The use of Mobile Technologies in Science Education in Nigeria: The Multi-Faceted Analysis of the Potentials, Challenges and Policy Imperatives

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Abstract
Science, Technology, Engineering, and Mathematics (STEM) education is considered to be an essential factor in the national progress, economic prosperity, and global competitiveness. In Nigeria, even though the primary importance of science education in secondary schools is explicitly recognized by the education policy, there are some systemic issues that impede the process such as the consistent lack of funding, the outdated curriculum, and a shortage of trained specialists. At the same time, there is some paradox in Nigerian digital environment as the cell phone penetration rate is very high, but the disparity between meaningful connectivity and digital literacy is significant. The following report discusses how mobile learning (m-learning) can be a highly effective, theoretically-informed solution to these institutional-level challenges. The research paper looks into the educational principles behind m-learning based on the principles of constructivism and connectivism theories, evaluates the existing digital infrastructure and human capacity of Nigeria and generalizes on the available empirical results of successful pilot projects. The report concludes that although mobile technology has enormous potential in improving equity in education, promoting active learning and reducing the geographical barriers, its successful and sustainable implementation is hindered by overlaying infrastructural, economic and human capacity barriers. In order to take full advantage of this potential, a multi-stakeholder system of policy reforms, pedagogical innovation, and strategic resource development can be suggested.

1. Introduction

History-Background:The Imperative of Science Education in Nigeria.

It is scientific education that is considered universally as a basis of socio-economic progress of a country (Kola, Gana, & Olu, 2019). In a developing nation as Nigeria, science is vital in teaching and learning in propelling economic growth and competitiveness in the world. The significance is officially declared by the Federal Ministry of Innovation, Science and Technology, which believes that STEM education acts as the access point to socio-economic development (Esuabana, 2025). The development of the main national policies like the Nigerian Vision 20:2020 and the 2012 policy on Science, Technology and Innovation (STI) also evidence a formal readiness to address the

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historical divide between economic planning and the development of science and technology. Although the importance of science education benefits the whole country and its development is high-level policy, the complete and complete implementation of science education in schools in Nigeria is still a challenge (Ezechi & Ogbu, 2017).

1.2.The Stumbling Blocks: Continuous Science Education Problems.

The structural problems facing successful implementation of the science education curriculum in Nigerian secondary schools are complex and internalized. The challenges mentioned above could be divided into three main groups including infrastructural, human capacity, and curricular.

In terms of infrastructure, one of the issues is that the resources required to support the process of instructional delivery and practical application are grossly insufficient (Adeyemi, 2019). This involves a widespread unavailability of current textbooks on science and working laboratory facilities (Nwagbo, 2006). A survey of schools in Africa discovered that although 92 percent of schools had science laboratories in them, only 82 percent of these well-equipped schools could also conduct practical lessons (NASAC survey, 2021). This shortage of resources is used as a justification to evade the most important practical aspect of science education that is essential in building critical thinking and objective reasoning.

Issues pertaining to human capacity are also very important.

The lack of qualified science teachers is widespread, and most scientists teachers in the field do not have pedagogical content knowledge (PCK) that leads to the conceptual understanding and practical application of scientific principles by students (Ezechi and Ogbu, 2017). It commonly leads to overreliance on old fashioned, abstract and expository forms of teaching as opposed to the more involving, activity based teaching methods that are fundamentally important in teaching science (Abba and Ubandoma, 2008).

Lastly, these issues are enhanced by curriculum and planning problems. There is a tendency to overload the science curriculum and a wide and dense content to be taught within a short period of time (Badmus and Omosewo, 2018). It is also noted that this curriculum is too old and fails to equip the youths with practical digital skills to suit the modern job market (Oparaugo, GetBundi survey, 2023). All of this results in an enormous policy-implementation gap, in which grandiose national plans are not achieved at the ground level because of internal malfunctions in the system and resource constraints.

Table 1 is a summary of these challenges.

Table 1: Key challenges in Science Education in Nigeria

Category	Specific Challenge
Infrastructural & Resource Deficits	**- Unavailable working laboratories and apparatus - Inadequate and old-fashioned textbooks in science - Inadequate money to fund science courses.**
Pedagogical & Human Capacity	**- The lack of qualified teachers in the field of science - the lack of the necessary pedagogical contents knowledge (PCK) - the use of expository and non-active ways of learning - insufficient motivation and training of teachers.**
Curricular	**-Too much content in the curriculum - Old curriculum, which is not easy to follow up - Misalignment of policy goals and curriculum implementation.**

1.3 The Rationale behind Mobile Learning as a Transformative tool.

M-learning, which is an extension to e-learning, can be defined as learning through the use of handheld devices like smart phones and tablets (Peters, 2007; Crescente and Lee, 2011). The popularity of this approach to pedagogy is great all around the world as a result of the active

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introduction of mobile technology and constant developments in the sphere of internet infrastructure (Harriet et al.). The benefits of M-learning are strong and it directly tackles the education gaps faced by Nigeria such as flexibility, convenience and it is not bound to the space and time limitations of the traditional education. Smartphones are everywhere, and most Nigerians use them as the main tool of internet access; hence, they are a highly promising medium of delivering the educational process. This report argues that Nigeria stands a good chance to address the longstanding challenges of access, equity, and pedagogical innovations in science education by using the current popularity of mobile technology.

1.4 Aims of the Article

The research article is organized to give a detailed discussion of the application of mobile technology in science education in Nigeria. The specific aims are to:

Review the theoretical frameworks, which furnish the pedagogical basis of mobile supported science learning.

Give a factual report of the current situation in Nigeria in terms of digital environment to get an insight into the opportunities as well as the constraints.

Record particular possibilities of using m-learning in the science classes.

Determine and critically evaluate the severe barriers to sustainable m-learning implementation.

Suggest a multi-stakeholder action plan in the form of recommendations on the progressive approach.

2. Theoretical Foundations of Mobile Learning in Science Education.

Mobile learning is not a technical tool but is a pedagogical practice that is based on the existing learning theories. These theoretical backgrounds are important in the design of effective and sustainable educational interventions.

2.1. Mobile Learning and Constructivist Paradigm

Mobile learning has a strong connection to the concepts of social-constructivism (Sharples et al., 2016). It is a paradigm that was linked to the work of foundational scholars, including Lev Vygotsky, John Dewey, and Jean Piaget, who assumed that learners do not passively receive information but are active users of their own knowledge relying on the previous experiences (Mattar, 2017). This philosophy of active learning is the complete opposite of the traditional, expository teaching approaches that are widely practiced in most of the Nigerian schools (Nwagbo, 2006).

Mobile devices can also conform to and support constructivist practices through providing experiential learning which is a fundamental principle of good science teaching. Mobile devices allow the students to carry out practical activities, collect data in the field or to use dynamic simulations (Abba and Ubandoma, 2008). Moreover, the mobile gadgets are portable and therefore learning can take place in various situations, learning students to construct meaning and develop knowledge in the real life situations (Quan et al.). Mobile technology can help reduce the divide between the abstract processes in science and the informal knowledge that students possess by enabling students to participate in virtual experiments and explorations involving the question of what is possible and what is not, to build conceptual knowledge in students.

2.2 Networked Learner and connectivism.

Whereas constructivism puts consideration on the active involvement of the individual learner, connectivism is a theory more fitting the digital age, and it views learning as a dynamic networked process (Mattar, 2017). In contrast to other previous theories where knowledge is perceived to be in the mind of the learner only, connectivism is the view that knowledge is in networks and learning is the process of traversing, searching and determining whether the information remains up to date and is still acceptable.

The application of this theory to the Nigerian situation is immense because most traditional education systems tend to segregate students of the real time and the information sources around the world. The mobile devices use their networking powers to give access to learners to extensive knowledge networks.

An example is that students may use services

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such as Khan Academy or Coursera to complete the outdated textbook material, engage in educational forums in addition to accessing multimedia materials. It is what allows students to become self-directed learners and international citizens and acquire skills that go way beyond the four classroom walls.

2.3.Technological Pedagogical Content Knowledge (TPACK) Framework:

Mobile technology requires a holistic framework to be successfully applied in the teaching context. Technological Pedagogical Content Knowledge (TPACK) model invented by Punya Mishra and Matthew Koehler is an essential guide to instructional change. TPACK focuses on the fact that in order to successfully integrate technologies, one should have an in-depth knowledge of the interdependence of three fundamental areas of knowledge, namely Content Knowledge (CK), Pedagogical Knowledge (PK), and Technology Knowledge (TK).

In Nigerian traditional educational environments, the teacher most often relies on his/her Content Knowledge and conveys the information by lectures and reading. This has been disputed by the TPACK framework where educators are required not only to be familiar with what is to be taught but also have the ability to teach it with the use of the right digital tools. Research has indicated that the TPACK of a teacher is best predicted by technological, pedagogical and technological pedagogical knowledge of teachers. This implies that merely providing the teachers with technology is not sufficient but a change in system in the way that teachers are trained is necessary so that technology can be used to complement, rather than to substitute, effective teaching methods.

3. The Digital Landscape of Nigeria As It is: A Data-driven analysis.

The opportunities of mobile learning in Nigeria are directly related to the digital reality of the country. An objective examination of the present situation creates a complicated image of the possibility and deep-seated problems.

3.1 The meaning of connectivity and The Gap of Meaningful connectivity.

Digitally, Nigeria might seem to be a strong country at the surface. By the beginning of 2025, 150 million active cellular mobile connections were recorded, which is equal to 64.0 percent of the overall population. There were also 107 million users who were internet users and 45.4 percent penetration. These raw figures are however misleading. Another more detailed examination by the Alliance of Affordable Internet (A4AI) has shown that there exists a major gap in meaningfully connectedness.

Meaningful connectivity is a more narrow metric that has four pointers, including: 4G connection, possessing a smart phone, having unlimited home/study internet, and using it every day. The A4AI has realized that only 12.1 percent of Nigerian population possesses this quality of internet services. There is still a sharp digital divide, with the level of meaningful connectivity of people in urban areas being more than three times higher than that of people in rural areas. This is one of the urban-rural disparities which are a major hindrance to educational equity. Also, the internet accessibility is still a major hindrance. By 2024, the median price of a mobile broadband plan was 4.2 percent of the gross national income per capita, which is over twice the affordability target of the UN Broadband Commission of 2 percent.

3.2 The Digital Literacy and Skills Gap

The infrastructure is not the only problem but human capital. It is recorded that more than half of the Nigerians do not have fundamentals of digital skills. This is a deep obstacle to m-learning, since basic literacy may have a pre-requisite to access of digital service and online applications.

This is especially a skills shortage among the young people in Nigeria. According to a survey in 2023, 85 percent of higher education graduates do not have any practical digital skills, and most have only a basic understanding of such tools as Microsoft Excel.

The level of smartphone use is only 68% among the population and it is only 39% in the case of laptops or tablets. There is also a major gender gap whereby 62 percent of men know how to

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use mobile internet as compared to 45 percent of women. These statistics demonstrate the extent of the human capacity dilemma which has to be overcome in order to make any m-learning initiative a success.

3.3 policy Initiatives and Implementation Hurdles.

The Nigerian government has shown signs of recognizing the necessity of a digital transformation and as such, has initiated some ambitious plans in this regard including the National Broadband Plan (NBP) 2020-2025, which was meant to see 70% broadband penetration by the end of 2025. This plan has however had huge hitches in its implementation. By July 2025, the broadband penetration rate was only 48.01, making it fail in its interim target of 50 per cent by the end of 2023.

This endemic disconnect between policy objectives and execution has been accredited to some key bottlenecks. The presence of high right-of-way fees charged by the state governments is a barrier to the deployment of the last-mile infrastructure, which is a critical disconnect between the federal and state-levels of action. The unstable power supply and the inability to regulate the situation also complicate the situation, increasing the cost of operations of the providers of services and lagging the pace. The fact that these structural barriers cannot be overcome implies that the nation will fail to enjoy the full fruits of the digital economy.

Table 2 is a summary of the digital metrics in Nigeria.

Table 2: Digital Metrics of connectivity and literacy of Nigeria.

Metric	Data (Early 2025 unless otherwise noted)	Implication
Total Mobile Connections	150 million (64.0% of Population)	Penetration of devices is high, which signifies wide access of the medium.
Internet Users	107 million (45.4% Penetration)	There is a large percentage of people who are online yet most of the people are offline.
Broadband Penetration	48.01% (as of July 2025)	Much lower than the 70 percent NBP 2025 objective, which shows the difficulties in implementation.
Meaningful Connectivity	12.1% Overall (Urban is three times greater than Rural)	Raw figures on internet penetration are not accurate; there is a high unequal access to quality.
Cost of Data	4.2% GNI per capita (2024)	A significant economic obstacle of more than doubling the affordability goal of the UN.
Basic Digital Skills	>50% of Population lacks basic skills	The reason is that human capacity gap is a major bottleneck to technology adoption.
Graduate Digital Skills	85% of Graduates lack practical digital skills	The curriculum in education is obsolete and does not equip students with the contemporary workforce.

4. The prospects of Mobile Learning in Nigerian Science Classs.

With such a strong opposition, mobile learning has strong potentials to eliminate the shortcomings in the science education system in Nigeria and create a more equal, interactive, and efficient learning process.

4.1 Improving Access, Equity and Flexibility.

The mobile learning can break the geographical

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and economic barrier creating a gateway to educational equity to the students in the underserved and rural communities (Zheng, 2009). With an environment whereby there is absence of school infrastructure, shortage of teachers and difference in accessibility to learning materials, mobile phones can make available a great number of learning materials through mobile applications, e-learning systems and even through SMS course materials.

Some African countries already have examples of successful implementation of low-cost, high-impact mobile solutions such as Eneza Education in Kenya and Ubongo Kids in Tanzania. Mobile devices provide the freedom of anytime, anywhere learning, through which students can go beyond the narrow and strict limits of the school schedule and learn as they please (Crescente and Lee, 2011). This becomes a very useful asset especially when a significant part of the learning process happens outside of the classroom and mostly in the house (Lenz, 2015). Self directed learning is an important enabler that can be made possible through this flexibility in areas where teacher shortages are a significant problem (Zhang, 2022).

4.2.Promoting Active and Interactive learning.

Mobile tool integration has the ability to radically alter the way pedagogical practice is delivered and learning is conducted, making it less passive and lecture-based and more student-based, inquiry-based, and active. The information can be collected via mobile devices, interactive quizzes and collaborative knowledge-building can be done through mobile learning environment which is usually social-constructivist.

In the case of science education, the abstract concepts can be made visible with the help of mobile technology.

In order to promote the students in making an exploration of what if, teachers can use using dynamic digital tools like simulations, data logging and projected animation to enable them to visualize the concepts of science, therefore, closing the gap between scientific and informal knowledge. Real time collaboration and feedback may also be enhanced by the use of mobile devices, where students can exchange resources and cooperate in teams and projects, thus, similar effects can be attained as in face-to-face collaboration (Franklin et al., 200
7).

4.3 The GenAI Pilot in Edo State: A Case Study in Transformative Potential

A pilot project funded by World Bank in Edo State in Nigeria is a recent example that gives a strong impression of what can be done when the appropriate pedagogical framework is combined with mobile technology. The study incorporated 800 high school-aged students utilizing a generative AI technology (Microsoft Copilot) throughout the after-school English courses. The educators acted as the orchestra conductors and directed the interactions of the students with the AI-based tool and guided reflection lessons.

The important conclusions made in this pilot were astounding and it showed the capacity of mobile technology to change the face of a structured learning setting. The GenAI treatment group greatly performed when compared to their peers in all of the assessed areas, especially in language acquisition of the English language. The result of the intervention in six weeks would normally take two academic years of the conventional teaching, and the success rate was more than 80 percent of other reported pedagogical programs. Besides, the program was able to decrease the achievement gaps that are based on gender with the female students who had a lower baseline performance improving faster. The high positive correlation between the frequency of participation and learnings outcomes demonstrated that the long-lasting use of the technology has considerable benefits, which the gains observed were not a novelty effect. Although aimed at English, the project is an effective demonstration of a prototype of the project in science education. (Martin et al.,2025)

5. The Challenges to M-Learning that are critical to Sustainable M-Learning Integration.

The potential of mobile learning in the Nigerian science education is great, but the way to achieve the positive outcome is conditional upon doing away with a wave of complicated and interdependent obstacles.

5.1 Barriers of infrastructure and Economy.

Infrastructural and economic barriers are the

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major obstacles to sustainable m-learning integration (Harriet et al.). Even though the Edo State pilot project was successful, the pilot project revealed the essential role of a strong technological infrastructure, observing that disconnection and intermittent power supply were major setbacks. This is compounded by the fact that there is a shortage of the so-called last-mile infrastructure, i.e. fiber optic backbones do not always end at homes and schools, so people are forced to use less reliable mobile internet.

Another significant hindrance is high cost of data. An increase in tariff to 50 percent on data in January 2025 increased the price of a 1 GB data plan even more and few students and teachers could afford to download or stream educational content. This economic challenge is directly related to infrastructural and regulatory challenges, including high right-of-way charges by state governments, which make the deployment process slower and operations more expensive to the service providers. The absence of a coherent policy at both federal and state levels adds to these issues and drives a vicious circle, in which infrastructure issues drive up the economic expenses, which in turn restricts access to digital resources.

5.2.Pedagogical and Human Capacity Problems.

Other than the infrastructure, the human factor is also a huge bottleneck. Several teachers in Nigeria do not know much about digital tools and are not confident and trained to use them properly in their lessons. Research has indicated low use rates of the existing e-learning technologies in certain institutions in Nigeria, which is to imply that any adoption of technology is not only a question of availability but a question of the willingness.

The fact that digital literacy of the students and the educators is low implies that a skills gap problem must be removed first before they can apply technology in higher learning processes. This underpinning challenge is evident in the case of the Edo State pilot project which had to spend first several weeks instructing students on the simplest aspects of digital skills such as email configuration and account creation. The very educational program can be often criticized as being outdated and not properly equipped to include the practical skills in digital that would equip the youth to fit in the modern job market.

5.3 Social and Behavioral Concerns

The social and behavioral issues that come up in the learning environment also happen because of the ubiquity of mobile telecommunication devices. There is serious concern in studies over the detrimental correlation between smartphone use and academic achievement and poor performance is blamed on distraction and addiction issues. Unless guided and given a proper policy, students might utilize their devices in non-learning issues, including social media, entertainment, or even inappropriate material, hence, wasting their time and thus affecting their studies negatively. All these problems require the development of an effective mobile device use policy in educational institutions, supported by educational initiatives, regulations, and relevant enforcement (Moshi et al., 2018). Moreover, m-learning implementation also poses certain ethical concerns of privacy and the ownership of the data which should be taken into account.

6. Suggestions to adopting a Future-Oriented Strategy.

The potential of mobile technology in science education in Nigeria needs a multi-stakeholder/holistic approach involving the intertwined issues of policy, pedagogy, and resource development.

6.1 Policy and Regulatory Recommendations.

While policymakers must stop making such grandiose promises, they should concentrate on using practical solutions to close the digital divide. The first step that must be critically undertaken is a revisit and reform state policies on the right-of-way fees to make the telecommunication firms more investment friendly, thus reducing the cost of laying the fiber optic cables in the last mile.

At the same time, it is necessary to invest in a resilient power grid and the development of the public-private relationships between governments, the private sector, and the civil society organizations. Such a cooperative work can result in a more coordinated and cost-efficient development of infrastructure

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construction and programs on education. The government is also required to develop such clear and friendly policies that will facilitate a smooth implementation of digital tools in schools and put a formal end of certification of mobile-based learning to gain quality and credibility.

6.2 Pedagogical Recommendations.

At the school level, emphasis should not be on merely scooping technology but also on how to apply technology into the learning process. There should be concerted efforts in training and retraining science teachers on the use of emerging technologies in instructional planning, delivery and assessment. The TPACK framework should inform training programs in order to have educators not only learn about the technology, but also learn how to apply it to improving sound pedagogical practices. The use of mobile learning should be implemented to complement and not to replace traditional classroom learning with a blended learning model that equips classroom learning with digital activities. Moreover, the lack in the digital literacy basic skills level will have to be resolved by schools and will be done through custom-to-need programs, likely through modifications to low-cost, offline-friendly learning formats such as SMS-delivered lessons.

6.3.Resource Recommendations and Development.

The educational resources should be developed in the context with regard to the existing infrastructural and economic realities. There is an urgent necessity of developing low-cost and contextually relevant mobile applications and platforms that will be developed to operate on the most widespread technologies (e.g., 2G/4G networks) and use the least amount of data. Educational content that is presented through mobile devices should be controlled and part of formal education to make it qualitative and recognized.

Moreover, the learning materials must be provided not only with academic material but also with information about how mobile devices could be used properly and ethically in order to reduce the risk of distraction and addiction.

Table 3 provides a summary of these recommendations.

Table 3: Multi-Stakeholder Framework of Mobile Learning Integration.

Stakeholder	Key Action Area	Specific Recommendations
Government/Policy Makers	Policy and Regulation infrastructure investment	- eliminate high right of way charges - invest in robust power grid - develop conducive M-learning policies that have certification systems.
School Administrators/Educators	Pedagogy & Human Capacity	- Introduce ongoing teacher education based on TPACK -Use a hybrid learning approach -Enforce basic digital literacy skills in students and employees.
Technology Developers/NGOs	Resource Development/Public-Private partnerships	- Build low-cost and context-sensitive mobile platforms - Build resources on frequent technologies (2G/4G) - Work with government to solve infrastructure and affordability.

7. Conclusion

The issue of mobile learning offers intense and timely solutions to the problem of science education that has been a persistent problem in Nigerian secondary schools. The ubiquity of the mobile devices provides an expedient and adequate platform to transcend longstanding obstacles of access, equity and pedagogical constraints. Using educational programs based on constructivism and connectivism educational theories, and facilitating the process with the help of a framework such as TPACK, mobile technology can help create a more active, engaging, and personalised learning process.

The way forward is however not as simple as deployment of technology. The analysis has shown that a complex picture of interrelated issues has been formed, among them a large disparity between policy and delivery, little

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meaning connectivity, and a lack of digital literacy in both students and teachers. These obstacles create a self consolidating loop in which the infrastructural and economical impediments hinder the development of human capacity.

M-learning requires a brilliant, connected, and integrated approach to be able to realize the maximum potential. This needs state intervention coupled with teacher intervention coupled with the business community to restructure policies, invest in basic infrastructures and focus on human capacity building. It is through a systematic, purposeful approach to the root problems that Nigeria can harness the strength of mobile technology to create an equitable, efficient, and progressive science education system among the young population to help put Nigeria on the road to a more successful and competitive future.

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