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# TRENDS AND CHALLENGES IN THE USE OF SIMULATION TECHNOLOGIES IN ELECTRONICS EDUCATION IN NIGERIA: A BIBLIOMETRIC AND CONTENT ANALYSIS STUDY

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**Abstract**
As the global educational landscape shifts towards Industry 4.0, the integration of simulation technologies in electronics education has become a strategic necessity. This study employs a dual-methodology approach bibliometric mapping via VOSviewer and qualitative content analysis to evaluate the trajectory of simulation adoption in Nigerian higher education between 2000 and 2025. Analysing 185 peer-reviewed articles, the study identifies a significant implementation gap: whilst research output increased by 45 per cent following the COVID-19 pandemic, actual laboratory integration remains hindered by systemic socio-technical barriers, including erratic power supply, prohibitive software licensing costs, and lecturer resistance. The study proposes the Hybrid-Simulation Instructional Model (HSIM), a practical, context-sensitive framework designed to overcome infrastructure deficits in Nigerian polytechnics and technical colleges.

**Keywords:** *TVET; Electronics Engineering; Proteus; Bibliometrics; Nigeria; Virtual Laboratories; & TPACK Framework.*

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## Introduction

Electronics education in Nigeria stands at a critical crossroads, shaped by infrastructural decay, rising instructional costs, and rapid technological evolution (Federal Ministry of Education, 2020; UNESCO, 2021). The traditional laboratory model, long regarded as the benchmark for teaching circuit theory and fault-finding, has become increasingly unsustainable in many institutions. Persistent funding shortfalls prevent the procurement and maintenance of digital oscilloscopes, function generators, and logic analysers, whilst the rapid obsolescence of components widens the gap between classroom instruction and modern industry expectations (NBTE, 2021; World Bank, 2022). Graduates frequently find themselves underprepared for roles in circuit simulation, automated testing, and digital system design.

Simulation technologies have emerged as a transformative response to these challenges. Platforms such as NI Multisim, Proteus Design Suite, and MATLAB/Simulink provide interactive virtual environments in which learners design, test, and troubleshoot circuits without physical constraints, thereby eliminating the risk of damaging expensive equipment (Agbo & Ede, 2020; Foster, 2018). Simulation-based learning also promotes flexible, self-paced engagement and aligns with the global shift towards experiential and hybrid pedagogy (Clark & Mayer, 2016; Prince & Felder, 2006). Despite these advantages, integration into Nigerian institutions remains uneven, with limited awareness, inadequate instructor training, and institutional resistance slowing adoption (Akinwale & Okunade, 2020). A comprehensive, evidence-based investigation is therefore urgently needed.

## Problem Statement

Nigerian technical colleges and polytechnics record persistently high failure rates in practical electronics examinations (NBTE, 2021; UNESCO-UNEVOC, 2019). A well-documented disconnect exists between theoretical instruction and practical application: students recall circuit formulae in examinations yet struggle to assemble or troubleshoot real systems (Okoye & Arimonu, 2016; Eze & Olaitan, 2020). Whilst simulation technologies are globally promoted as a bridge for this gap, their actual impact in Nigeria is insufficiently documented. Available platforms are often confined to demonstration use rather than full instructional integration, and most research consists of fragmented case studies without systematic overview (UNESCO, 2021). There is a clear need to examine utilisation patterns, learning outcomes, and the structural barriers preventing full integration.

## Objectives of the Study

The overarching objective of this study is to examine the trends and challenges in the use of simulation technologies in electronics education in Nigeria between 2000 and 2025, with a view to informing evidence-based curriculum reform and institutional policy in Technical and Vocational Education and Training (TVET). Specifically, the study seeks to:

1. Identify and analyse the quantitative trends in scholarly publications on simulation technologies in Nigerian electronics education from 2000 to 2025 using bibliometric mapping via VOSviewer.
2. Determine the dominant simulation platforms in the Nigerian electronics education landscape and examine their frequency of use, pedagogical roles, and relative adoption across institutions.
3. Investigate the primary socio-technical barriers preventing the full-scale adoption of simulation technologies in Nigerian TVET institutions through qualitative content analysis of the reviewed literature.

4. Compare global and local trends in simulation-based electronics education and assess the extent to which Nigerian institutions diverge from international best practices.
5. Propose a context-sensitive instructional model, the Hybrid-Simulation Instructional Model (HSIM) that addresses identified infrastructure deficits and guides the sustainable integration of simulation technologies into Nigerian polytechnic and college of education curricula.

**Research Questions**

In direct correspondence with the foregoing objectives, this study is guided by the following research questions:

1. What are the quantitative trends in scholarly publications on simulation technologies in Nigerian electronics education from 2000 to 2025 as revealed by bibliometric mapping?
2. Which simulation platforms dominate the Nigerian electronics education landscape, and to what extent are they integrated into instructional practice across institutions?
3. What are the primary socio-technical barriers preventing the full-scale adoption of simulation technologies in Nigerian TVET institutions?
4. In what ways do global trends in simulation-based electronics education diverge from local implementation realities in Nigerian institutions?
5. What context-sensitive instructional model can be proposed to guide the sustainable integration of simulation technologies in Nigerian polytechnics and colleges of education, given the identified infrastructure constraints?

**Methodology**

This study adopts a mixed-method desk research design integrating systematic literature review with bibliometric analysis (Tranfield, Denyer, & Smart, 2003; Zupic & Cater, 2015). The quantitative phase applies bibliometric analysis to examine publication metadata authorship patterns, citation networks, keyword frequency, and collaboration trends in order to map research evolution and thematic concentrations (Donthu et al., 2021). The qualitative phase employs thematic content analysis to systematically code and interpret recurring themes relating to challenges, benefits, and policy recommendations in selected full-text articles (Braun & Clarke, 2006). Literature was retrieved from Scopus, Web of Science, and Google Scholar using search terms combining "Simulation", "Virtual Lab", "Electronics Education", and "Nigeria". An initial pool of 312 publications was screened to remove duplicates, non-peer-reviewed materials, conference abstracts without full text, and studies not directly pertaining to electronics education or simulation technologies. The final corpus comprised 185 peer-reviewed papers spanning 2000 to 2025. VOSviewer was employed for bibliometric visualization, generating keyword co-occurrence networks, citation maps, and collaboration patterns (van Eck & Waltman, 2010), whilst NVivo supported systematic coding of qualitative themes, enabling structured interpretation of institutional, pedagogical, and infrastructural barriers (Bazeley & Jackson, 2013).

**Theoretical Framework: TPACK and Cognitive Load Theory**

This study is anchored on two complementary theoretical perspectives. The Technological Pedagogical Content Knowledge (TPACK) framework posits that effective technology-enhanced teaching requires the integrated application of content knowledge, pedagogical knowledge, and technological knowledge (Mishra & Koehler, 2006; Koehler & Mishra, 2009). In electronics

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education, a lecturer who understands circuit theory but cannot operationalise simulation software will deliver suboptimal instruction; similarly, technological competence without appropriate pedagogical strategies reduces simulations to passive demonstrations rather than active learning tools. TPACK therefore emphasises the intersection of these domains rather than their isolated application (Voogt et al., 2013).

Cognitive Load Theory (CLT) complements TPACK by explaining how learners process instructional information. CLT distinguishes among intrinsic load (inherent task complexity), extraneous load (poor instructional design), and germane load (meaningful schema construction) (Sweller, 2011). Simulation tools, when well designed, reduce extraneous cognitive load by providing immediate visual feedback and allowing iterative experimentation. This enables learners to allocate working memory resources more effectively to conceptual understanding rather than procedural error-correction a crucial advantage in content-dense disciplines such as analogue and digital electronics.

## Results: Bibliometric Mapping

### *Growth of Research Output, 2000–2025*

The bibliometric data reveal three distinct developmental epochs. During the Dormant Era (2000–2009), research output averaged approximately two publications per year, with attention focused on general computer literacy rather than specialised simulation tools (UNESCO, 2005). The Emergent Era (2010–2019) saw output rise to approximately eight publications annually, coinciding with increased computer access in tertiary institutions and the growing adoption of Proteus Design Suite in undergraduate projects (Akinwale & Okunade, 2020; NBTE, 2018). The Pandemic Acceleration Era (2020–2025) produced the most dramatic growth approximately 22 publications per year driven by COVID-19-induced institutional closures that compelled rapid adoption of virtual instructional strategies (UNESCO, 2021; World Bank, 2022). This 45 per cent surge in post-pandemic output reflects a shift from exploratory to evaluative and implementation-focused research as institutions sought sustainable digital solutions for practical electronics instruction.

### *Keyword Co-occurrence Clusters*

VOSviewer analysis identified four major thematic clusters. The first cluster, encompassing microcontrollers, embedded systems, and Proteus Design Suite, emphasises applied, skills-based outcomes, particularly hardware prototyping and digital circuit testing (Ibrahim & Abdullah, 2019; Agbo & Ede, 2020). The second cluster e-learning, COVID-19, higher education, and digital transformation reflects the systemic shift towards blended and remote instruction during the pandemic (UNESCO, 2021). The third cluster, associated with MATLAB, control systems, and power electronics, is linked to university-level computational modelling and advanced engineering research (Fletcher, 2019; Ma & Nickerson, 2006). The fourth cluster, centred on TVET, curriculum, technical colleges, and skills acquisition, highlights vocational curriculum design and competency-based training in developing economies (NBTE, 2021; UNESCO-UNEVOC, 2019). Collectively, these clusters confirm that simulation research in Nigeria is multidimensional, spanning applied engineering, digital transformation, advanced modelling, and vocational pedagogy.

### *Dominant Simulation Platforms*

Content analysis of the 185 studies identified the following platform distribution across Nigerian institutions:

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***Table 1:*** *Dominant simulation platforms in Nigerian electronics education.*

| SOFTWARE | PRIMARY USE CASE IN NIGERIA | POPULARITY INDEX | KEY ADVANTAGE |
|---|---|---|---|
| PROTEUS DESIGN SUITE (VSM) | Microcontroller and Arduino simulation | 85% | Real-time code execution simulation |
| NI MULTISIM | Analogue and digital logic circuits | 60% | High-fidelity virtual instruments (oscilloscope, etc.) |
| MATLAB/SIMULINK | Power systems and signal processing | 45% | Mathematical rigour for engineering research |
| AUTODESK TINKERCAD | Introductory electronics | 30% | Browser-based; no installation required |

## Discussion of Findings

*Infrastructure: The Energy–Internet Nexus*

Infrastructure-related constraints are the most frequently cited barrier to simulation adoption, appearing in approximately 88 per cent of reviewed studies consistent with broader reports on ICT limitations in sub-Saharan Africa (World Bank, 2022; UNESCO, 2021). In many Nigerian polytechnics, a scheduled three-hour practical session is routinely disrupted by electricity outages, resulting in the loss of unsaved work, equipment downtime, and student frustration. This energy -internet nexus describes the dual dependency on stable electricity and reliable connectivity: where both are absent, even offline simulation tools function sub-optimally. High data costs render cloud-based platforms largely inaccessible, confining most institutions to standalone desktop software such as NI Multisim, Proteus, and MATLAB/Simulink tools that partially mitigate connectivity challenges but do not fully resolve the broader infrastructural constraint (Akinwale & Okunade, 2020).

*The "Digital Immigrant" Lecturer*

A significant generational divide separates younger, digitally fluent educators from senior faculty socialised within analogue, hardware-based instructional traditions (Prensky, 2001; Mishra & Koehler, 2006). Senior lecturers often regard simulation tools with scepticism, questioning their capacity to replicate authentic laboratory experiences. This scepticism manifests as hidden resistance: simulations are tolerated for preparatory assignments but excluded from formal practical assessments, reducing them from core instructional platforms to peripheral supplements. Through the TPACK lens, the barrier is attributable not to technological unavailability but to insufficient technological knowledge and pedagogical confidence (Koehler & Mishra, 2009). Targeted professional development programmes and institutional policies mandating simulation integration in assessed work are therefore necessary prerequisites for genuine adoption.

*Intellectual Property and Software Piracy*

Prohibitive licensing costs represent a structural barrier that is particularly acute in developing-country contexts. A single professional NI Multisim licence can exceed the annual ICT budget of an entire academic department, restricting access to a handful of computers or senior-level students only (UNESCO, 2021; World Bank, 2022). This financial constraint has in some cases encouraged the informal use of unauthorised software, which carries system instability, limited

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functionality, absence of technical support, cybersecurity risks, and exposure to intellectual property infringement (Akinwale & Okunade, 2020). Open-source alternatives have been proposed in the literature, but transitioning from proprietary platforms requires instructor retraining, curriculum revision, and institutional policy support that are not yet adequately developed in many Nigerian technical institutions.

**Proposed Model: The Hybrid-Simulation Instructional Model (HSIM)**

In response to the identified infrastructural, pedagogical, and economic barriers, this study proposes the Hybrid-Simulation Instructional Model (HSIM). Grounded in blended learning theory, the HSIM integrates simulation-based practice with targeted physical laboratory verification, optimising skill acquisition within resource-constrained environments (Graham, 2006; UNESCO-UNEVOC, 2019).

Phase A (Simulation) requires students to design, test, and debug electronic circuits using Proteus or NI Multisim independently, outside formal laboratory hours and in any available digital space computer laboratories, homes, or shared ICT facilities. During this phase, learners engage in iterative experimentation, identify design errors, and refine circuit behaviour in a risk-free environment. Research confirms that this approach improves conceptual understanding whilst reducing cognitive and material constraints (Brinson, 2015; Sweller, 2011).

Phase B (Verification) transfers the completed and tested simulation design to the physical laboratory for a condensed hands-on session, typically approximately 30 minutes per task. Students reconstruct their verified circuit on breadboards or experimental kits. Critically, since error detection has already occurred in Phase A, physical sessions focus exclusively on verification, fine-tuning, and psychomotor skill reinforcement rather than initial troubleshooting. This approach conserves limited components, reduces electricity consumption, and increases laboratory efficiency benefits of particular significance in environments with erratic power supply and inadequate consumables budgets (World Bank, 2022).

The HSIM's dual-phase structure simultaneously strengthens cognitive competencies analytical reasoning and problem-solving through the simulation phase, and psychomotor competencies hands-on assembly and measurement through physical verification. This structure aligns with global engineering education best practices and addresses the three principal barriers identified in this study: infrastructure constraints are mitigated by minimising physical laboratory time; lecturer resistance is overcome by requiring both phases in assessed tasks; and software cost barriers are addressed by enabling single-licence, shared-access simulation arrangements in Phase A. Overall, the HSIM provides a practical, scalable, and context-sensitive instructional architecture for electronics education in Nigeria.

**Conclusion and Recommendations**

Simulation technology is no longer merely an alternative instructional strategy in Nigerian electronics education; it has become an essential component for sustaining effective teaching and learning in TVET institutions. Bibliometric evidence demonstrates a clear trajectory from minimal scholarly engagement in 2000 to rapid expansion post-2020, driven largely by COVID-19-induced institutional disruptions (Donthu et al., 2021; UNESCO, 2021). Despite this positive intellectual trajectory, however, a substantial implementation gap persists: simulation tools remain underutilised relative to their demonstrated potential because the supporting institutional frameworks stable power, ICT infrastructure, faculty training, and licensing provisions have not matured sufficiently to enable widespread, sustained adoption (NBTE, 2021; World Bank, 2022).

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Closing this gap requires systemic reforms rather than isolated technical interventions. Future efforts must prioritise: (a) investment in stable ICT infrastructure and battery-backup systems for simulation laboratories; (b) continuous professional development programmes to build lecturer competence and confidence with TPACK-aligned pedagogy; (c) institutional procurement of open-source or consortium-licensed simulation software to address the intellectual property barrier; and (d) curriculum reform that formally embeds simulation requirements within assessed practical outcomes at both NBTE and NCCE accreditation levels.

Future research should extend beyond current simulation environments to explore emerging immersive technologies. Augmented Reality (AR) represents a particularly promising frontier: AR applications could overlay real-time voltage distribution, current flow, and signal behaviour directly onto physical breadboards via smartphones or AR headsets, providing learners with intuitive, spatially rich circuit understanding. Studies examining the feasibility, cost-effectiveness, and pedagogical impact of AR-based electronics instruction within Nigerian technical institutions as well as hybrid ecosystems combining AR overlays with existing Proteus and NI Multisim environments would significantly advance both theory and practice in this domain.

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## References

Agbo, F. J., & Ede, M. O. (2020). Simulation-based laboratory learning in Nigerian technical colleges: A review. Journal of Vocational and Technical Education, 12(2), 45–62.

Akinwale, A. S., & Okunade, A. A. (2020). Digital learning barriers in Nigerian polytechnics: An empirical investigation. African Journal of Educational Technology, 8(1), 22–40.

Bazeley, P., & Jackson, K. (2013). Qualitative data analysis with NVivo (2nd ed.). SAGE Publications.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. Qualitative Research in Psychology, 3(2), 77–101.

Brinson, J. R. (2015). Learning outcome achievement in non-traditional (virtual and remote) versus traditional (hands-on) laboratories. Computers & Education, 87, 218–237.

Clark, R. C., & Mayer, R. E. (2016). E-learning and the science of instruction (4th ed.). Wiley.

Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research*, 133, 285–296.

Eze, T. I., & Olaitan, S. O. (2020). Practical skill acquisition in Nigerian electronics education: Challenges and prospects. Journal of Technical Education and Training, 12(1), 88–101.

Federal Ministry of Education. (2020). National policy on education (7th ed.). Federal Government Press.

Fletcher, J. (2019). Simulation in engineering and technical education: A global perspective. International Journal of Engineering Education, 35(4), 112–128.

Foster, P. (2018). Simulation technologies in TVET: A conceptual overview. Technical and Vocational Education Review, 5(3), 1–18.

Gomes, L., & Bogosyan, S. (2009). Current trends in remote laboratories. IEEE Transactions on Industrial Electronics, 56(12), 4744–4756.

Graham, C. R. (2006). Blended learning systems: Definition, current trends, and future directions. In C. J. Bonk & C. R. Graham (Eds.), Handbook of blended learning (pp. 3–21). Pfeiffer Publishing.

Heradio, R., de la Torre, L., Galan, D., Esquembre, F., Dormido, E., & Dormido, S. (2016). Virtual and remote labs in education: A bibliometric analysis. Computers & Education, 98, 14–38.

Ibrahim, A. B., & Abdullah, N. (2019). Microcontroller simulation in technical education: A review of Proteus VSM applications. Asian Journal of Technical and Vocational Education, 4(1), 11–25.

Koehler, M. J., & Mishra, P. (2009). What is technological pedagogical content knowledge? Contemporary Issues in Technology and Teacher Education, 9(1), 60–70.

Ma, J., & Nickerson, J. V. (2006). Hands-on, simulated, and remote laboratories: A comparative literature review. ACM Computing Surveys, 38(3), 7.

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. Teachers College Record, 108(6), 1017–1054.

Mongeon, P., & Paul-Hus, A. (2016). The journal coverage of Web of Science and Scopus: A comparative analysis. Scientometrics, 106(1), 213–228.

National Board for Technical Education (NBTE). (2018). NBTE statistics on simulation use in Nigerian polytechnics. NBTE Press.

National Board for Technical Education (NBTE). (2021). Report on the state of technical and vocational education in Nigeria. NBTE Press.

Okoye, R., & Arimonu, M. U. (2016). Technical and vocational education in Nigeria: Issues, challenges and a way forward. Journal of Education and Practice, 7(3), 113–118.

Prensky, M. (2001). Digital natives, digital immigrants. On the Horizon, 9(5), 1–6.

**Sponsored by TETFUND**/(TETFUND/DESS/POLY/WANNUNE/ARJ/2022-2025/VOL.1)
WIJSITAR Volume 1 Number 1, 2025
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Prince, M. J., & Felder, R. M. (2006). Inductive teaching and learning methods: Definitions, comparisons, and research bases. Journal of Engineering Education, 95(2), 123–138.

Sweller, J. (2011). Cognitive load theory. In J. P. Mestre & B. H. Ross (Eds.), Psychology of learning and motivation (Vol. 55, pp. 37–76). Academic Press.

Tranfield, D., Denyer, D., & Smart, P. (2003). Towards a methodology for developing evidence-informed management knowledge by means of systematic review. British Journal of Management, 14(3), 207–222.

UNESCO. (2005). UNESCO world report: Towards knowledge societies. UNESCO Publishing.

UNESCO. (2021). Education in a post-COVID world: Nine ideas for public action. UNESCO.

UNESCO-UNEVOC. (2019). TVET in a time of change: UNESCO-UNEVOC global review. UNESCO-UNEVOC.

van Eck, N. J., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. Scientometrics, 84(2), 523–538.

Voogt, J., Fisser, P., Pareja Roblin, N., Tondeur, J., & Van Braak, J. (2013). Technological pedagogical content knowledge — a review of the literature. Journal of Computer Assisted Learning, 29(2), 109–121.

World Bank. (2022). Nigeria education sector analysis: An analytical synthesis of performance and cross-cutting issues. World Bank.

Zutin, D. G., Auer, M. E., Maier, C., & Niederstätter, M. (2010). Lab2go — a repository to locate online accessible remote laboratories. IEEE EDUCON 2010, 1741–1746.

Zupic, I., & Cater, T. (2015). Bibliometric methods in management and organisation. Organizational Research Methods, 18(3), 429–472