

Assessing the Impact of Internet of Things (IoT) Devices on Research and Education: Opportunities, Challenges, and Prospects in Nigeria

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Abstract

This study investigates the extent to which IoT devices are being adopted in Nigerian tertiary institutions, with specific attention to their potential, constraints, and future implications. The study was guided by four objectives: to explore the opportunities IoT offers for enhancing teaching, learning, and research; to identify major challenges associated with its implementation in the Nigerian context; to evaluate the impact of IoT on the efficiency and outcomes of academic activities; and to highlight the future prospects and trends in IoT for transforming education and research in Nigeria. A mixed-methods approach was adopted, involving quantitative data from 360 respondents and qualitative insights from 12 key stakeholders interviewed across selected institutions nationwide. The findings reveal that IoT devices are increasingly being used to improve instructional delivery, personalize student learning, and enhance data collection for research. However, the study also identifies critical challenges including inadequate digital infrastructure, high cost of IoT systems, limited technical expertise, and the absence of clear national or institutional policies. Despite these challenges, respondents expressed strong optimism about the future role of IoT in enabling smart campuses, AI-driven learning environments, and innovative research collaboration. The study concluded that while the integration of IoT into Nigerian education and research is still in its formative stage, its transformative potential is evident. To fully realize this potential, there should be strategic investments in infrastructure, comprehensive training programmes, policy formulation, and inclusive implementation strategies are required. The study recommended a collaborative, future-oriented approach involving government, institutions, and industry stakeholders to ensure that IoT becomes a sustainable driver of academic excellence and national development.

Keywords: Digital Innovation, Educational Technology, Internet of Things, Research, Smart Campus.

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1. Introduction

The rapid advancement of digital technologies has significantly altered the landscape of education and research across the globe. Among these technological innovations, the Internet of Things (IoT) stands out as a transformative force, enabling the interconnection of physical devices, sensors, software, and networks to facilitate real-time data exchange and automation (Al-Fuqaha et al., 2025; Noura et al., 2024). In the educational and research sectors, IoT devices such as smartboards, sensor-enabled laboratory equipment, wearable learning aids, and intelligent campus infrastructure are increasingly being deployed to improve teaching, learning, and data-driven research processes. Atzori, et al. (2023) opined that these innovations are redefining the way educators deliver content, students engage with learning materials, and researchers collect and analyse data.

In the Nigerian context, the integration of IoT in education and research is still at a nascent stage but is gaining momentum as academic institutions and policymakers seek to leverage digital technologies to address systemic challenges. Nigeria, as Africa's most populous country and a leader in the continent's educational development, is presented with unique opportunities to embrace IoT in its academic institutions. The implementation of IoT can revolutionise traditional teaching methods by promoting interactivity, personalised learning, and improved access to real-time information (Oyelaran-Oyeyinka & Adeya, 2020). Similarly, in research, IoT facilitates the seamless

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collection and transmission of data, remote experimentation, and real-time monitoring, thereby enhancing the scope and accuracy of scientific investigations.

However, while the benefits of IoT are substantial, the Nigerian educational and research environment also faces significant challenges in fully realising these potentials. These include infrastructural deficits, unreliable internet connectivity, limited technical expertise, cybersecurity concerns, and insufficient funding (Aderibigbe & Kolawole, 2022). In rural and under-resourced institutions, the digital divide is particularly pronounced, potentially widening gaps in educational equity and research capacity. Despite these constraints, the future prospects of IoT integration in Nigerian academia remain promising. As digital infrastructure improves and awareness increases, IoT is poised to play a more central role in smart campus development, adaptive learning environments, and multidisciplinary research collaboration. Exploring global trends and aligning them with local realities can help Nigeria tap into the transformative power of IoT for long-term educational and scientific advancement.

1.1. Statement of the Problem

The integration of Internet of Things (IoT) devices in education and research has become increasingly important in fostering innovation, efficiency, and improved outcomes globally. These technologies offer immense potential to enhance teaching and learning through real-time data sharing, remote monitoring, personalized learning environments, and intelligent classroom interactions. In research, IoT enables the automation of data collection, improved experimental accuracy, and real-time analytics, all of which contribute to the quality and scope of scholarly outputs (Al-Fuqaha et al., 2025; Atzori et al., 2023). However, in the Nigerian context, the adoption and implementation of IoT technologies remain limited and uneven across institutions. Several challenges hinder the full-scale deployment and utilisation of IoT devices in Nigeria's educational and research institutions. These include poor internet connectivity, unstable power supply, limited digital infrastructure, inadequate funding, and a lack of technical expertise among educators and researchers (Aderibigbe & Kolawole, 2022). Moreover, issues of cybersecurity, data privacy, and institutional resistance to technological change further complicate efforts to integrate IoT into the academic environment. Consequently, many Nigerian institutions are unable to leverage the full benefits of IoT, thereby missing out on opportunities to improve learning experiences, research efficiency, and global competitiveness.

Furthermore, while global discourse around IoT in education continues to evolve, there is a significant gap in empirical studies that assess the specific impact, challenges, and prospects of IoT integration in Nigeria's academic and research sectors. This lack of localized data makes it difficult for stakeholders to make evidence-based decisions on policy formulation, resource allocation, and strategic planning. Without a clear understanding of how IoT devices are currently being adopted and what barriers exist, efforts to digitalize education and research may remain fragmented and ineffective. This study is therefore necessitated by the urgent need to assess how IoT technologies are shaping the teaching, learning, and research landscape in Nigeria. It seeks to explore the opportunities presented by IoT, identify context-specific challenges, evaluate its actual impact, and highlight potential future trends that can guide effective integration in Nigerian institutions. By addressing these issues, the study aims to provide a comprehensive framework for harnessing IoT as a tool for academic transformation and innovation in Nigeria.

1.2. Objectives

- a. To explore the opportunities IoT devices offer for enhancing teaching, learning, and research processes.
- b. To identify the major challenges associated with the implementation and utilisation of IoT technologies in the Nigerian context.
- c. To evaluate the impact of IoT integration on the efficiency, interactivity, and outcomes of educational and research activities.
- d. To highlight future prospects and trends in IoT that can further transform the academic and research landscape in Nigeria.

2. Literature Review

The integration of IoT in education and research has opened new dimensions in pedagogy, student engagement, and scientific inquiry. Qasem and Abu—Shanab (2021) suggest that IoT technologies facilitate smart learning environments where devices such as interactive whiteboards, wearable devices, and sensor-enabled tools provide real-time feedback

and personalized learning pathways. In classrooms, Khan, et. al (2024) noted that IoT supports blended and flipped learning models by enabling access to digital content and interactive simulations beyond the traditional four walls of learning. In the research domain, IoT plays a critical role in automating data collection, enhancing collaboration through cloud-based platforms, and supporting real-time monitoring in experiments. According to Sharma and Sharma (2020), IoT-enabled research labs improve efficiency by reducing manual data entry and allowing remote access to instruments. This is particularly useful in fields like environmental science, agriculture, health, and engineering, where real-time data from sensors can enrich research findings. In Nigeria, Okafor and Edeh (2022) reported that some tertiary institutions have begun experimenting with smart classroom initiatives and automated attendance systems using RFID and IoT sensors. However, these efforts are often limited to pilot phases and do not reflect a broad-based transformation.

While the benefits of IoT are evident, several contextual barriers hinder its adoption in Nigeria. The most significant challenges include poor infrastructure, unreliable power supply, and limited broadband internet coverage. The World Bank (2023) highlights that only about 36% of Nigerians have access to reliable internet, which severely restricts real-time device communication — a core requirement of IoT functionality. Moreover, as reported by Aderibigbe and Kolawole (2022), there is a critical skills gap. Many educators and researchers lack the technical competencies needed to deploy and manage IoT devices effectively. Institutional resistance to change, high procurement and maintenance costs, and inadequate cybersecurity measures further complicate the adoption process. Noura, et. al (2024) averred that cybersecurity, in particular, is a growing concern, with many institutions lacking robust protocols to protect sensitive data transmitted through IoT devices. Policy and regulatory frameworks are also lagging. While Nigeria's National Digital Economy Policy (2020) outlines broad strategies for digital transformation, it lacks specific directives for IoT integration in the education and research sectors. This policy vacuum limits institutional guidance and funding support for IoT projects.

Empirical studies globally suggest that IoT integration significantly enhances educational outcomes by promoting interactivity, accessibility, and learner autonomy. IoT-based systems such as smart attendance, real-time progress tracking, and AI-assisted tutoring have been shown to improve student retention and performance (Zhou et al., 2020). In research, Atzori, et. al (2023) opined that IoT allows for remote collaboration, data synchronization, and access to experimental tools from geographically dispersed locations, enhancing the scope and scale of projects. In Nigeria, however, few studies have quantitatively assessed the actual impact of IoT on academic outcomes. Existing evidence remains largely anecdotal or theoretical. Where implementation exists, the impact tends to be limited by intermittent power supply, poor user training, and system unreliability. For instance, Egbujie and Adeyemi (2023) found that IoT tools improved the quality of environmental monitoring in university research projects, but challenges in device calibration and maintenance often undermined reliability. Nonetheless, there is a growing awareness among Nigerian institutions about the value of digital transformation, and some universities are beginning to track improvements in administrative efficiency and research output resulting from partial IoT deployments.

Globally, IoT trends point toward the rise of smart campuses, AI-integrated learning environments, and interoperable research platforms. The convergence of IoT with other emerging technologies such as Artificial Intelligence (AI), Machine Learning (ML), and Blockchain promises a more adaptive, secure, and efficient academic ecosystem (Li et al., 2021). In Nigeria, Oyelaran-Oyeyinka and Adeya (2020) noted that the prospects for these advancements are contingent on deliberate investment in digital infrastructure, policy support, and capacity building. Strategic partnerships with global tech firms and research institutions could help Nigeria leapfrog some of the infrastructural and skill barriers currently impeding IoT deployment. Furthermore, local innovation hubs are beginning to explore IoT applications in agriculture, health, and education, creating a potential pipeline for domestic solutions tailored to Nigerian realities. Government interventions, such as the National Broadband Plan and Smart Nigeria Digital Strategy, offer frameworks through which the adoption of IoT in academia can be accelerated. However, implementation remains slow, and focused policy attention on education and research applications of IoT is still lacking.

Conclusively, the literature reveals that IoT has transformative potential for education and research in Nigeria but remains underutilised due to infrastructural, technical, financial, and policy-related barriers. While isolated successes exist, there is a need for a more structured, well-funded, and context-sensitive approach to IoT integration in Nigerian academic institutions. Future studies should aim to provide empirical insights that guide such an approach, with clear metrics for measuring impact and sustainability.

3. Methods

The study adopts a mixed-methods research design, combining both quantitative and qualitative approaches. The quantitative component captures the breadth of institutional experiences and perceptions, while the qualitative component offers depth and contextual insights from key stakeholders. The target population consists of academic staff and researchers in universities, polytechnics, and research institutions across Nigeria; ICT personnel and system administrators responsible for managing technological infrastructure; students who use IoT-based tools in their learning activities; and policy and administrative personnel involved in educational technology planning.

A multi-stage sampling technique was employed: at the first stage, there was a purposive selection of six (6) tertiary institutions (including both federal and state universities and polytechnics) from the six geopolitical zones of Nigeria to ensure national representation; at the second stage, there was stratified sampling within each institution to select respondents across key stakeholder groups (lecturers, researchers, students, ICT staff); at the third stage, there was simple random sampling of individuals within the strata. The estimated sample size is 360 respondents, with approximately 60 respondents from each institution, distributed to include Academic staff/researchers, ICT/system administrators, Students, and Administrators/Policy staff.

For the qualitative component, in-depth interview was conducted with 12 key stakeholders, including Directors of ICT and Deans of Faculties. Quantitative data were collected through Google Forms and qualitative data were collected through recorded in-person and virtual interviews using Zoom, Microsoft Teams, or WhatsApp calls. Data from the questionnaires were coded and analysed using Statistical Package for the Social Science (SPSS), using both descriptive and inferential statistics; and the data from the interviews were transcribed and analysed using thematic analysis, supported by NVivo software.

4. Result and Discussion

Table 1. Presentation of Results and Discussion of Findings

Demographics	Percentage (%)	Frequency
Gender Distribution		
Females	42%	151
Males	58%	209
Total	100%	360
Educational Qualifications		
Postgraduate	65%	234
Undergraduate	30%	108
Diploma	5%	18
Total	100%	360
Role in Institution		
Students	40%	144
Academic staff	30%	108
ICT personnel	20%	72
Administrators	10%	36
Total	100%	360
Years of Experience with IoT tools		
None	22%	79
1 – 3 years	38%	137
4 – 6 years	25%	90
Above 6 years	15%	54
Total	100%	360

The demographic data showed that the respondents were evenly distributed without bias based on gender; their educational qualification showed they are educated enough to understand the requirements of the questionnaire items and the objectives of the study. Similarly, as students, academic staff, ICT personnel, and administrators who have experiences in the handling of IoT tools for educational purposes, the respondents were well poised for providing answers to the research questions.

Table 2. Objection 1: Opportunities IoT Devices Offer for Enhanced Teaching, Learning, and Research

Opportunities IoT Devices Offer	Yes (%)	No (%)
IoT enhances classroom interactivity and engagement	83%	17%
Smart devices (projector, tablets) improve instructional delivery	76%	24%
IoT has enhanced data collection and real-time monitoring in scientific studies	69%	31%
Increase motivation to learn when IoT technologies were used	55%	45%

4.1. *Qualitative Interviews (1)*

Interviewees mentioned smart laboratories, IoT-supported learning management systems (LMS), RFID-based attendance systems, and remote monitoring tools as current applications, noting that the application of IoT in research saves time and provides more accurate results.”

The findings are consistent with Qasem and Abu-Shanab (2021), who noted that IoT creates immersive learning experiences and data-driven instruction. IoT has demonstrated its value not only in instruction but also in transforming research methodologies across disciplines. However, adoption appears higher among urban institutions with better digital infrastructure. The findings also align with global literature, where IoT is described as a facilitator of context-aware learning environments (Qasem & Abu-Shanab, 2021). By providing real-time access to educational content and enabling interactive engagement, IoT helps shift teaching away from passive learning models to students-centered pedagogies. In Nigeria, institutions that have invested in such technologies reported improved student participation and increased motivation to learn, especially among science and technology students. The research findings also support previous assertions by Atzori et al. (2023), who argued that IoT transforms students from passive receivers of knowledge to active participants in a dynamic and connected learning ecosystem.

Collectively, these findings suggest that IoT offers vast opportunities to modernize and optimize Nigeria’s educational and research systems. However, the actual utilization of these opportunities is currently uneven, it is more prevalent in technologically advanced institutions, and mostly pilot-based in others. There remains a significant gap between awareness of IoT benefits and widespread, sustained implementation. The findings affirm previous studies (e.g., Zhou et al., 2020; Li et al., 2021) that position IoT as a key driver of innovation in global education systems. In the Nigerian context, the opportunity lies in scaling up existing initiatives, fostering collaborations between academia and the tech industry, and providing targeted funding and training to expand IoT adoption.

Conclusively, IoT presents numerous opportunities to improve teaching delivery, deepen student engagement, and enhance the quality and scope of research in Nigerian tertiary institutions. While some progress has been made, realizing the full potential of IoT in education and research requires deliberate investment, staff training, infrastructure development, and a national framework to guide systematic adoption. The next phases of IoT adoption should move from isolated interventions to institutional and policy-level integration for sustainable impact.

Table 3. Objective 2: Challenges Associated with the Implementation and Utilisation of IoT Technologies in Nigeria

Challenges to IoT	Yes (%)	No (%)
Inadequate internet access	81%	19%
Frequent power outages	78%	22%
High cost of devices and maintenance	74%	26%
Lack of skilled personnel	70%	30%
Data privacy concerns	55%	45%
Lack of institutional policies	60%	40%

4.2. *Qualitative Interviews (2)*

Respondents described difficulties in sustaining IoT projects as mainly due to budget constraints and lack of training; as many of the smart devices are there, but they are underutilised because staff don’t fully understand how to use them.

These challenges are similar to those highlighted by Aderibigbe and Kolawole (2022) and the World Bank (2023), reflecting systemic infrastructural and policy constraints. The digital divide between rural and urban institutions exacerbates inequality in access to emerging technologies. These infrastructural deficits mirror broader national development issues and are consistent with the findings of the World Bank (2023), which highlighted Nigeria’s uneven digital infrastructure as a major bottleneck to technological innovation. The findings also support Aderibigbe and Kolawole (2022), who emphasized the unsustainable cost of IoT systems in under-resourced educational settings across

Nigeria. Similarly, Qasem and Abu-Shanab (2021) argue that digital illiteracy among educators remains one of the most overlooked challenges in IoT implementation, particularly in developing countries.

Summarily, despite the acknowledged benefits of IoT in enhancing research and education, its implementation in Nigeria is hindered by a convergence of infrastructural, financial, technical, and policy-related barriers. To address these challenges, there must be a deliberate and coordinated effort involving government agencies, educational institutions, development partners, and the private sector to invest in infrastructure, build capacity, reduce costs, and develop regulatory frameworks. Without such efforts, the transformative potential of IoT in Nigeria’s academic system will remain largely unrealised.

Table 4. Objective 3: Impact of IoT Integration on Efficiency, Interactivity, and Outcomes

Impact of IoT Integration	Yes (%)	No (%)
IoT improved task efficiency in both teaching and administrative process	68%	32%
IoT devices made learning more interactive		
Improvement in academic performance due to IoT-enhanced instruction	72%	28%
Reduced data collection time and increased reliability	59%	41%
	66%	34%

4.3. Qualitative Interviews (3)

Interviewees remarked that students interact more with course content through digital whiteboards and sensors; and they see better participation rates.

These findings reinforce those of Zhou et al. (2020), who argued that IoT promotes autonomy, interaction, and efficiency in learning environments. Despite infrastructural limitations, institutions that have successfully integrated IoT report tangible benefits in both pedagogy and research. These findings are in line with those of Zhou, et. al (2020), who observed that IoT-based automation significantly reduces redundancy in academic processes and enhances the responsiveness of administrative systems. The findings also align with the student-centered learning model advocated in the literature, where IoT serves as a bridge between traditional pedagogy and immersive, real-time learning environments (Qasem and Abu-Shanab, 2021; Atzori et al., 2023). Similarly, Sharma and Sharma (2020) emphasized that IoT contributes to increased research accuracy, reduced experimental errors, and timely data interpretation.

The findings clearly show that IoT integration, when effectively implemented, has a measurable impact on educational efficiency, learning interactivity, and research productivity. These improvements are consistent with global evidence that positions IoT as a key driver of innovation and efficiency in education. However, Nigeria's experience reflects a dual reality: institutions with infrastructure and policy support are experiencing these benefits, while others remain on the periphery due to systemic challenges. The research supports calls for a system-wide digital transformation strategy, where IoT is not treated as a luxury or experimental tool, but as an essential infrastructure for modern education and research.

Conclusively, the study showed that IoT has positively impacted educational and research outcomes in Nigerian institutions by improving operational efficiency, enabling interactive learning, and supporting data-driven research. However, the full realization of these benefits depends on broader adoption, increased investment, sustained capacity building, and inclusive implementation strategies. A deliberate approach to overcoming existing limitations will allow institutions to harness the full transformative power of IoT in advancing educational excellence and research innovation.

Table 5. Objective 4: Future Prospects and Trends in IoT for Academic Transformation in Nigeria

Future Prospects and Trends in IoT	Yes (%)	No (%)
Optimism about future role of IoT in education and research	85%	15%
Increased government investment in smart campuses	70%	30%
Partnership with tech companies to localize solutions	61%	39%
Need for continuous training and digital literacy programmes	64%	36%

4.4. Qualitative Interviews (4)

The respondents envisioned a future with AI-integrated IoT systems, automated learning environments, and real-time data dashboards for research, where smart campuses will soon be inevitable, but there is need for strategic investment and clear policy frameworks.

The findings highlight that while IoT adoption is still in early stages, stakeholders acknowledge its potential to radically transform Nigeria's academic landscape. This aligns with global trends toward AI-IoT convergence, adaptive learning environments, and cloud-integrated research ecosystems (Li et al., 2021). This optimism aligns with global forecasts (Li et al., 2021; UNESCO, 2023) that predict the widespread integration of IoT into next-generation learning environments, especially in developing countries embracing EdTech transformation.

The future prospects of IoT in Nigerian education are rich with promise, but they are contingent upon critical enablers, policy coherence, funding, skills development, and equity planning. Stakeholders envision a future where IoT serves as the backbone of an intelligent academic ecosystem, but they also recognize that Nigeria's capacity to innovate, localize, and govern these technologies will determine whether this vision is realized. The study supports the notion that Nigeria stands at a crossroad; with strategic action, IoT can drive inclusive, effective, and future-ready education; without it, the digital divide may widen.

The findings reveal that Nigerian academia is poised for a technological leap through the adoption of IoT—particularly in smart campus development, AI integration, and research digitization. However, future success depends on government commitment, institutional readiness, localized solutions, and a strong emphasis on capacity building. To harness these emerging prospects, Nigeria must adopt a long-term, inclusive, and innovation-driven approach that ensures IoT becomes a sustainable and equitable tool for academic and research excellence.

5. Conclusion

The study was set out to explore the transformative role of IoT technologies in Nigeria's academic landscape. Through a mixed-methods approach, incorporating quantitative survey data and qualitative interviews, the research critically examined four key dimensions: the opportunities IoT presents, the challenges confronting its implementation, the measurable impact of its integration, and the future prospects for broader adoption in Nigerian education and research systems. The findings affirm that IoT devices are gradually reshaping teaching, learning, and research experiences in Nigeria. Educational stakeholders—students, lecturers, ICT staff, and administrators—acknowledge that IoT has improved interactivity, enhanced learner engagement, streamlined data collection for research, and increased instructional efficiency. Tools such as smart boards, IoT-enabled laboratory sensors, automated attendance systems, and connected learning platforms are positively influencing educational delivery and research output.

However, the study also highlights critical systemic challenges that constrain widespread and effective implementation. These include infrastructural deficiencies such as erratic power supply and poor internet connectivity, limited technical expertise among users, high cost of IoT infrastructure and maintenance, inadequate cybersecurity frameworks, and an absence of well-defined institutional and national policies guiding IoT adoption in education. These constraints reflect a broader digital divide that continues to limit equitable access to educational innovation in Nigeria. Despite these barriers, the future of IoT in Nigerian academia remains promising. There is widespread optimism among stakeholders regarding the potential of IoT to drive smart campus development, personalized learning, and more efficient, data-driven research. Emerging technologies, such as AI, cloud computing, and big data analytics, are poised to integrate with IoT, unlocking new possibilities for academic transformation. Realizing this potential, however, will require deliberate policy interventions, increased investment in digital infrastructure, structured capacity-building programs, and strong public-private partnerships.

In conclusion, IoT stands as a catalyst for educational and research innovation in Nigeria. The study recommends that educational institutions and policymakers take a strategic approach to its adoption, focusing on building infrastructure, developing institutional capacity, formulating regulatory frameworks, and fostering a culture of technological adaptability. With these measures in place, IoT can significantly enhance Nigeria's ability to produce globally competitive graduates and impactful research, contributing to national development in the digital age.

In light of the findings from this study the following recommendations are proposed in alignment with the study's specific objectives:

- a. Nigerian educational institutions should actively adopt and integrate IoT devices into core academic operations. This includes deploying smart classrooms, sensor-enabled laboratories, and digital learning platforms to foster interactive and personalized learning experiences. Similarly, these educational institutions should have reform on their curricula, at both undergraduate and postgraduate levels to include practical components on IoT usage, thereby equipping students and educators with hands-on knowledge of emerging technologies.

- b. Government and stakeholders must prioritise investment in basic infrastructure such as stable electricity and broadband internet, particularly in rural and underserved academic environments. They must ensure continuous professional development programmes are organized for lecturers, researchers, and ICT personnel to enhance their competence in IoT deployment and maintenance.
- c. Educational institutions should set up performance indicators to assess the impact of IoT on academic outcomes, including metrics on learner engagement, teaching effectiveness, and research productivity. They should deploy IoT-enabled analytics platforms to track student learning patterns and tailor instructional delivery accordingly.
- d. Educational authorities should encourage the development of smart campuses through phased implementation plans involving IoT systems for classroom automation, energy management, security, and student services. They should set up innovative hubs and tech incubators within institutions to support and develop indigenous IoT solutions relevant to Nigeria's educational and research needs.

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