives depends largely on implementation, sustained funding, and alignment with global best practices in STEM education.

In summary, while Kano State recognizes the importance of STEM education, systemic constraints—ranging from infrastructural deficits to lack of teacher capacity and outdated curricula—continue to limit its effectiveness. A comprehensive reform agenda that incorporates technology integration, teacher development, and curriculum redesign is urgently needed to transform STEM education into a tool for socio-economic development in the state.

4. Some Case Studies on Emerging Technologies Integration in STEM Education in Africa

Several African countries have made significant progress in integrating emerging technologies into STEM education. Here are some notable examples with key initiatives as depicted in the table below:

Table 1. *Case Studies on Emerging Technologies Integration in STEM Education in Africa.*

Country	Initiative/Program	Focus Areas	Key Technologies	Target Group
Rwanda	Coding in Schools Program	Mandatory coding and CS in schools	Programming, Computer Science	Primary & Secondary students
	Africa Digital Academy	AI and robotics education	AI, Robotics	Students
	One Laptop Per Child (OLPC)	Enhance digital literacy in classrooms	Laptops, Digital Tools	School children
	Digital Literacy Programme (DLP)	STEM learning through digital devices	Tablets, STEM apps	Primary school pupils
Kenya	STEM Model Schools	Coding, AI, IoT training centers	Coding, AI, IoT	Secondary & post-secondary learners
	Robotics Competitions	Promote innovation through contests	Robotics	Students (national/international)
Ghana	STEMbees	Empower girls in STEM	Robotics, AI	Girls in schools
	Ghana Code Club	Teach coding to underserved youth	Coding, Scratch, Python	Children & Teens
Nigeria	RoboRAVE Nigeria	Hands-on robotics contests	Robotics	Secondary school students
Egypt	STEM Egypt Schools	STEM-focused schools with tech labs	AI, IoT, Robotics	Secondary students

5. Significance of the Study

Some of the significance of this study is as enumerated below:

1) It addresses gaps in STEM education delivery in Kano State.
2) It provides a framework for sustainable technology integration in Science and technical schools.
3) It enhances students' employability and innovation

capacity [9].

6. Current State of STEM Education in Kano State

Kano State, located in Northwestern Nigeria, is home to a wide network of science and technical schools established to promote vocational and STEM (Science, Technology, Engineering, and Mathematics) education. These schools aim to equip students with practical skills and scientific knowledge necessary for national development. However, despite the government's commitment to education, the current state of STEM education in Kano reveals significant challenges in infrastructure, curriculum modernization, teacher readiness, and technological integration [1, 3].

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7. Proposed Framework for Integration

To effectively integrate emerging technologies into the STEM curriculum in Kano State's science and technical schools, this paper proposes a contextualized framework modeled after Rwanda's successful implementation of the "Smart Classrooms" initiative. The framework addresses critical systemic gaps through a multi-component strategy aligned with local realities.

Table 2. *Proposed Framework for Emerging Technologies Integration into Kano State Science and Technical Schools Curriculum.*

Component	Adapted Strategy for Kano State	Expected Implementation Actions
1. Policy Alignment and Leadership	Establish a state-level STEM and Digital Education Policy aligned with Nigeria's ICT roadmap.	Set up a Kano STEM-Edu Taskforce under the Ministry of Education to coordinate policy execution.
2. Curriculum Modernization	Integrate coding, robotics, AI, and digital fabrication (e.g., 3D printing) into school syllabi.	Partner with institutions like NCCE and NBTE to revise curricula and create modular digital STEM units.
3. Infrastructure Development	Equip schools with smart classrooms and power solutions (e.g., solar panels).	Roll out solar-powered ICT labs with laptops, internet, and projectors in all science and technical schools.
4. Teacher Capacity Building	Conduct large-scale training in digital pedagogy and emerging tech use.	Train STEM teachers via workshops, online platforms, and exchange programs with institutions like TETFund or NTI.
5. Localized Digital Content	Develop and deploy offline-accessible, Nigeria-focused STEM apps and simulations.	Collaborate with Nigerian EdTech startups to produce Hausa-language STEM content and virtual labs.
6. Public–Private Partnerships (PPPs)	Leverage industry expertise and funding through partnerships.	Engage companies like MTN Foundation, Google Nigeria, and Andela for devices, training, and mentorship.
7. Monitoring and Evaluation (M&E)	Use digital dashboards to track learning impact, teacher usage, and tech maintenance.	Implement school-level ICT reporting tools to guide data-driven improvements and budgeting.

7.1. Objectives of the Proposed Framework

1) To align STEM curriculum with the 4th Industrial Revolution demands.
2) To promote hands-on skills acquisition using emerging technologies.
3) To build teacher capacity and infrastructure for technology-enhanced learning.
4) To establish industry-academia partnerships for sustainable innovation.
5) To enhance student engagement, creativity, and entrepreneurship potential.

7.2. Expected Outcomes of the Proposed Framework

1) Increased student proficiency in tech-driven STEM applications.
2) Improved teacher competence in delivering practical STEM lessons.
3) Establishment of innovation hubs in technical schools.
4) Higher transition rates of students into technical careers and entrepreneurship.

8. Challenges and Limitations with Corresponding Mitigation Strategies

1. Inadequate Funding

Challenge:

Implementing smart classrooms, procuring devices, and training teachers require significant investment, which may be constrained by budget limitations.

Mitigation Strategies:

1) Establish Public-Private Partnerships (PPPs) with tech firms (e.g., MTN Foundation, Google Nigeria).
2) Apply for grants from international donors (e.g., UNESCO, World Bank).
3) Integrate STEM-tech priorities into the state education budget and TETFund proposals.

2. Poor Electricity and Internet Access

Challenge:

Many rural and semi-urban schools lack reliable power and internet infrastructure, limiting technology usage.

Mitigation Strategies:

1) Deploy *solar-powered* ICT labs and backup battery systems.
2) Use *offline digital tools* (e.g., Kolibri, RACHEL servers) that don't require internet for STEM content delivery.
3) Partner with telecom companies to improve school connectivity.

3. Low Digital Literacy Among Teachers

Challenge:

Teachers may lack the skills to effectively use AI, robotics, and VR tools in classroom instruction.

Mitigation Strategies:

1) Implement *continuous professional development* programs focused on tech integration.
2) Establish *teacher mentorship programs* with tech-savvy educators.
3) Provide *certification-based training* in collaboration with institutions like NTI, NCCE, or private training providers.

4. Curriculum Misalignment

Challenge:

The existing curriculum may not be flexible enough to incorporate new technologies or may be outdated.

Mitigation Strategies:

1) Collaborate with NCCE, NBTE, and relevant stakeholders to *revise and align curriculum* with emerging tech trends.
2) Introduce modular STEM components that allow gradual integration without overhauling the entire curriculum.

5. Resistance to Change

Challenge:

Stakeholders (e.g., school heads, policymakers, or teachers) may be hesitant or skeptical about adopting new technologies.

Mitigation Strategies:

1) Conduct *sensitization workshops* and pilot programs to demonstrate impact.
2) Engage stakeholders in the planning and implementation phases to build ownership.
3) Recognize and reward early adopters and innovators in schools.

6. Maintenance and Sustainability Issues

Challenge:

Tech tools may fall into disrepair due to lack of maintenance skills or budget for replacements.

Mitigation Strategies:

1) Train *ICT support staff* at zonal education levels for routine maintenance.
2) Establish *school-based ICT committees* for monitoring and accountability.
3) Create a *budget line for maintenance* and upgrades in annual school plans.

7. Language and Cultural Barriers

Challenge:

Students in Kano may struggle with English-based tech content, affecting comprehension and engagement.

Mitigation Strategies:

1) Develop *localized content* in Hausa and culturally relevant examples.
2) Use *blended instruction* that combines local language explanations with tech-based demonstrations.

9. Conclusion

The integration of emerging technologies into STEM education in Kano State presents a transformative opportunity to enhance learning outcomes and prepare students for the digital

economy. Despite systemic challenges—such as infrastructural deficits, teacher capacity gaps, and curriculum misalignment—strategic interventions can mitigate these barriers. Case studies from Africa demonstrate that low-cost, scalable solutions can significantly improve STEM education in resource-constrained settings. By adopting a structured framework that includes policy reforms, teacher training, and industry collaboration, Kano State can modernize its STEM education system, fostering innovation and socio-economic development.

10. Recommendations

The following recommendations were forwarded:

1) *Policy and Leadership:* Establish a state-level STEM and Digital Education Policy, supported by a dedicated task force to oversee implementation.
2) *Curriculum Modernization:* Integrate emerging technologies (AI, robotics, IoT, 3D printing) into the STEM curriculum in collaboration with regulatory bodies like NCCE and NBTE.
3) *Infrastructure Development:* Equip schools with solar-powered ICT labs, offline digital tools, and reliable internet connectivity to support tech-enhanced learning.
4) *Teacher Capacity Building:* Conduct large-scale training programs in digital pedagogy, supported by institutions like TETFund and NTI, with certification incentives.
5) *Localized Content Development:* Partner with EdTech firms to create Hausa-language STEM resources and virtual labs for better accessibility.
6) *Public-Private Partnerships (PPPs):* Engage tech companies (e.g., MTN Foundation, Google Nigeria) for funding, mentorship, and device provisions.
7) *Monitoring and Evaluation (M&E):* Implement digital dashboards to track progress, teacher adoption, and infrastructure maintenance for data-driven improvements.
8) *Pilot Programs and Sensitization:* Launch pilot projects in select schools to demonstrate impact and encourage stakeholder buy-in before statewide scaling.

Abbreviations

STEM	Science Technology, Engineering and Mathematics
AI	Artificial Intelligence
IoT	Internet of Things
VR	Virtual Reality
AR	Augmented Realty
ICT	Information and Communication Techology
PPP / PPPs	Public Private Partnership(s)
NCCE	National Commission for Colleges of Education
NBTE	National Board for Technical Education
TETFund	Tertiary Education Trust Fund
NTI	National Teachers' Institute

Conflicts of Interest

The authors declare no conflicts of interest.

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