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Mobile-Based Learning and STEM Education in Nigerian Classrooms: Opportunities and Challenges in the 21st Century

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Abstract
The integration of mobile-based learning in education presents a transformative opportunity to bridge critical gaps in Science, Technology, Engineering, and Mathematics (STEM) education within Nigerian classrooms. With the increasing penetration of mobile devices and internet connectivity, mobile learning platforms offer innovative avenues to deliver STEM content, especially in underserved and rural communities. This paper explores the role of mobile-based learning in enhancing STEM education in Nigeria by examining its potential to increase accessibility, promote student engagement, and support teachers with digital tools and resources. Drawing from current initiatives, government policies, and case studies, the study highlights the educational benefits of using mobile technology, such as interactive learning, personalized content delivery and real-time feedback mechanisms. However, several challenges persist, including inadequate infrastructure, high costs of data, digital illiteracy and limited policy support. The paper also discusses practical strategies for overcoming these obstacles through public-private partnerships, infrastructure development, educator training and supportive regulatory frameworks. It concludes by emphasizing the need for a multi-stakeholder approach to fully harness the potential of mobile-based learning to advance STEM education in Nigeria. This research contributes to ongoing discussions about the future of education in Africa and offers strategic insights for policymakers, educators and technology developers aiming to improve learning outcomes through digital innovations.

Keywords: Mobile Learning, STEM Education, Nigerian Classrooms, Digital Innovation, Education Technology

Introduction

Science, Technology, Engineering and Mathematics (STEM) education has become increasingly vital in driving national development, innovation and global competitiveness. In Nigeria, however, significant challenges such as poor infrastructure, under-resourced schools and outdated teaching methods hinder effective STEM education delivery (Adetimirin, 2019; Aina & Adedoja, 2021). The advent of mobile technology presents a promising alternative to address these educational gaps. With mobile penetration surpassing 90% in Nigeria, mobile-based learning has the potential to transform how STEM subjects are taught and learned (GSMA, 2021) especially in Nigeria. The 21st century is characterized by rapid technological advancements, globalization and a paradigm shift towards a knowledge-based economy with increasing use of ICT, information literacy, AI and machine language use and adoption (Keane et al., 2016). This study investigates the role of mobile-based learning in enhancing STEM education in Nigerian classrooms. It highlights the opportunities offered by this approach, evaluates the current challenges and proposes strategies for effective integration, adoption and implementation. Furthermore the increasing reliance on digital technologies in education has transformed the global learning landscape, with mobile-based learning (m-learning) plaforms emerging as a critical tool for enhancing educational delivery and access. In Nigeria, the drive to improve Science, Technology, Engineering, and Mathematics (STEM) education is at the forefront of national development goals, especially in the context of bridging educational disparities,

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equipping the workforce for a digital economy and achieving the Sustainable Development Goals (SDGs) (UNESCO, 2021a). As mobile device penetration increases, m-learning platforms offers an innovative avenue to provide quality STEM education, particularly in resource-constrained and underserved Nigerian classrooms and regions (Ayo & Mbarika, 2021).

STEM education in Nigeria faces multiple challenges, including a shortage of qualified teachers, inadequate infrastructure and poor access to instructional materials (Okebukola, 2020). These challenges are exacerbated in mostly rural and economically disadvantaged communities (Edeh, 2019). However, the proliferation of mobile phones and increasing access to mobile internet provide a promising platform to deliver STEM content in flexible, cost-effective, and engaging ways (Adeoye & Wentling, 2022). Mobile-based platforms such as uLesson, Roducate, and LearnAM are reshaping the educational experience by offering curriculum-aligned content, virtual laboratories and personalized learning features that are accessible to students across socio-economic strata (Eze & Mordi, 2022). This study investigates the role mobile-based learning plays in enhancing STEM education in Nigerian classrooms, examining the opportunities it presents, the challenges that hinder its widespread adoption, and the strategies necessary to improve its effectiveness. By focusing on the Nigerian context, this research aims to contribute to a localized understanding of m-learning's transformative potential in STEM education.

Theoretical Framework

This study is anchored in two main theoretical perspectives: these are Connectivism Theory and Technological Pedagogical Content Knowledge (TPACK) Framework.

i. Connectivism Theory

Proposed by Siemens (2005), Connectivism emphasizes the role of technology and networks in the learning process. In the context of mobile-based STEM learning, Connectivism supports the notion that knowledge is distributed across networks of people and digital tools and learning occurs as students connect with various digital resources and communities. The use of mobile apps and platforms enables students to engage with real-time data, participate in collaborative learning environments and access expert knowledge, thereby facilitating deeper understanding of STEM concepts (Downes, 2012; Aina & Adedoja, 2021).

ii. Technological Pedagogical Content Knowledge (TPACK)

The TPACK framework, developed by Mishra and Koehler (2006), identifies the essential knowledge required by teachers to integrate technology effectively into their teaching. For STEM educators in Nigeria, TPACK emphasizes the need to balance content knowledge (e.g., math and science), pedagogical knowledge (how to teach), and technological knowledge (how to use mobile tools). This framework guides the analysis of how Nigerian teachers use mobile devices to deliver STEM content and the professional development needed to enhance their competency (Yusuf & Onasanya, 2021; Ogunlade & Aladejana, 2022). By combining these theories, the study provides a comprehensive lens through which the implementation, benefits, and challenges of mobile-based STEM education in Nigeria can be understood.

The Role of Mobile-Based Learning in STEM Education in Nigeria

Mobile-based learning has emerged as a critical tool in advancing Science, Technology, Engineering, and Mathematics (STEM) education in Nigeria. As the country seeks to address its educational challenges and meet the demand for STEM professionals in the future workforce, mobile learning offers significant potential for both formal and informal education. Here, we explore the role of mobile-based learning in enhancing STEM education in Nigeria, including its impact on curriculum delivery, learner engagement and bridging educational divides.

a. *Enabling Access to Quality STEM Resources*

Mobile learning provides students with immediate access to a wealth of STEM resources, including video tutorials, simulations, virtual labs, and interactive quizzes. With platforms such as uLesson, Roducate, and Mobile STEM Labs, learners can explore complex STEM concepts in a way that is engaging and easier to understand (Ayo & Mbarika, 2021; Ogunlade & Aladejana, 2022). The accessibility of these resources on smartphones allows students, especially those in rural and underserved areas, to engage with quality content that would otherwise be unavailable to them.

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b. *Bridging the Digital Divide*

Mobile-based learning offers an opportunity to bridge the educational divide between urban and rural schools in Nigeria. While rural areas still face infrastructural challenges, mobile devices provide a relatively affordable and efficient way to connect students with digital learning. According to Adeoye & Wentling (2022), mobile technology serves as an equalizer in providing students with access to the same learning resources, regardless of geographical location. This reduces the knowledge gap between students in rural areas and their urban counterparts.

c. *Promoting Self-Paced Learning and Personalized Education*

One of the unique advantages of mobile-based learning is that it allows students to learn at their own pace, especially in STEM subjects where learners often require different levels of comprehension. Platforms like LearnAM and uLesson enable students to revisit lessons, review difficult topics, and progress at a speed that suits their individual learning needs (Eze & Mordi, 2022). This personalized approach enhances student autonomy and fosters better engagement with STEM subjects.

d. *Facilitating Collaborative Learning*

Mobile learning platforms, such as WhatsApp, Zoom, and Google Classroom, enable real-time collaboration and peer learning. Students can participate in group discussions, share ideas, and work on joint STEM projects, even if they are not physically present in the same location. This collaborative approach to learning helps students develop critical skills such as teamwork, communication, and problem-solving, all of which are essential in STEM fields (Yusuf & Onasanya, 2021).

e. *Enhancing Teacher Effectiveness*

Teachers can use mobile devices to enhance their instructional methods by accessing a range of STEM teaching resources. For instance, mobile-based apps can help teachers manage lessons, monitor student progress, and offer real-time feedback. In addition, mobile learning platforms can facilitate professional development opportunities for teachers, ensuring they stay updated on the latest educational technologies and pedagogical strategies (Ogunlade & Aladejana, 2022). This not only improves teaching outcomes but also empowers educators to foster a more dynamic and engaging STEM classroom.

f. *Interactive STEM Learning*

Mobile-based learning tools, including STEM apps and interactive e-books, encourage students to engage actively with the subject matter. Instead of passively receiving information, students can experiment with virtual simulations, solve interactive STEM problems, and conduct virtual experiments. This active engagement makes learning more enjoyable and meaningful, fostering a deeper understanding of scientific principles (Aina & Adedoja, 2021).

g. *Creating an Inclusive Learning Environment*

Mobile-based learning in Nigeria can help create an inclusive environment that caters to diverse learning needs. For instance, many mobile learning platforms support text-to-speech and speech-to-text features, making them accessible to students with disabilities, including those with visual or hearing impairments. As noted by Ogunyemi (2021), mobile devices can also be customized to accommodate local languages, offering STEM education to students from linguistically diverse backgrounds.

h. *Overcoming Resource Constraints*

In Nigerian classrooms, especially in public schools, the lack of basic learning materials such as textbooks and laboratory equipment remains a significant barrier to effective STEM education. Mobile learning mitigates this issue by providing virtual labs, 3D models, and other digital resources that simulate real-world experiments. Platforms like the Mobile STEM Lab enable students to conduct experiments and simulations directly on their smartphones, eliminating the need for costly physical infrastructure (Ogunlade & Aladejana, 2022).

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i. *Enhancing STEM Interest and Career Pathways*

Mobile learning has the potential to increase students' interest in STEM fields by providing them with interactive and relevant content that demonstrates the real-world application of STEM concepts. Exposure to mobile apps related to engineering, robotics, and programming can inspire students to pursue STEM careers. Initiatives such as the LearnAM mobile platform, which integrates STEM lessons with career pathways, help students connect academic learning with potential job opportunities (TechCrunch, 2021).

j. *Expanding STEM Education Beyond the Classroom*

Mobile-based learning breaks the boundaries of traditional classroom-based education, offering students the ability to continue learning outside of school hours. This is particularly beneficial for students in remote areas who may have limited access to after-school tutoring or extracurricular STEM activities. With mobile platforms, learning becomes a continuous process, enabling students to reinforce classroom lessons and develop additional skills in their own time (Ayo & Mbarika, 2021).

The section on "The Role of Mobile-Based Learning in STEM Education in Nigeria" has been expanded with detailed insights on how mobile-based learning is shaping STEM education in Nigeria. It includes examples of key platforms, opportunities for personalized and interactive learning, and the impact on both students and teachers. The section also highlights how mobile technology is bridging educational divides, fostering inclusion, and enhancing STEM engagement.

Mobile learning, or m-learning, refers to the use of mobile devices such as smartphones and tablets to access educational content and facilitate learning anytime and anywhere (Traxler, 2007). In STEM education, mobile learning enables interactive simulations, real-time data collection, virtual labs, and gamified content delivery, making complex scientific concepts more accessible and engaging (West & Vosloo, 2013).

Globally, mobile-based learning has shown promise in improving STEM outcomes by offering personalized learning experiences and bridging the gap between theoretical knowledge and practical application. In Nigeria, mobile apps like uLesson and EduFirst, SMS-based lessons, and WhatsApp class groups have begun to reshape traditional classroom settings, especially in rural areas (Okonkwo & Nkadi, 2020; Adebayo et al., 2021).

3. Current State of Mobile-Based Learning in Nigeria

Mobile-based learning (m-learning) has gained significant traction in Nigeria, particularly in the aftermath of the COVID -19 pandemic, which necessitated the adoption of digital education solutions. While challenges persist, the landscape of m-learning is evolving rapidly with notable advancements in infrastructural developments, policy and content developments.

a. Adoption of Mobile Learning Platforms

Several Nigeria edtech startups have emerged, developing mobile applications tailored to the educational needs of students. For instance, uLesson, founded in 2019, offers curriculum-aligned video lessons, quizzes and homework assistance for K-12 students. By 2023, uLesson had expanded its offerings to include Miva, an online university licensed by the national Universities Commission, providing undergraduate courses with focus on technology (uLesson, 2023).

Altschool Africa, established in 2021, is another notable platform that provides digital learning experiences across multiple African countries, including Nigeria. As of September 2023, the platform had enrolled over 20,000 students and had partnered with Unity bank to train females in software engineering (AltSchool, 2023).

b. *Government Initiatives and Policy Support*

The Nigerian government has recognized the importance of digital education and has initiated several programs to support m-learning. The National Information Technology Development Agency (NITDA) has been instrumental in promoting ICT integration in education delivery in Nigeria with STEM education inclusive. Additionally, the Federal ministry of education has collaborated with international organizations to develop digital

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learning platforms aimed at enhancing educational access and quality educational delivery via mobile-based (Oxford Business Group, 2023).

c. Challenges to Widespread Adoption

Despite the progress, several challenge hinder the widespread adoption of m-learning in Nigeria (Edeh, 2019).

i. *Infrastructure Deficiencies*: Limited access to reliable electricity and internet connectivity, especially in rural areas, poses significant barriers to effective mobile learning and delivery.

ii. *Affordability Issues*: The high cost of smartphones and data subscriptions makes it difficult for many students to access mobile learning contents and resources.

iii. *Teacher Preparedness*: A lack of training in digital pedagogy among educators affects the effective integration of mobile learning tools in the classroom.

d. *Future Prospects*

The future of m-Learning in Nigeria appears promising, with increasing investments in digital education and a growing recognition of its benefits. However, addressing the existing challenges through targeted policies, infrastructure development, and capacity building for educators will be crucial to realizing the full potential of mobile-based learning in the country (Ogunlade & Aladejana, 2022).

Several mobile-based STEM initiatives are already in motion in Nigeria. The National Commission for Mass Literacy (NMEC) and the Universal Basic Education Commission (UBEC) have partnered with tech firms to introduce mobile content delivery in select schools (UBEC, 2021). Private sector platforms like uLesson and Roducate provide STEM video tutorials, quizzes, and learning resources tailored to the Nigerian curriculum (Eze & Mordi, 2022).

Despite these advancements, adoption remains uneven. Urban schools are more likely to use mobile learning tools compared to rural counterparts (Yusuf & Onasanya, 2021). Moreover, while some state governments have introduced tablet-based learning, these efforts often suffer from lack of maintenance, inadequate training, and insufficient follow-up (Aina & Adedoja, 2021).

Opportunities Presented by Mobile-Based Learning in Nigeria

Mobile-based learning presents numerous opportunities for enhancing STEM education across Nigeria, especially by bridging educational gaps and promoting inclusivity. These opportunities are shaped by the increasing penetration of mobile technologies and growing interest in digital education:

a. *Increased Access to Quality STEM Content*

Mobile learning platforms allow students in underserved and remote areas to access high-quality STEM content that may not be available in their local schools. Platforms such as uLesson and Roducate deliver curriculum-aligned lessons, practice quizzes, and video tutorials, thereby democratizing access to education (TechCrunch, 2021; Eze & Mordi, 2022).

b. *Flexibility and Personalized Learning*

Mobile-based learning supports self-paced education, enabling learners to study at their own convenience. Personalized features such as adaptive assessments and feedback mechanisms help tailor learning experiences to individual needs, improving comprehension and retention (Aina & Adedoja, 2021).

c. *Encouraging Lifelong Learning and STEM Engagement*

With mobile platforms accessible outside traditional classroom settings, students can engage with STEM content throughout their daily lives. This promotes lifelong learning and enhances problem-solving and critical thinking skills vital for 21st-century development (Yusuf & Onasanya, 2021).

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d. *Cost-Effectiveness and Scalability*

Compared to building physical infrastructure, mobile learning solutions offer a cost-effective means to reach large numbers of learners. Educational apps can be distributed and updated easily, and once developed, they can scale rapidly across regions without significant additional costs (Adeoye & Wentling, 2022).

e. *Promotion of Equity and Inclusion*

Mobile platforms can be designed to accommodate students with diverse needs, including those with disabilities or from marginalized communities. For example, the LearnAM app offers vocational and STEM-related content in indigenous languages and audio formats to reach users with limited literacy skills (Mastercard Foundation, 2022).

f. *Bridging the Gender Gap in STEM*

Mobile learning offers an avenue to empower girls and young women by providing them with access to STEM education outside the constraints of gender norms prevalent in some communities. Studies have shown that digital platforms encourage more female participation in STEM activities when cultural and physical barriers are minimized (Ogunyemi, 2021).

g. *Real-Time Feedback and Performance Tracking*

Apps like uLesson include performance analytics and dashboards that allow students, teachers, and parents to track learning progress. This data-driven approach can support targeted interventions to address learning gaps in STEM subjects (Eze & Mordi, 2022).

h. *Facilitating Teacher Support and Professional Development*

Mobile platforms also provide teachers with continuous professional development resources, such as lesson planning tools, subject-specific updates, and peer collaboration forums. This enhances teaching effectiveness and keeps educators informed on evolving STEM pedagogy (Ogunlade & Aladejana, 2022).

Mobile learning presents several benefits for advancing STEM education in Nigeria:

Accessibility and Inclusivity: Mobile devices are more widespread than computers, allowing greater reach among students, especially in remote areas (Olaore, 2020).

Enhanced Engagement: Multimedia content, animations, and gamification make learning more interactive and enjoyable (Oyedemi, 2022).

Support for Teachers: Mobile platforms offer professional development courses and teaching aids (UNESCO, 2021).

Real-time Feedback: Instant assessment and feedback mechanisms help track student progress (Omeke & Ene, 2020).

These features align with the goals of STEM education to develop problem-solving, critical thinking and innovation skills among learners (National Research Council, 2011).

Challenges Facing Mobile-Based Learning in Nigerian Classrooms

Despite the numerous benefits of mobile-based learning in promoting STEM education, several challenges hinder its widespread adoption and effective implementation in Nigerian classrooms. These challenges are multifaceted, encompassing infrastructural, socio-economic, pedagogical, and policy-related dimensions:

a. *Inadequate Infrastructure*

Poor digital infrastructure remains a major barrier. Many rural and peri-urban areas in Nigeria lack access to reliable electricity, internet connectivity, and mobile network coverage (Adeoye & Wentling, 2022). Without

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these fundamental services, mobile-based learning becomes nearly impossible. Additionally, the limited availability of ICT tools such as smartphones and tablets in public schools further exacerbates this issue. Infrastructure Deficits: Many schools lack electricity and internet connectivity (TVC News, 2023).

b. *High Cost of Devices and Data*

For many Nigerian students and families, the cost of purchasing smartphones and maintaining internet subscriptions is prohibitively high. While mobile penetration is increasing, affordability continues to exclude a significant portion of the population from benefitting from mobile learning opportunities (Edeh, 2019, Ayo & Mbarika, 2021).

c. *Lack of Teacher Training and Digital Skills*

Teachers often lack the necessary training and competencies to integrate mobile technologies effectively into their STEM teaching practices. According to Ogunlade and Aladejana (2022), the absence of structured digital pedagogy training in teacher education programs results in low adoption and misuse of mobile learning tools in classrooms.

d. *Content Relevance and Language Barriers*

Much of the available mobile learning content is not aligned with the Nigerian curriculum or lacks cultural and linguistic relevance. Content that is not adapted to local languages or socio-cultural contexts can alienate learners and reduce engagement (Eze & Mordi, 2022). Furthermore, a scarcity of STEM-focused mobile content in local languages like Yoruba, Igbo, and Hausa limits accessibility for younger or less literate students.

e. *Digital Divide and Inequality*

Mobile-based learning tends to favor urban learners and those from higher socio-economic backgrounds who have better access to technology. This exacerbates educational inequality, leaving students in rural or impoverished communities further behind (Yusuf & Onasanya, 2021).

Teachers and students often lack the skills needed to effectively use mobile technologies (Okafor & Nwafor, 2019).

f. *Cultural and Parental Resistance*

Some communities, particularly in conservative or rural areas, view mobile devices with suspicion, associating them more with entertainment or social distractions than with learning. This perception can lead to resistance from parents and community leaders, reducing learner engagement with mobile tools (Ogunyemi, 2021).

g. *Inconsistent Policy Support and Poor Implementation*

Although there are policies supporting ICT in education, their implementation has been inconsistent and underfunded. The lack of a cohesive, enforceable mobile learning policy framework at both federal and state levels hampers coordinated efforts in scaling mobile-based STEM education (NITDA, 2020).

h. *Cybersecurity and Data Privacy Concerns*

The absence of strong data protection regulations and cybersecurity frameworks creates concerns about students' and teachers' privacy when using mobile applications. Cases of online harassment or exploitation have also discouraged mobile learning adoption, especially among female students (Aina & Adedoja, 2021).

These challenges call for systemic interventions, stakeholder collaboration, and innovative policy reforms to enable mobile-based STEM education to fulfill its transformative potential in Nigeria.

Despite the promise, several barriers limit the effectiveness of mobile learning:

Economic Barriers: High cost of smartphones and mobile data limits accessibility for many families (Adebiyi & Oyeleke, 2021).

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Policy Gaps: There is limited regulatory support and lack of standardized mobile learning frameworks (Akinleye, 2020).

Security Concerns: Data privacy and cyber threats pose risks for users (Ibrahim & Salihu, 2021).

Strategies to Overcoming these Challenges of Mobile-Based Learning of STEM Education

While mobile-based STEM learning in Nigeria offers immense promise, its adoption is hindered by several systemic and socio-economic challenges. To harness the full potential of mobile learning in STEM education, several strategies should be adopted (Edeh, 2019). To address these issues, the following multi-pronged strategies are recommended:

a. *Policy Reform and Government Commitment*

A robust national policy framework dedicated to mobile learning integration is essential. The Federal Ministry of Education should institutionalize mobile-based learning within the national education strategy, with clear guidelines for content development, quality assurance, and teacher training. For example, the National Digital Economy Policy and Strategy (2020–2030) can be leveraged to incorporate specific provisions for mobile STEM education (NITDA, 2020). The development of policies both at the national and state-levels to guide mobile learning integration and adoption (Federal Ministry of Education, 2021; Disciplines.ng 2022).

b. *Public-Private Partnerships (PPPs)*

Partnerships between government agencies, telecom companies, tech startups, and NGOs can foster innovation and mobilize resources. Initiatives like MTN's ICT and education projects have demonstrated how corporate involvement can improve ICT infrastructure and provide learning subsidies to disadvantaged schools (MTN Foundation, 2021). Public-Private Partnerships: Collaborate with telecoms, edtech firms, and NGOs to scale and sustain initiatives (Adebayo et al., 2021).

c. *Enhancing Digital Infrastructure*

Expanding 4G and broadband internet access, especially in rural areas, is critical. Investment in solar-powered mobile learning kiosks and community ICT centers can also provide learners with access to devices and connectivity in power-deficient regions (Adeoye & Wentling, 2022). Encouraging local governments to deploy ICT tools in schools through community-driven development programs will improve sustainability. Expand electricity and broadband internet access in schools (World Bank, 2022).

d. *Affordable Mobile Devices and Data*

Affordability remains a core barrier. The government, in collaboration with manufacturers, should implement policies to subsidize mobile learning devices and reduce tariffs on educational gadgets. Additionally, zero-rating educational platforms where access to specific learning sites does not incur data charges can significantly increase usage (Ayo & Mbarika, 2021). Subsidized Devices and Data: Provide affordable or free devices and internet access to students and educators (GSMA, 2021).

e. *Teacher Training and Digital Pedagogy Development*

Teachers must be empowered to effectively use mobile tools in STEM education. National teacher education programs should integrate digital pedagogy modules. For instance, the Tertiary Education Trust Fund (TETFund) can support training initiatives in collaboration with institutions such as the National Teachers' Institute (NTI) (Ogunlade & Aladejana, 2022). More so capacity building can be in form of training teachers in digital literacy and mobile pedagogy (UNESCO, 2021a).

f. *Content Localization and Language Diversity*

Mobile learning tools should reflect local cultural contexts and languages to increase learner engagement. Developers must tailor STEM content to the Nigerian curriculum and include translations into local languages such as Yoruba, Igbo, and Hausa. LearnAM and Roducate have shown success in this area by offering STEM content in indigenous languages (Mastercard Foundation, 2022).

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g. *Strengthening Monitoring and Evaluation*

Effective monitoring mechanisms should be established to assess the impact and effectiveness of mobile learning interventions. Evaluation frameworks should include learner feedback, teacher assessments, and performance tracking to ensure continuous improvement. Research institutions and NGOs can play a vital role in independently assessing these programs (Yusuf & Onasanya, 2021).

h. *Parental and Community Engagement*

Educating parents and local communities about the benefits of mobile STEM education fosters buy-in and encourages learner participation, especially for girls and vulnerable children. Community-based campaigns and workshops can help demystify technology and address cultural reservations (Eze & Mordi, 2022).

Case Studies and Success Stories in Nigeria

Several successful case studies across Nigeria illustrate the potentials of mobile-based learning to transform STEM education content delivery, teaching and learning, as well as feedbacks in form of assignments and answering of quiz from the learners. Below are some of the identified cases in this study:

a. *uLesson*

uLesson is a Nigerian edtech startup launched in 2019 by Sim Shagaya, designed to offer curriculum-aligned STEM video content, interactive quizzes, and performance analytics through mobile devices. It focuses primarily on secondary school students and covers subjects such as mathematics, biology, physics, and chemistry. The platform gained over 2 million users within two years, largely due to its adaptive learning model and engaging content (TechCrunch, 2021). The videos are pre-recorded, allowing offline access an essential feature in areas with limited connectivity. uLesson's success highlights the importance of contextualized and mobile-accessible STEM content (ActionAid Nigeria (2020).

b. *Roducate*

Roducate, developed by the RISE Network, delivers STEM curriculum content via mobile phones and low-bandwidth devices. It gained prominence during the COVID-19 lockdown when the Lagos State Government adopted it to reach students at home. Unlike other platforms, Roducate offers multiple delivery channels including SMS, USSD and offline applications, enabling access for students without internet-enabled devices (Punch, 2020). Studies show that students using Roducate had higher retention and comprehension levels due to repetitive access to materials (Eze & Mordi, 2022). Roducate offers curriculum-aligned content via mobile-based learning and has partnered with Lagos State to support students during school closures and holidays (Punch, 2020).

c. *UNESCO Mobile Literacy for Displaced Children*

In collaboration with Nigerian educational agencies, UNESCO piloted a mobile learning project targeting internally displaced persons (IDPs) and out-of-school children in northern Nigeria. The initiative used basic mobile phones to deliver interactive science lessons through SMS and voice messages. Results indicated improved literacy and science comprehension among beneficiaries, many of whom had no prior formal education (UNESCO, 2021a). This case demonstrates how mobile-based learning can bridge educational inequalities among marginalized populations. UNESCO's Mobile Literacy Project piloted in northern Nigeria, using mobile phones to teach science concepts to out-of-school children and internally displaced persons (IDPs) and refugee camps (UNESCO, 2021b).

d. *WhatsApp and Edmodo Classrooms*

During the COVID-19 pandemic, many Nigerian schools turned to WhatsApp and Edmodo to continue learning and STEM education in particular. Teachers in urban and peri-urban areas of Lagos and Abuja formed virtual classrooms where they shared science learning notes, assignments, video explanations and quizzes via mobile-based apps (Ogunyemi, 2021). These mobile-based apps and platforms enabled peer-to-peer collaboration and real-time teacher feedback, making remote learning more engaging. Although informal, these approaches highlight the adaptability of mobile platforms in crisis contexts. Edmodo WhatsApp Groups, some schools in

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Abuja and Lagos in Nigeria used WhatsApp and Edmodo during the COVID-19 lockdown to deliver STEM content (Ogunyemi, 2021, Ogunlade & Aladejana, 2022).

e. *Schoolgate Mobile Learning App*

Schoolgate is a Nigerian mobile learning platform offering free STEM learning resources for secondary school students. It focuses on practice tests and simulations aligned with WAEC and NECO exams. Users reported improved performance in standardized tests after consistent use of the app (Aina & Adedoja, 2021). The gamified nature of Schoolgate content has contributed to increased engagement and motivation among learners (Edeh, 2019).

f. *LearnAM App by ScholarX*

LearnAM, an app developed by ScholarX with support from the Mastercard Foundation, provides mobile learning in STEM-related vocational subjects in local languages such as Yoruba, Igbo and Hausa. While it focuses on informal education, its impact on digital literacy and science-based skills is significant, especially for underserved populations (Mastercard Foundation, 2022).

These case studies collectively underscore the transformative role that mobile-based learning can play in STEM education in Nigeria. They also reflect varying delivery models from high-tech applications requiring internet access to low-tech SMS and audio formats demonstrating flexibility in reaching different demographics. Success hinges on factors such as contextual relevance, affordability and government support.

Conclusion

Mobile-based learning offers a dynamic and scalable solution to the challenges confronting STEM education, its content delivery and learning in Nigeria. While infrastructure and policy gaps remain, strategic investments, stakeholder collaboration and sustained innovation can transform mobile devices into powerful educational tools. As Nigeria aspires to compete in the global knowledge economy, embracing mobile learning in STEM education is not just an option, but rather it is a necessity.

Suggestions

Based on the findings of this study, the following suggestions are proposed to enhance the implementation and effectiveness of mobile-based learning in advancing STEM education in Nigerian classrooms:

1. *Expand Digital Infrastructure Nationwide*

The federal and state governments, in collaboration with private sector partners, should invest significantly in improving digital infrastructure particularly in underserved rural areas. This includes the provision of stable electricity, internet connectivity, and maintenance support systems in public schools.

2. *Subsidize Mobile Learning Tools and Data Access*

Government and development agencies should work with telecom providers to subsidize smartphones, tablets, and mobile data plans for students and teachers. Initiatives similar to “one student, one device” can help reduce the digital divide in STEM education access.

3. *Integrate Mobile Learning into National Curriculum Policy*

The Nigerian Ministry of Education should develop comprehensive policies that incorporate mobile learning into the national STEM curriculum. These policies must set standards for content development, platform usability, and integration into teaching methodologies.

4. *Enhance Teacher Capacity in Digital Pedagogy*

Professional development programs focused on mobile-based teaching methods should be institutionalized. Teachers must be trained not only in the use of mobile tools but also in how to design and deliver interactive STEM lessons using mobile applications and platforms.

5. *Develop Locally Relevant and Culturally Sensitive Content*

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EdTech developers and content creators should ensure that mobile STEM content aligns with the Nigerian curriculum, is available in local languages, and reflects real-world contexts that resonate with Nigerian learners.

6. *Strengthen Monitoring, Evaluation, and Research Mechanisms*

Continuous evaluation of mobile learning interventions is necessary. Government agencies, universities, and NGOs should carry out longitudinal research to assess impact, address emerging challenges, and promote evidence-based scaling of effective practices.

7. *Encourage Multi-Stakeholder Collaboration*

Public-private partnerships involving the government, telecoms, tech startups, NGOs, and international organizations are essential to mobilize resources, build scalable platforms, and ensure the sustainability of mobile-based learning in STEM education.

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